Contents

0.1 Electroweak and QCD physics at LHC

0.2 Introduction

The discovery of a new boson consistent with the standard model (SM) Higgs boson has been reported by ATLAS and CMS Collaborations in 2012. The discovery has been followed by a comprehensive set of studies of properties of this new boson in several production and decay channels and no evidence of deviation from the SM expectation has been found so far. The CMS studies in the $\rightarrow 22\nu$ decay channel include the measurement of the Higgs properties, as well as constraints on the Higgs total decay width and gauge bosons anomalous couplings.

In this document we present a measurement of the transverse momentum spectrum of the Higgs boson, produced in proton collisions at a center of mass energy of $\sqrt{s} = 8$ TeV. This measurement can be used to directly inspect the perturbative QCD theory in the Higgs sector. In particular the p_T^H variable is sensitive to the Higgs production mode and the differential distribution in this variable can be used to inspect the effects of the top quark mass in the gluon fusion top loop. Moreover, any observed deviation from the SM expectation, especially in the tail of the p_T^H distribution, could be a hint of physics beyond the SM.
Similar measurements have already been performed by CMS and ATLAS experiments in the ZZ and $\gamma\gamma$ Higgs decay channels. The measurement reported here is the first measurement of the Higgs p_T spectrum in the WW decay channel.
The cross section has been measured in a fiducial phase space defined using generator level variables in order to mimic the experimental acceptance and reduce the systematic uncertainties on the procedure of extrapolating the results in a larger phase space.
The Higgs transverse momentum has been reconstructed calculating the vector sum of the dilepton system transverse momentum plus missing transverse energy ($\vec{p}_T^H = \vec{p}_T + \vec{E}_T^{miss}$).
The signal has been extracted subtracting all backgrounds by means of a binned Maximum Likelihood fit and has been then corrected for the efficiency of the analysis selections and for the detector resolution effects using an unfolding procedure.
The differential measurement has been performed in six bins of p_T^H with variable widths, chosen to have approximately the same purity in each bin, as explained in section **??**.

0.3 Datasets, Triggers and MC samples

This analysis is largely built on top of the existing analysis in terms of code, selections and background estimates for both the gluon fusion (GF) [**AN-2013-022**] and the vector boson fusion (VBF) [**AN-13-097**] channels.

0.3.1 Datasets

The datasets used for the analysis correspond to at $\sqrt(s) = 8$ of integrated luminosity composed of the following data-taking periods: 2012A (892 pb^{-1}), 2012B (4440 pb^{-1}), and 2012C (6898 pb^{-1}) and 2012D (7238 pb^{-1}). Only data corresponding to good data taking quality ("Golden JSON") are considered. The final state is considered in this analysis. The following five Primary Datasets have been used for the signal extraction: SingleElectron, SingleMu and MuEG (Muon-ElectronGamma). From the framework side the analysis is based on the CMSSW 53X release.

0.3.2 Trigger

For the data samples, the events are required to fire one of the unprescaled single-electron, single-muon or muon-electron triggers. A full description of these triggers in given in [**AN-2012-228**] for 8 data. Although identification and isolation criteria are also applied, a brief overview of the HLT transverse momentum () criteria on the leptons is given in Table **??**. While the HLT lepton thresholds of 17 and 8 for the double lepton triggers accommodate the offline lepton selection of 20 and 10 , the higher thresholds in the single lepton triggers help partially recovering double lepton trigger inefficiencies as a high lepton is on average expected due to the kinematic of the Higgs decay.

Table 1: Highest transverse momentum thresholds applied in the lepton triggers at the HLT level. Double set of thresholds indicates the thresholds for each leg of the double lepton triggers.

Trigger Path	7	8
Single-Electron	> 27	> 27
Single-Muon	> 15	> 24
Muon-Electron	> 17 and 8	> 17 and 8
Electron-Muon	> 17 and 8	> 17 and 8

No trigger requirement is made on the simulated events but the combined trigger efficiency is estimated from data and applied to all simulated events. The detailed trigger efficiencies and the weighting procedure can be found in Appendix C of [**AN-2013-022**] [**AN-2013-052**]. The average trigger efficiency for signal events that pass the full event selection is measured to be about 96% in the $e\mu$ final state for a Higgs boson mass of about 125.

0.3.3 Monte-Carlo samples

Several Monte Carlo event generators are used to simulate the signal and background processes:

- The POWHEG program [**powheg**] provides event samples for the $H \to WW$ signal for the Gluon Fusion (ggH) and VBF production mechanisms, as well as and tW processes.
- The $q\bar{q} \to WW$, Drell-Yan, ZZ, WZ, $W\gamma$, $W\gamma^*$, tri-bosons and W+jets processes are generated using the MADGRAPH 5.1.3 [**madgraph**] event generator.
- The VH process is simulated using PYTHIA 6.424 [**pythia**].

For leading-order generators samples, the CTEQ6L [**cteq66**] set of parton distribution functions (PDF) is used, while CT10 [**ct10**] is used for next-to-leading order (NLO) ones. Cross section calculations [**LHCHiggsCrossSectionWorkingGroup:201**] at next-to-next-to-leading order (NNLO) are used for the $H \to WW$ process (POWHEG NLO generator is tuned to reproduce NNLO accuracy on the on-shell Higgs p_T spectrum and scaled to NNLO inclusive cross-section), while NLO calculations are used for background cross sections. For all processes, the detector response is simulated using a detailed description of the CMS detector, based on the GEANT4 package [**Agostinelli:2002hh**].

Minimum bias events are superimposed on the simulated events to emulate the additional pp interactions per bunch crossing (pile-up). The number of pile-up events simulated in the MC samples (in the same bunch crossing, in time, or in the previous or following one, out of time pile-up) have been generated poissonianly sampling from a distribution similar to what is expected from data. These samples are reweighted to represent the pile-up distribution as measured in the data. For a given range of analyzed runs, the mean number of pile-up interactions per bunch crossing is estimated per luminosity block using the instantaneous luminosity provided by the LHC, integrated over the entire run range and normalized. This distribution is then used to reweight the simulated pile-up distribution. The average number of pile-up events per beam crossing in the 2011 data is about 10, and in the 2012 data it is about 20.

We checked that the contribution of the ttH production mechanisms is negligible in each bin of p_T^H (below 1%) and has been neglected. In figure **??** is shown the relative fraction of the four different production modes in each bin of p_T^H.

images/signal_composition_ttH.pdf

Figure 1: Relatve fraction of ggH, VBF, VH and ttH in each bin of the Higgs boson transverse momentum.