

Measurement of inclusive and differential fiducial cross sections of Higgs boson production in the $H \rightarrow 4\ell$ decay channel in proton-proton collisions at 7 TeV and 8 TeV

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In this document we present measurements of inclusive and differential fiducial cross sections of the Higgs boson production in proton-proton collisions with integrated luminosities of 5.1 fb^{-1} at $\sqrt{s} = 7 \text{ TeV}$ and 19.7 fb^{-1} at $\sqrt{s} = 8 \text{ TeV}$ using the $H \rightarrow 4\ell$ decays ($\ell = e, \mu$), recorded with the CMS detector in 2011 and 2012. The differential cross section measurements are performed in bins of the transverse momentum and rapidity of the four-lepton system, invariant masses of the two lepton pairs, five helicity angles formed by the leptons in the Collins-Soper frame, jet multiplicity, transverse momentum of the leading jet, and distance in rapidity between the Higgs boson candidate and the leading jet. The measurement of the cross section of the Z boson production in $Z \rightarrow 4\ell$ decay channel and its ratio to the Higgs boson production cross section in $H \rightarrow 4\ell$ channel is also performed. All results are corrected for the detection efficiency and resolution effects. The inclusive fiducial cross section for the Higgs boson production in $H \rightarrow 4\ell$ decay channel is measured to be $0.56^{+0.67}_{-0.44}$ (stat.) $^{+0.21}_{-0.06}$ (sys.) fb for proton collisions at 7 TeV and $1.11^{+0.41}_{-0.35}$ (stat.) $^{+0.14}_{-0.10}$ (sys.) fb for proton collisions at 8 TeV. The results of all measurements are compared with theoretical calculations based on Standard Model and no significant deviation is observed.

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1. Introduction

Selected results of inclusive and differential fiducial cross section of Higgs production in the $H \rightarrow 4\ell$ decay channel are reported. A detailed description of the analysis can be found in reference [1]. The cross sections are measured in a fiducial phase space which is defined to closely match the experimental acceptance in terms of the lepton kinematics, lepton isolation, and topological event selection, and constitutes approximately 42% of the total phase space. The differential fiducial cross sections are reported for several kinematic observables which are sensitive to the Higgs boson production mechanism: transverse momentum and rapidity of the four-lepton system, transverse momentum of the leading jet, as well as separation in rapidity between the Higgs boson candidate and the leading jet. Due to the strong dependence of the $\sigma \times BR$ on the true Higgs boson mass m_H in the region around 125.0 GeV, and in order to facilitate easier comparison of the measurement results with the theory predictions, the measurements are performed assuming the Higgs boson mass of $m_H = 125.0$ GeV as measured by the CMS experiment using the decay channels $H \rightarrow 4\ell$ and $H \rightarrow 2\gamma$ [2].

2. Inclusive cross sections

Inclusive fiducial cross sections measurements at 7 and 8 TeV, performed in the $m_{4\ell}$ range from 105 GeV to 140 GeV for Higgs boson, are presented in Figure 1 and Table 1. The central values of the measurements are obtained using the efficiencies for a SM Higgs boson, red error bars represent the systematic uncertainties, while black error bars represent the combined statistical and systematic uncertainties, summed in quadrature. The additional systematic uncertainty associated with the model dependence is separately represented by a grey box. Table 2 shows the corresponding results of inclusive fiducial cross section measurement of the process $Z \rightarrow 4\ell$ in the $m_{4\ell}$ range from 50 GeV to 105 GeV and of the ratio of the inclusive fiducial cross sections of $H \rightarrow 4\ell$ and $Z \rightarrow 4\ell$ at 8 TeV.

Table 1: Results of the $H \rightarrow 4\ell$ inclusive fiducial cross section measurements.

Fiducial cross section $H \rightarrow 4\ell$ at 7 TeV	
Measured	$0.56^{+0.67}_{-0.44}$ (stat.) $^{+0.21}_{-0.06}$ (sys.) $^{+0.02}_{-0.02}$ (model) fb
$gg \rightarrow H(\text{HRES}) + XH$	$0.93^{+0.10}_{-0.11}$ fb
Fiducial cross section $H \rightarrow 4\ell$ at 8 TeV	
Measured	$1.11^{+0.41}_{-0.35}$ (stat.) $^{+0.14}_{-0.10}$ (sys.) $^{+0.08}_{-0.02}$ (model) fb
$gg \rightarrow H(\text{HRES}) + XH$	$1.15^{+0.12}_{-0.13}$ fb
Ratio of fiducial cross sections of $H \rightarrow 4\ell$ at 7 and 8 TeV	
Measured	$0.51^{+0.71}_{-0.40}$ (stat.) $^{+0.13}_{-0.05}$ (sys.) $^{+0.00}_{-0.03}$ (model)
$gg \rightarrow H(\text{HRES}) + XH$	$0.805^{+0.003}_{-0.010}$

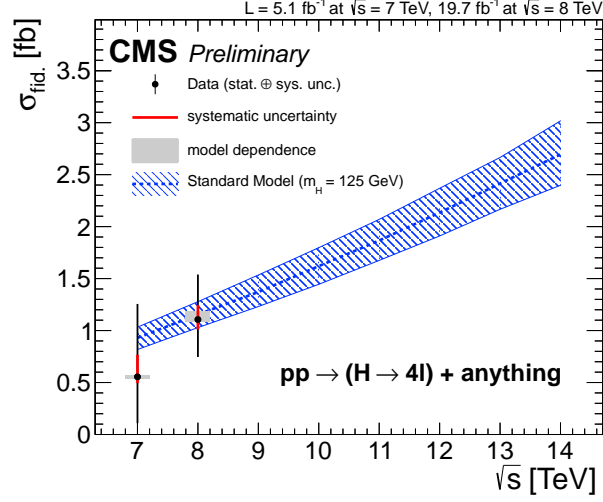


Figure 1: Results of the inclusive $H \rightarrow 4\ell$ fiducial cross section measurements at proton collisions at 7 and 8 TeV, and comparison to the theoretical estimates.

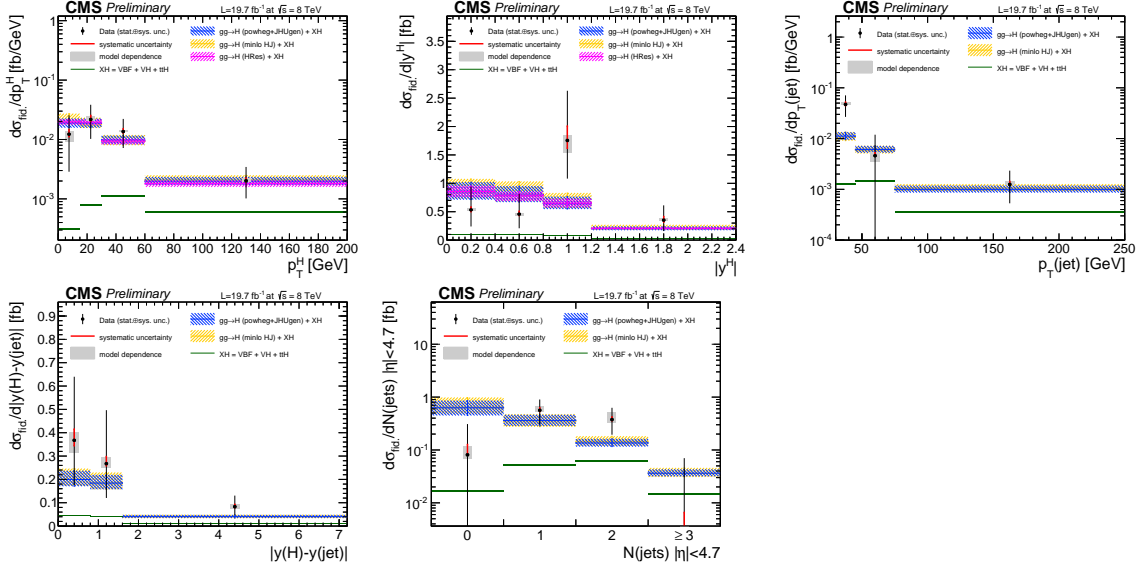


Figure 2: Observed data along with the SM signal ($m_H = 125.0$ GeV) and background expectations for different observables and for all final states combined.

3. Differential cross section

The measured $H \rightarrow 4\ell$ differential fiducial cross sections at 8 TeV, along with the theoretical estimations for a SM Higgs boson with $m_H = 125.0$ GeV are presented in Figure 2. Results are shown for the transverse momentum, the rapidity of the four-lepton system, jet multiplicity, transverse momentum of the leading jet and separation in rapidity between the Higgs boson candidate and the leading jet. In the measurement procedure the fractions of the $4e$, 4μ and $2e2\mu$ contributions to the fiducial cross section in each bin are allowed to vary. The measurement of the transverse

Table 2: $Z \rightarrow 4\ell$ inclusive fiducial cross section and ratio of inclusive fiducial cross section of $H \rightarrow 4\ell$ and $Z \rightarrow 4\ell$, obtained from a simultaneous fit of the mass peaks of $Z \rightarrow 4\ell$ and $H \rightarrow 4\ell$.

Fiducial cross section $Z \rightarrow 4\ell$ at 8 TeV	
Measured	$4.81^{+0.69}_{-0.63}$ (stat.) $^{+0.18}_{-0.19}$ (sys.) fb
POWHEG	$4.56^{+0.19}_{-0.19}$ fb
Ratio of fiducial cross sections $H \rightarrow 4\ell / Z \rightarrow 4\ell$	
Measured	$0.21^{++0.09}_{-0.07}$ (stat.) $^{+0.01}_{-0.01}$ (sys.)
$gg \rightarrow H(\text{HRES}) + X$	$0.25^{+0.04}_{-0.04}$

momentum of the four-lepton system probes the perturbative QCD modelling of the dominant loop-mediated gluon fusion production mechanism, where this transverse momentum is expected to be balanced by the emission of soft gluons and quarks. In addition, the rapidity distribution of the four-lepton system is sensitive both to the modelling of the gluon fusion production mechanism and to the PDFs of the colliding protons. Similarly, the jet multiplicity, transverse momentum of the leading jet, and its separation in rapidity from the Higgs boson candidate are sensitive to the theoretical modelling of hard quark and gluon radiation in this process, as well as to the relative contributions of different Higgs boson production mechanisms.

4. Conclusions

This report shows the results of inclusive and differential fiducial cross section of Higgs production in the $H \rightarrow 4\ell$ decay channel in proton-proton collisions, performed using 5.1 fb^{-1} of 7 TeV and 19.7 fb^{-1} of 8 TeV. The differential measurements have been performed in a fiducial phase space region as a function of the transverse momentum and the rapidity of the four-lepton system, transverse momentum of the leading jet, distance in rapidity between the Higgs boson candidate and the leading jet, and the jet multiplicity. The uncertainty on the measurement results due to the underlying assumption on the model of the Higgs boson production and its properties has been estimated by studying a range of exotic Higgs boson production and spin-parity models, and it has been found to be no more than 7% for the total fiducial cross section. The fiducial cross section for the Higgs boson production in the $H \rightarrow 4\ell$ decay channel is measured to be $0.56^{+0.67}_{-0.44}$ (stat.) $^{+0.21}_{-0.06}$ (sys.) and $1.11^{+0.41}_{-0.35}$ (stat.) $^{+0.14}_{-0.10}$ (sys.) fb at 7 TeV and 8 TeV, respectively. Measurements have been compared with SM-based theoretical calculations and no significant deviation has been observed.

References

- [1] CMS Collaboration, “Measurement of inclusive and differential fiducial cross sections of Higgs boson production in the $H \rightarrow 4\ell$ decay channel in proton-proton collisions at 7 TeV and 8 TeV”, CMS Physics Analysis Summary CMS PAS HIG-14-028, 2015.
- [2] CMS Collaboration, “Precise determination of the mass of the Higgs boson and tests of compatibility of its couplings with the standard model predictions using proton collisions at 7 and 8 TeV”, Eur. Phys. J. C 75 (2015) 212.