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Measurement of differential and integrated fiducial cross sections for Higgs boson production in the four-lepton decay channel in pp collisions at $\sqrt{s} = 7, 8$ and 13 TeV

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Integrated fiducial cross sections for the production of four leptons via the $H \to 4\ell$ decays ($\ell = e, \mu$) are measured in pp collisions at $\sqrt{s} = 7, 8$ and 13 TeV. Measurements are performed with data corresponding to integrated luminosities of 5.1 fb^{-1} at $\sqrt{s} = 7$ TeV, 19.7 fb^{-1} at $\sqrt{s} = 8$ TeV and 12.9 fb^{-1} at $\sqrt{s} = 13$ TeV, collected with the CMS experiment at the LHC. Differential cross sections are measured as a function of transverse momentum of four-lepton system and accompanying jet multiplicity using 8 and 13 TeV data set. All cross sections are measured within a fiducial phase space defined by the requirements on lepton kinematics and event topology. The integrated $H \to 4\ell$ fiducial cross section is measured to be $0.56^{+0.67}_{-0.44}\,(\text{stat.})\,^{+0.21}_{-0.06}\,(\text{sys.}) \pm 0.02\,(\text{model})$ fb at 7 TeV, $1.11^{+0.41}_{-0.35}\,(\text{stat.})\,^{+0.14}_{-0.10}\,(\text{sys.})\,^{+0.08}_{-0.02}\,(\text{model})$ fb at 8 TeV and $2.29^{+0.74}_{-0.64}(\text{stat.})^{+0.30}_{-0.23}(\text{sys.})^{+0.01}_{-0.05}(\text{model})$fb at 13 TeV. The measurements are found to be compatible with the theoretical calculations based on the standard model.

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1. Introduction

Selected results of the differential and integrated fiducial cross sections for Higgs production in the four-lepton decay channel are reported. A detailed description of the analysis and additional results can be found in References [1, 2]. The differential cross sections are determined using 8 and 13 TeV data set due to the limited statistics of the 7 TeV data. The $H \to 4\ell$ denotes the Higgs boson decay to the four-lepton final state via an intermediate pair of neutral electroweak bosons. The cross sections are corrected for the effects related to detector efficiency and resolution. The cross sections are extracted in a fiducial phase space which is defined to closely match the experimental acceptance that constitutes 42% of the total available phase space and there is no attempt to extrapolate the measurements to the full phase space. This approach is chosen to reduce the systematic uncertainty related with underlying model of Higgs boson properties and production mechanism. The differential cross sections are measured as a function of transverse momentum of the four-lepton system and accompanying jet multiplicity. Due to the strong dependence of the cross section times branching fraction on the mass of the Higgs boson (m_H) in the region around 125.0 GeV, the measurements are performed assuming a mass of $m_H = 125$ GeV, as measured by the CMS experiment using the decay channels $H \to 4\ell$ and $H \to 2\gamma$ [3].

2. Measurement Methodology

The aim is to determine the differential and integrated cross sections within the fiducial phase space, corrected for the effects of limited detection efficiencies, resolution, and known systematic biases. In order to achieve this goal, we estimate those effects using simulation and include them in the parameterization of the expected $m_{4\ell}$ spectra at the reconstruction level. We then perform a maximum likelihood fit of the signal and background parameterizations to the observed 4ℓ mass distribution, N_{obs} $(m_{4\ell})$, and directly extract the fiducial cross sections of interest (σ_{fid}) from the fit. In this approach all systematic uncertainties are included in the form of nuisance parameters, which are profiled (floated) in the fit procedure.

3. Results

Integrated fiducial cross section measurements at 7, 8 and 13 TeV are performed in the $m_{4\ell}$ range from 105 GeV to 140 GeV for the Higgs boson. The results are summarized in the Figure 1 and Table 1. The central values of the measurements are obtained using the efficiencies for a standard model (SM) Higgs boson, red vertical bars represent the systematic uncertainties, while black vertical bars represent the combined statistical and systematic uncertainties, summed in quadrature. The additional systematic uncertainty associated with the model dependence is shown separately by a grey box.

The measured H→ 4ℓ differential fiducial cross sections at 8 and 13 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 of the four-lepton system and accompanying jet multiplicity. 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 momentum of the

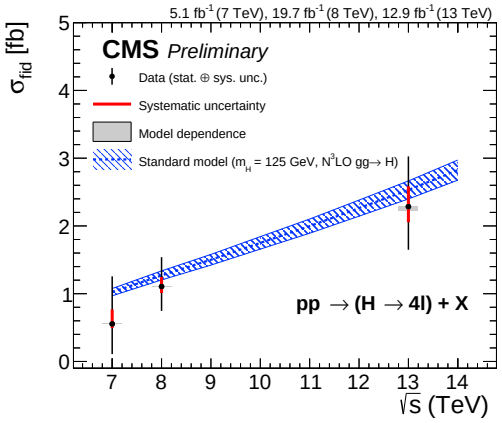

Figure 1: Results of measurements of the integrated H $\to 4\ell$ fiducial cross section in pp collisions at 7, 8 and 13 TeV, with a comparison to SM estimates.

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

Fiducial cross section H $\to 4\ell$ **at 7 TeV**	
Measured	$0.56^{+0.67}_{-0.44}\,(\text{stat.})\,^{+0.21}_{-0.06}\,(\text{sys.})\,^{+0.02}_{-0.02}\,(\text{model})$ fb
gg→H(HRES) + XH	$0.93^{+0.10}_{-0.11}$fb
Fiducial cross section H $\to 4\ell$ **at 8 TeV**	
Measured	$1.11^{+0.41}_{-0.35}\,(\text{stat.})\,^{+0.14}_{-0.10}\,(\text{sys.})\,^{+0.08}_{-0.02}\,(\text{model})$ fb
gg $\to$ H(HRES) + XH	$1.15^{+0.12}_{-0.13}$ fb
Fiducial cross section H $\to 4\ell$ **at 13 TeV**	
Measured	$2.29^{+0.74}_{-0.64}\,(\text{stat.})\,^{+0.30}_{-0.23}\,(\text{sys.})\,^{+0.01}_{-0.05}\,(\text{model})$
gg→H(HRES) + XH	2.53 ± 0.13 fb

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 jet multiplicity is 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 presents the results of differential and integrated fiducial cross sections measurements for the production of four leptons via the $H \to 4\ell$ decays in pp collisions, performed using integrated luminosities of 5.1 fb^{-1} at $\sqrt{s} = 7$ TeV, 19.7 fb^{-1} at $\sqrt{s} = 8$ TeV and 12.9 fb^{-1} at $\sqrt{s} = 13$ TeV. Differential cross sections are also measured as a function of transverse momentum of four-lepton system and accompanying jet multiplicity using 8 and 13 TeV data set.

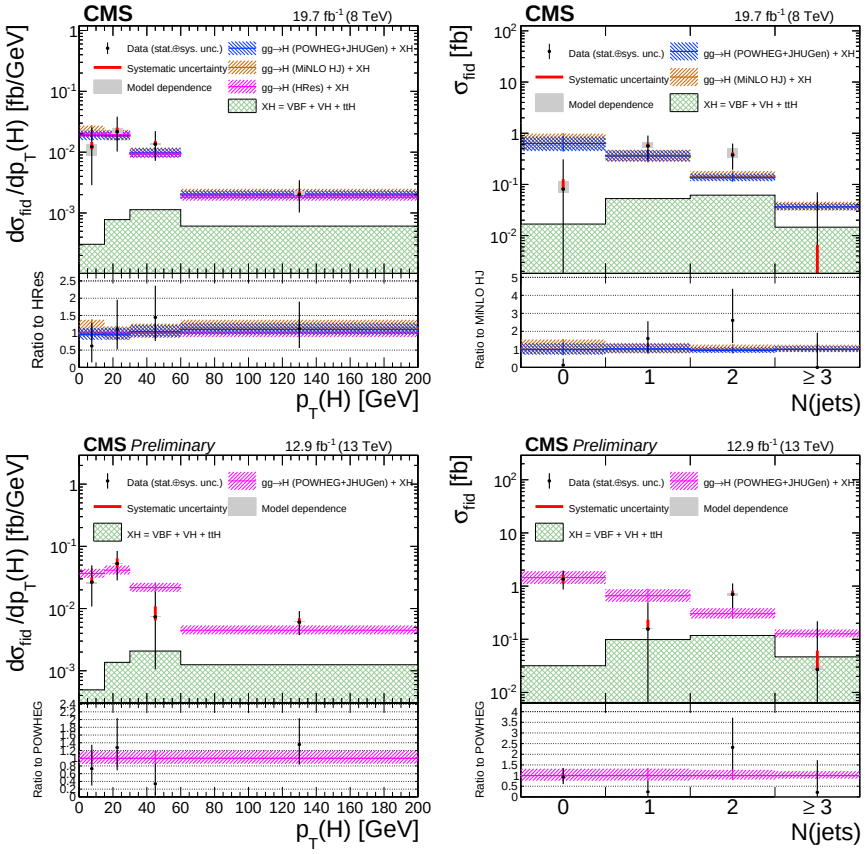

Figure 2: Observed data along with the SM signal ($m_H = 125.0$ GeV) and background expectations for different observables and for all final states combined.

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 integrated $H \to 4\ell$ fiducial cross section is measured to be $0.56^{+0.67}_{-0.44}\,(\text{stat.})\,^{+0.21}_{-0.06}\,(\text{sys.}) \pm 0.02\,(\text{model})$ fb at 7 TeV, $1.11^{+0.41}_{-0.35}\,(\text{stat.})\,^{+0.14}_{-0.10}\,(\text{sys.})\,^{+0.08}_{-0.02}\,(\text{model})$ fb at 8 TeV and $2.29^{+0.74}_{-0.64}(\text{stat.})^{+0.30}_{-0.23}(\text{sys.})^{+0.01}_{-0.05}(\text{model})$fb at 13 TeV. The measurements are found to be compatible with the theoretical calculations based on the standard model.

References

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