The impact of LO, NLO and NNLO for the Higgs searching at $\sqrt{s} = 7$TeV of LHC

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Most of current Monte Carlo studies on the Higgs searching are based on LO, or NLO calculation. However, in recent years, the next-to-next-to-leading order(NNLO) corrections have been computed for some physics process, and found that the cross section increases, the kinematics changes. As the results, the analysis results could be impacted by these high order QCD corrections. We use standard Monte Carlo generator for LO, as well as MC@NLO for NLO and ResBos for NNLO at 7 TeV of LHC to evaluate this impact for physics channel of the Higgs, mass at 165 GeV, to WW, then W decay to lepton and neutrino as the final states. We found the signal rate could be effected by ratio of 1:2.6:3.4 for LO, NLO and NNLO using the same standard $H \to WW \to l\nu l\nu$ searching analysis process.[6].

Keywords: NNLO, Higgs searching.

1. Introduction

In the QCD perturbation theory at the leading order, LO, the cross section is proportional to the QCD coupling α_s^2. The QCD radiative corrections to the total cross section at the next-to-leading order(NLO) will increase the cross section by above 80%.[1] The NNLO effects are not as much as NLO to LO, some calculation indicates the cross section will be increased by 15-20%, the kinematics also change which will impact to the lepton transverse momentum (p_t) and pseudorapidity(η) cuts and jet veto etc. Due to the nature of the complication, only a few highly inclusive reactions were calculated to NNLO and $H \to WW$ is one of them.[2]

We have used HERWIG(6.510) to generate $H \to WW$ at LO, and MC@NLO(3.4) for NLO, and ResBos for NNLO, we will compare their cross section and kinematics, to see how much will impact to our Higgs searching by these all impact combined which we have done before[6]. The move from NLO to NNLO accuracy is desirable to improve the QCD predication and to better assess their uncertainties.

2. SM Higgs Production at the LHC and the Result by the LO, NLO, NNLO

In the standard production of the Higgs Boson, the K-factor for NLO is about 1.84, and for NNLO is about 2.21, with the condition of renormalization and factorization scales are set to the default values, μ_R=μ_R=M_H, the M_H=165 GeV. The cross section is about 112, 206 and 247 fb respectively when no cuts are applied from Refs. [3],[4],[5]. If with some cuts, the cross section will be around 53, 97 and 116 fb. That shows the NLO and NNLO correction made significant differences in term of the cross section for $H \to WW$ process. This calculation based on the $WW \to l\nu l\nu$, the lepton could be e or μ. Our production cross section is about 26, 61, and 78 fb for LO, NLO and NNLO with some basic cuts applied, and the K-factor for LO, NNLO are about 2.34 and 3, which are at the reasonable agreement with references since our lepton is limited with μ only. see Table 1.

Table 1. Cross sections (fb) of $H \to WW \to \mu\nu\mu\nu$.

	LO	NLO	NNLO
Before cuts	26	61	78
After cuts	15	39	51

The major kinematics differences between LO, NLO and NNLO corrections are the lepton p_t distribution, the azimuthal separation of the charged lepton in the transverse plane ($\Delta\phi$), and the rapidity distribution of the Higgs and charge leptons.[1]. These are important kinematics parameters which will effected to the signal selections for the data analysis.

3. The Simulation Results

We have produced 10,000 events each for the process of $H \to WW \to \mu\nu\mu\nu$ with LO, NLO and NNLO.

We have made the p_t and η distributions of higher p_t μ (first μ), lower p_t μ (second μ). See Fig. 1-4. Fig. 5 shows the azimuthal separation of the two μ in the transverse plane ($\Delta\phi$). Fig. 6 shows the missing transverse energy (MET) distribution of the events. Fig. 7 shows the rapidity distribution of the Higgs.

If we follow the signal selection cuts we used in our analysis[6], we got the selection efficiency for each individual cuts as shown in the Table 2.

The overall efficiencies are shown in the Table 3.

If we normalize to LO as a unit 1, the NLO will be 2.6, NNLO will be 3.4

4. Impact to the Higgs Discovery Potential

In our $qqH \to WW \to l\nu l\nu$ study, we have reached the significance about 1.7 at the Higgs mass of 165GeV with 1 fb^{-1} data for LHC at 14 TeV.[6] We do not have

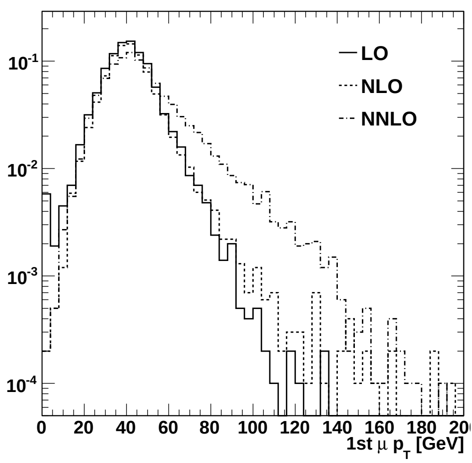

Fig. 1. p_t of first μ.

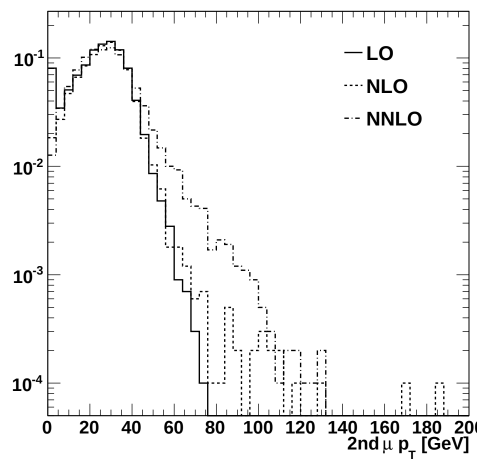

Fig. 2. p_t of second μ.

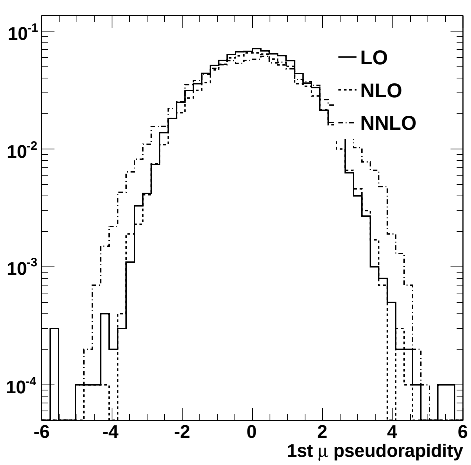

Fig. 3. η of first μ.

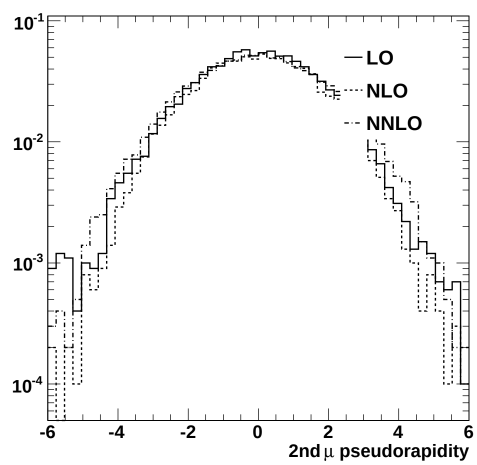

Fig. 4. η of second μ.

full simulation study for $H \to WW \to l\nu l\nu$ at 7 TeV. However, if we make an approximate estimation, and suppose all the backgrounds are the same with LO, NLO and NNLO corrections, then the significance could be increased from 1.7 to roughly factor of 3 if with NNLO corrections.

5. Conclusion

Including NLO and NNLO will increase the significance of Higgs discovery potential with channel $H \to WW \to l\nu l\nu$, M_H=165 GeV by estimation of factor of 2 to 3.

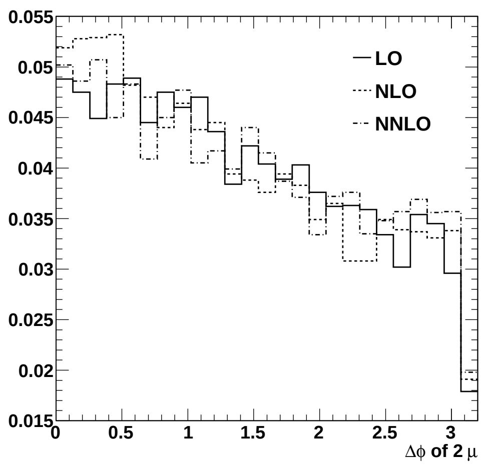

Fig. 5. Azimuthal separation of the two μ in the transverse plane.

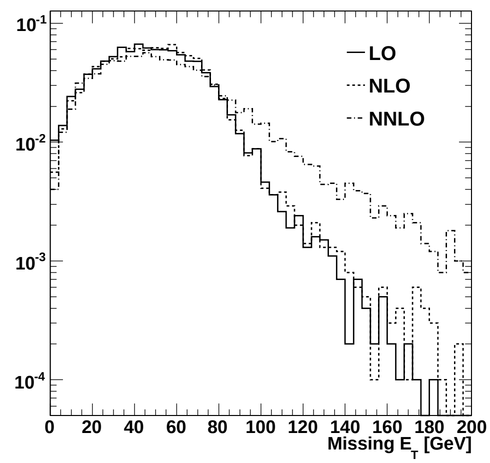

Fig. 6. Missing transverse energy.

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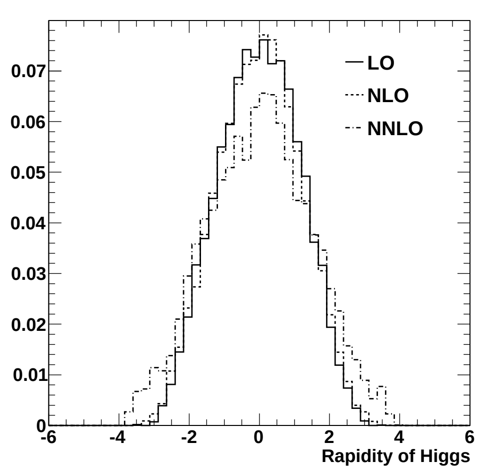

Fig. 7. Rapidity of Higgs

Table 2. Efiiciencies of each step with respect to previous step.

	LO	NLO	NNLO
First μ $p_t > 20$ GeV	0.96	0.98	0.98
Second μ $p_t > 10$ GeV	0.88	0.94	0.93
First μ $\|\eta\| < 2.5$	0.96	0.95	0.95
Second μ $\|\eta\| < 2.5$	0.91	0.92	0.94
MET > 30 GeV	0.80	0.80	0.80

Table 3. Efficiencies after each step with respect to total events.

	LO	NLO	NNLO
First μ $p_t > 20$ GeV	0.96	0.98	0.98
Second μ $p_t > 10$ GeV	0.84	0.92	0.91
First μ $\|\eta\| < 2.5$	0.81	0.87	0.86
Second μ $\|\eta\| < 2.5$	0.74	0.80	0.81
MET > 30 GeV	0.59	0.64	0.65

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