The state of Art Of Monte Carlo for tt+W and tt+Z Processes

Theraa Tork
Supervisors: Maria Moreno Llacer, Josh Mcfayden

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Abstract

The production of top quark in association with heavy boson is important as a signal and background. Due to the large mass of the top quark its Yukawa coupling is about unitary, ttH production offers a unique opportunity for direct measuring of such coupling which is essential to understand elector weak symmetry breaking and could give hints for new physics. $t\bar{t}H$ multi-lepton channel is the most sensitive channel for $t\bar{t}H$ and to improve the precision of this channel needs an improving of the modeling of $t\bar{t}V$ signal. This report study the modeling of the $t\bar{t}V$ using different Monte Carlo generators.

Contents

1 Introduction

The production of top-quark in association with heavy bosons is very important as a signal and background for many of ATLAS analysis. $t\bar{t}H$ production provides precise information of Higgs-top Yukawa coupling which will help to understand the electro weak symmetry breaking (EWSB) and also could be significant background to many beyond standard model searches.

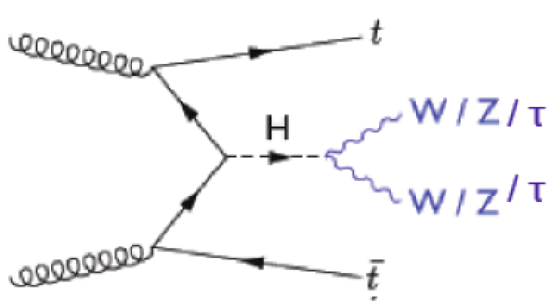


Figure 1: $t\bar{t}H$ feyman diagram

This report is focusing on studying the modeling $t\bar{t}Z$ and $t\bar{t}W$ signals which are important as a back ground for $t\bar{t}H$ process. $t\bar{t}Z$ signal is interesting to measure the top-quark coupling to Z boson, the final state radiation of $t\bar{t}Z$ allows to test SM assumptions such as that top quark is a weak isospin partner of bottom quark. $t\bar{t}W$ signal is interesting as a rare source of same-sign dileptons.[1]

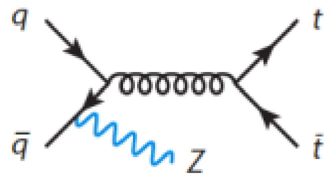


Figure 2: ttZ initial state radiation

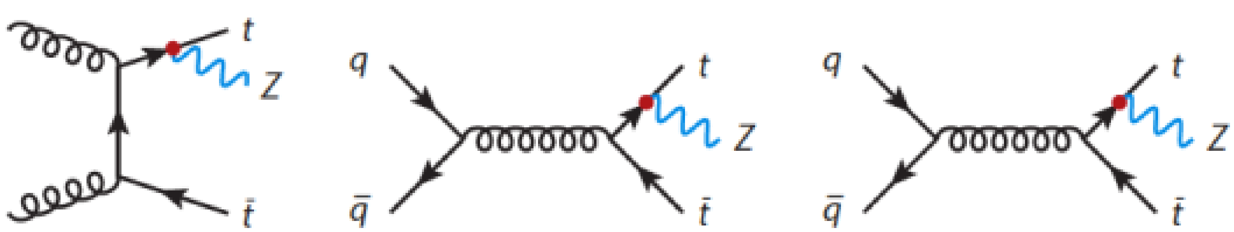


Figure 3: ttZ final state radiation

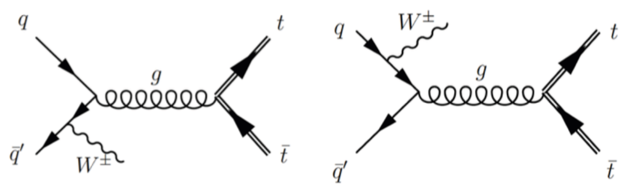


Figure 4: $t\bar{t}W$ initial state radiation

2 Generated Samples

A summary of Monte Carlo (MC) samples, the generators and the order of calculations is given in the following section. There are three families of samples:

MG5_aMC+Pythia8 NLO Events are generated using MG5_aMC at NLO interfaced with PYTHA8[4]. The re-normalization and factorization scales are set to half the transverse mass of the particles produced in the central process $H_T/2$. The top quark and vector boson decays are performed with MadSpin such that the spin correlations are preserved. The NNPDF3.0NLO PDF is used in the matrix element. The A14 tune is used in the shower.

LO multileg using Sherpa 2.2.0
samples are produced using LO ME with one or two additional partons included in the ME calculations for each process and merged with shepa parton shower using the ME+PS@LO prescription. The re-normalization and factorization scale is also $H_T/2$. The NNPDF3.0NLO PDF set is used in conjunction with a dedicated PS tune developed by Sherpa authors.[2]

NLO multileg using Sherpa 2.2.5
samples are produced using NLO ME with the number of additional partons included in the ME calculations

for each process and merged with Sherpa parton shower using the ME+PS@NLO prescription.[2]

Table 1 shows the comparison between MC generators setups. The NLO QCD and NLO EWK corrections have been introduced for the first time for this background. This has improved the accuracy and will lead to improve modelling of these process and reduce theoretical uncertainty of precise measurement.

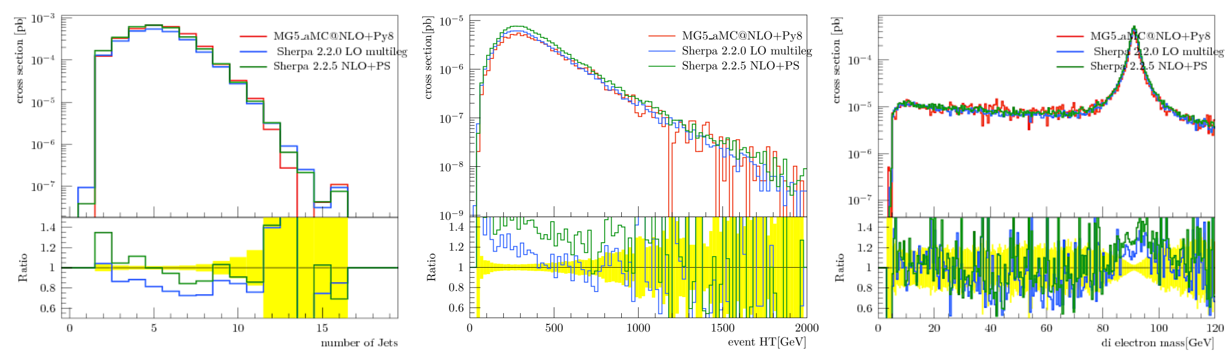
Generator	QCD Order	QED Order	Process and number of additional jets
MadGraph_aMC@NLO	NLO	LO	ttW and ttZ
Sherpa 2.2.0	LO	LO	ttW :0, 1, 2 LO jets ttZ: 0, 1 jets
sherpa 2.2.5	NLO	NLO	ttZ: 0,1 jets

Table 1: The order of calculation and number of additional jets are shown for different processes and generators setups.

3 Results

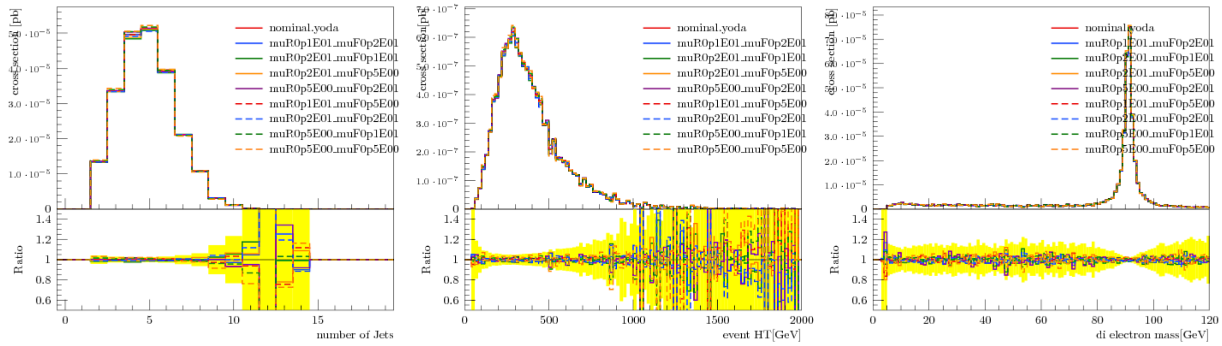
3.1 $t\bar{t}Z$ Process

In this section,the comparison between the various samples of $t\bar{t}$+$l\bar{l}$ are shown in Figure 5 and 6. The purpose of these studies is to provide a validation of generators and expose differences in the modeling in each generator setup. The analysis was performed using Rivet.[3]
The three setups described in section 2 are used to simulate $t\bar{t}Z(\rightarrow \mathrm{ll})$. There is a discrepancy which can be observed at high $\mathrm{H_T}$ in Figure5, otherwise a good agreement between the three setups.
Samples with renormalization μ_{R} and factorization μ_{F} scales variations were produced for $t\bar{t}Z$ NLO MG5_aMC+Py8 samples, where μ_{R} and μ_{F} are varies simultaneously up and down by a factor of two from a central scale μ_0= $\mathrm{H_T}/2$.



(a) (b) (c)

Figure 5: This Figures show the comparison between MG5_aMC+ Pythia8@NLO,LO sherpa2.2.0 and NLO Sherpa 2.2.5 for $t\bar{t}$+$l\bar{l}$ process. Figure(a)show the cross section as a function of number of jets in the event. Figure (b) show the cross section as a function of the sum of jets transverse momentum. Figure(c)shows the absolute cross section as a function of di-electron mass.



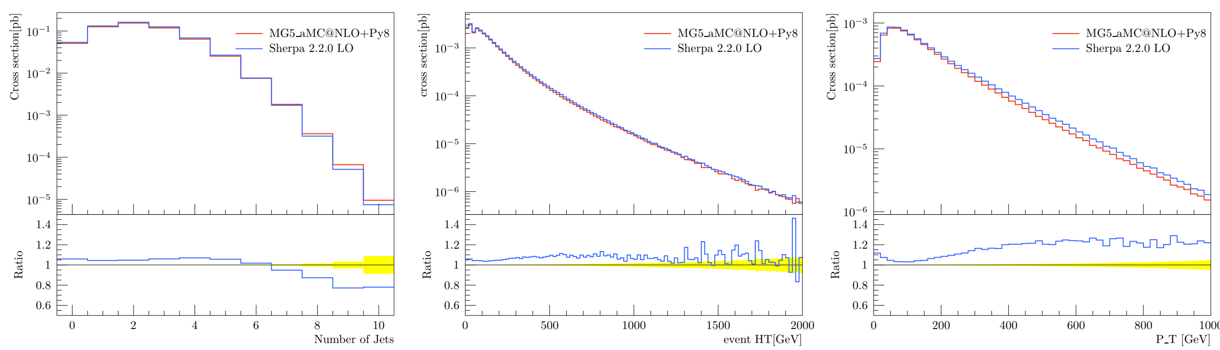
(a) (b) (c)

Figure 6: MG5_aMC+ Pythia8@NLO scale variations are shown.Figure(a)show the cross section as a function of number of jets in the event. Figure (b) show the cross section as a function of the sum of jets transverse momentum. Figure(c)shows the absolute cross section as a function of di-electron mass.

3.2 $t\bar{t}W$ Process

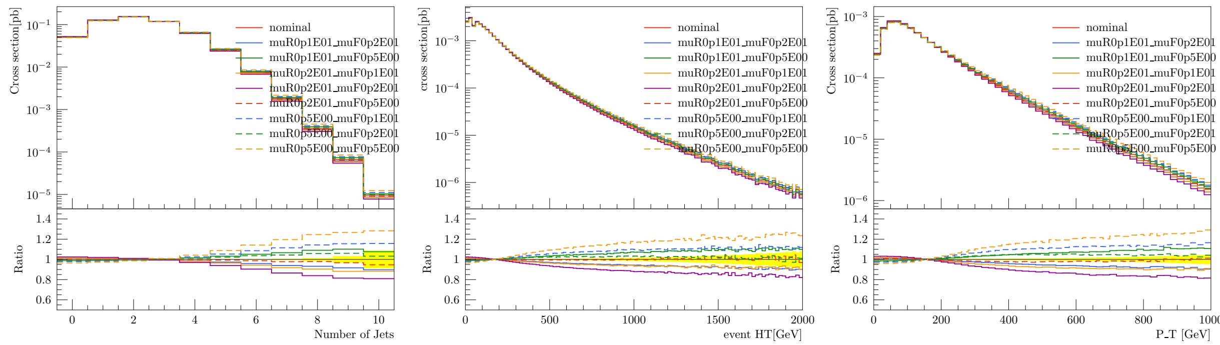
The comparison between MG5_aMC+PYTHIA8 NLO and SHERPA 2.2.0 LO has been studied for $t\bar{t} + W$ samples. Figure 7 shows a good agreement between the two generator setups.
μ_{R} and μ_{F} scale variations are produced for $t\bar{t} + W$ MG5_aMC+PYTHIA8 NLO samples. Figure 8 show the effect of renormalization and factorization scales for jet multiplicity, $\mathrm{H_T}$ and $t\bar{t}$ transverse momentum.

The jet multiplicity which is shown in (a) in both figures 7 and 8, show that the ratio difference between the two setups is less than 20% and SHERPA 2.2.0 ratio shape is following the $\mu_{\mathrm{R},2}\mu_{\mathrm{F},0.5}$ ratio shape. Plot(b) shows the cross section as a function of event $\mathrm{H_T}$, it is observed that the ratio of the nominal scale of SHERPA 2.2.0 in figure 6 is following $\mu_{\mathrm{R},0.5}\mu_{\mathrm{F},0.5}$, the same for $t\bar{t}$ transverse momentum can be observed in Plot(c).



(a) (b) (c)

Figure 7: This Figures show the comparison between MG5_aMC+ Pythia8@NLO and LO SHERPA2.2.0 for $t\bar{t}$W process. Figure(a)show the cross section as a function of number of jets in the event. Figure (b) show the cross section as a function of the sum of jets transverse momentum $\mathrm{H_T}$. Figure(c)shows the cross section as a function of $t\bar{t}$ transverse momentum.



(a) (b) (c)

Figure 8: This Figures show the MG5_aMC+ Pythia8 renormalization and factorization scale variations. Figure(a)show the cross section as a function of number of jets in the event. Figure (b) show the cross section as a function of the sum of jets transverse momentum. Figure(c)shows the absolute cross section as a function of $t\bar{t}$ transverse momentum .

4 Conclusion

The production of a top quark in association with a heavy SM vector boson (Z,W) has been studied in this report. MG5_aMC+ Pythia8,LO sherpa2.2.0 and NLO Sherpa 2.2.5 setups have been compared for tt+ll process. For ttW process MG5_aMC+ Pythia8,LO sherpa2.2.0 setups have been compared and validated using Rivet.

References

[1] ATLAS Collaboration, *Modelling of $t\bar{t}H$ $t\bar{t}V$ (V= W, Z) process for $\sqrt{s}$= 13 TeV ATLAS Analysis.*

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[4] J. Alwall et al., *The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations.*