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Standard setup for the comparison of tTH simulations at NLO QCD + Parton Shower

This is the setup we propose for the comparison of tTH production in NLO QCD+Parton Shower simulations.

General framework

For the comparison among existing NLO QCD+PS tools we will consider only the case of a scalar and will include only NLO QCD corrections. EW corrections will be discussed in the section on signal and are included in the tables that give fixed-order results obtained scanning over MH for various center of mass energy.

We propose to compare results from:

- Sherpa2.2.0+Openloops1.2.3
- MG5_aMC@NLO 2.3.2+Pythia8.2.1.0
- POWHEG-BOX+Pythia8.2.1.0
- PowHel +Pythia8.2.1.0

The last two simulations should give very similar results since they are both based on POWHEG, but they have never been compared and we think it will be useful to. Upon agreement, we would probably quote only one set of results based on the interface with POWHEG.

Simulation setup

All the input parameters will be chosen in compliance with the official Higgs HXSWG note <https://cds.cern.ch/record/2047636/files/LHCHXSWG-INT-2015-006.pdf>

Specific input parameters and PDFs

- consider $\sqrt{s}=13$ TeV;
- use MH=125 GeV and $m_t=172.5$ GeV (see recommendation);
- use $y_t=m_t*\sqrt{2}*\sqrt{2}*GF$ for the top Yukawa coupling;
- use NLO PDF4LHC15_30;
- 5F scheme

QCD scales and variations

- dynamical renormalization/factorization scale choice: $\mu_R=\mu_F=\mu_0$ =geometric mean of transverse energy of H,t,T, where $\text{transverse energy}=\sqrt{M^2+P_T^2}$
- scale uncertainties should be estimated with the usual independent factor-2 variations of (μ_R,μ_F) excluding antipodal variations

Resummation scale (HT/2)

- In Sherpa+OpenLoops the resummation scale HT/2 should be used, with HT= sum of t,T,H transverse energies
- In POWHEG $\text{hdamp}=\text{HT}/2$ should be used. It should be possible to set such a dynamical hdamp factor by adapting the Bornzerodamp.f routine. Alternatively a fixed scale $M_t+MH/2$ should be used.
- In MG5aMC@NLO the resummation scale $\mu_Q=\text{HT}/2$ should be used.

Other MC related aspects

- hadronization, UE and QED shower should be switched off
- no generation cuts should be applied; all cuts will be applied at the level of the Rivet analysis (see below)

Decays

- two separate simulations: (a) tTH production w.o. decays and (b) with decays $t\bar{t}H \rightarrow 4b + e^+ + \mu^- + 2$ neutrinos
- for top and $H \rightarrow b\bar{b}$ decays the BRs provided by the shower should be used
- spin correlation effects should be included in top decays
- in order to minimize the effect of treating decays at LO, normalize the corresponding branching ratios to the following values:
 - ◆ $BR(H \rightarrow b\bar{b}) = 57.7\%$ (taken from YR3 at 125.0 GeV)
 - ◆ $BR(t \rightarrow e \nu b) = BR(W \rightarrow e \nu) = 10.83\%$ (taken from PDG 2014)

Analyses

The following two analyses (without and with decays) will be implemented in a public Rivet routine that will be available very soon.

(a) Observables for tTH production without decays

- total cross section
- p_T of t, T, H (20 bins from 0, 500 GeV)
- η of t, T, H (20 bins from -4, 4)
- p_T of tTH and tT system (20 bins from 0, 500 GeV)
- p_T of 1st light jet (non-b jets) with $R=0.4$ anti-kT algorithm and $\eta < 2.5$ (20 bins from 25, 525 GeV)
- geometric average of t, T, H transverse energies (20 bins from 0, 1000 GeV)
- $HT = \text{sum of } t, T, H \text{ transverse energies (ignoring extra jet emissions)}$ (20 bins from 400, 1000 GeV)

(b) Observables for $t\bar{t}H \rightarrow e^+ \mu^- \nu \bar{\nu} + 4b$ (leptonic and b-jet cuts: see below)

- total cross section without any cut
- exclusive and inclusive b-jet multiplicity distribution after leptonic cuts; the following observables should be computed with leptonic cuts and requiring four b-jets
- p_T of first four b jets, e^+ , μ^- (20 bins from 0, 400 GeV)
- η of first four b jets, e^+ , μ^- (20 bins from -4, 4)
- $\phi(l^+, l^-)$ (azimuthal angle between hardest l^+ and l^-), studying effects of spin correlation in this last case
- MET (20 bins from 0, 400 GeV)

Basic leptonic cuts for $t\bar{t}H \rightarrow e^+ \mu^- \nu \bar{\nu} + 4b$

- 2 charged leptons with $p_T > 20 \text{ GeV}$ and $\eta < 2.5$
- $MET > 30 \text{ GeV}$

b-jets

- b-jets are defined as $R=0.4$ anti-kT b-jets with $p_T > 25 \text{ GeV}$ and $\eta < 2.5$, which contain at least 1 b-quark

Rivet analyses

- Rivet routines that implement the above two analyses (as well as example plots corresponding to a LO+PS simulation) can be found at this URL [↗](#)
 - ◆ hxswg_tth_dilep = with dileptonic decays
 - ◆ hxswg_tth_stable = without decays
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