Sherpa Generator Studies for HWW analyses

Amandeep Kaur under supervision of
Frank Krauss, Marek Schönherr and Gurpreet Singh Chahal

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Introduction : About Me and The Project

Hi All , I am Amandeep Kaur .

I am a PhD student at Panjab University , India .

Working with HWW for my PhD analysis ; a subgroup of CMS Higgs Physics Analysis Group (Higgs PAG)

Joined Durham University as Early Stage Researcher for six month under MCnet studentship program .

Title : Sherpa Generator Studies for HWW analyses .

Supervisor(s) : Frank Krauss, Marek Schönherr and Gurpreet Singh Chahal

Duration : 01 June 2020 - 30 Nov 2020

Aim :

- Generate the WW+jets sample , number of jets upto 3-4 , categorised as WW+0jet, WW+1jet, WW+2jets, WW+3jets, WW+4jets samples . Check the accuracy of these processes with Sherpa. **Processes** : qqWW , ggWW

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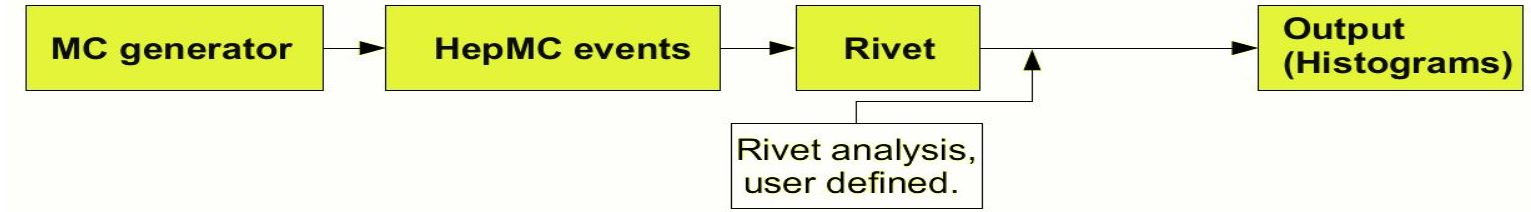
In the whole process, generating events / WW+jets (& Higgs+jets) sample via Sherpa and then creating hepmc file , finally running Rivet code over it and creating the validation plots .



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- (HWW) Planning to publish* a differential cross section measurement as a function of number of jets (also up to 4-5 jets), it is important to have a precise theoretical description of H+jets events also at high jet multiplicities .
- So far , we tried to have WW + jets , Higgs +jets and ttbar sample at LO and set up a rivet code as per our selections and plotted the validation plots for kinematical variables.

* underway (paper submitted in JHEP) , sherpa samples will be explored for version 2 of this analysis.

Selections :

Trying to validate the sample as per following analysis requirements:

- Leading two leptons have opposite sign and different flavour.
- pT should be greater than 25 , 13 GeV
- eta requirement : $|\eta| < 2.5$ (2.4) for electron (muon)
- pTmiss > 20 GeV
- pT of pair of lepton > 30 GeV
- No additional lepton i.e. pT <10 GeV
- b-veto , cleaning jet of leptons

Run card : WW sample

```
(run){
  % general settings
  EVENTS 1M;

  % scales, tags for scale variations
  FSF:=1.; RSF:=1.; QSF:=1.;
  SCALES METS{FSF*MU_F2}{RSF*MU_R2}{QSF*MU_Q2};

  % tags for process setup
  NJET:=0; LJET:=0; QCUT:=30.;

  % me generator settings
  ME_SIGNAL_GENERATOR Comix Amegic LOOPGEN;
  EVENT_GENERATION_MODE Weighted;
  LOOPGEN:=OpenLoops;
  EXCLUSIVE_CLUSTER_MODE 1;
  METS_CLUSTER_MODE 16;

  % define parton container without b-quarks to
  % remove any processes with top contributions
  PARTICLE_CONTAINER 901 lightflavs 1 -1 2 -2 3 -3 4 -4 21;
  NLO_CSS_DISALLOW_FLAVOUR 5;

  % collider setup
  BEAM_1 2212; BEAM_ENERGY_1 6500.;
  BEAM_2 2212; BEAM_ENERGY_2 6500.;
}(run)
```

```
(processes){
  Process 901 901 -> 90 91 90 91 901{NJET};
  Order (*,4); CKKW sqr(QCUT/E_CMS);
  NLO_QCD_Mode MC@NLO {LJET};
  ME_Generator Amegic {LJET};
  RS_ME_Generator Comix {LJET};
  Loop_Generator LOOPGEN {LJET};
  Integration_Error 0.05 {5,6,7,8};
  End process;
}(processes)
```

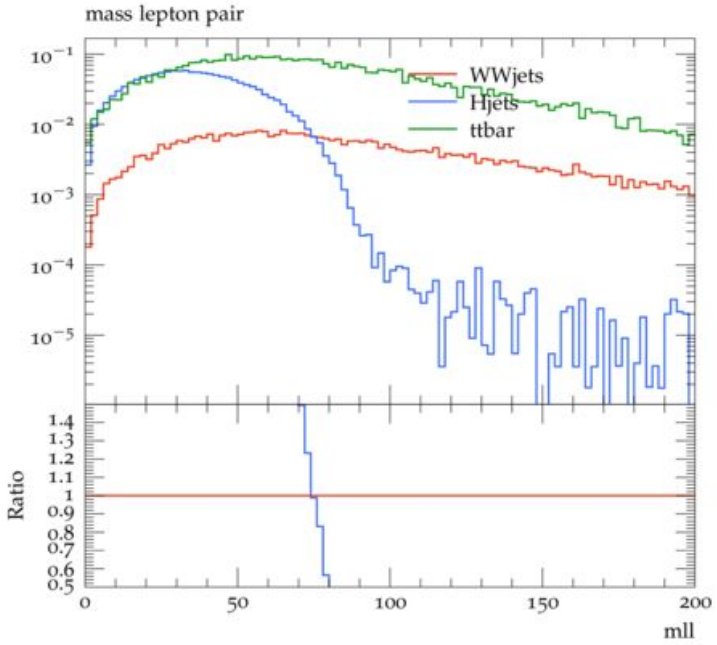
90 : Lepton ; 91: neutrino

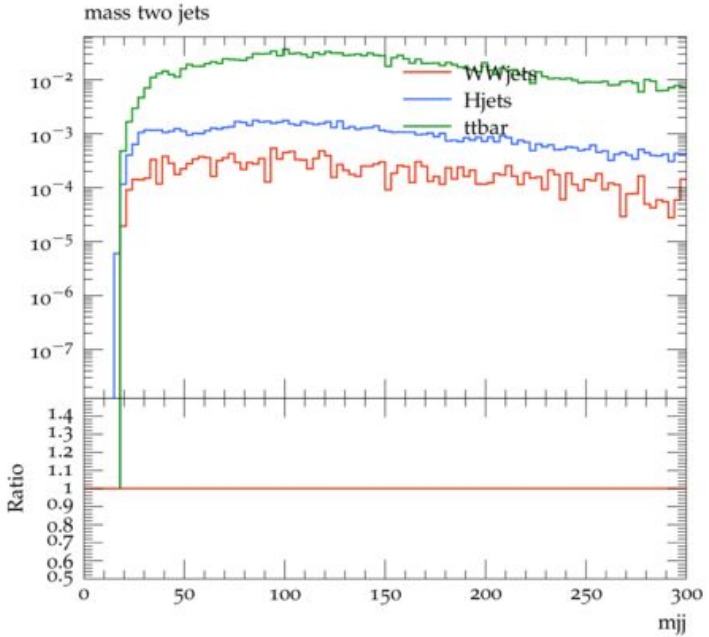
LO accuracy

Higgs+jets , ttbar Run cards are in backup !

Beam setup

Kinematical Distributions :





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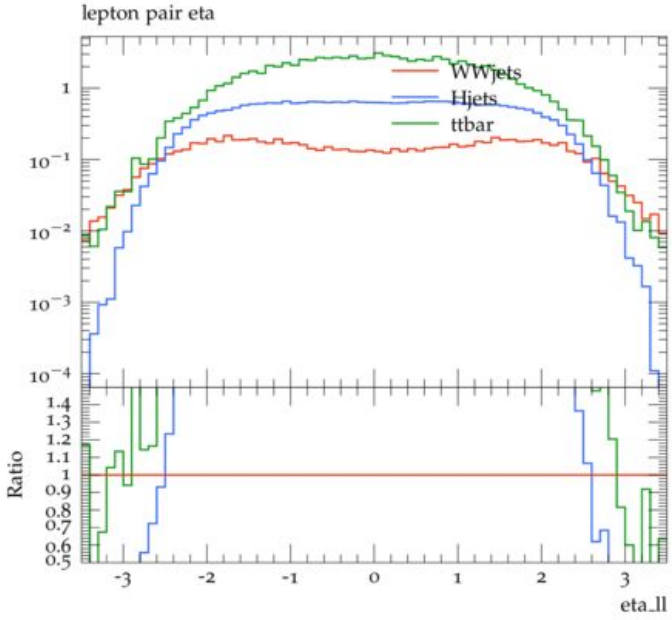

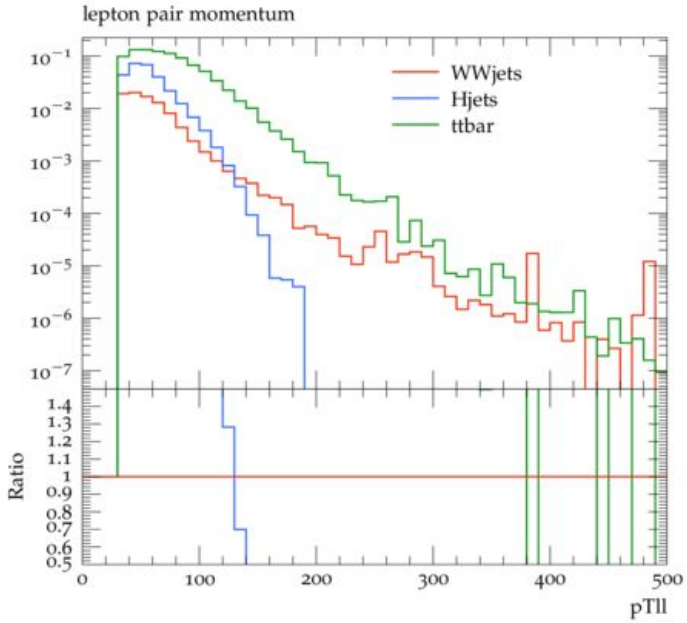

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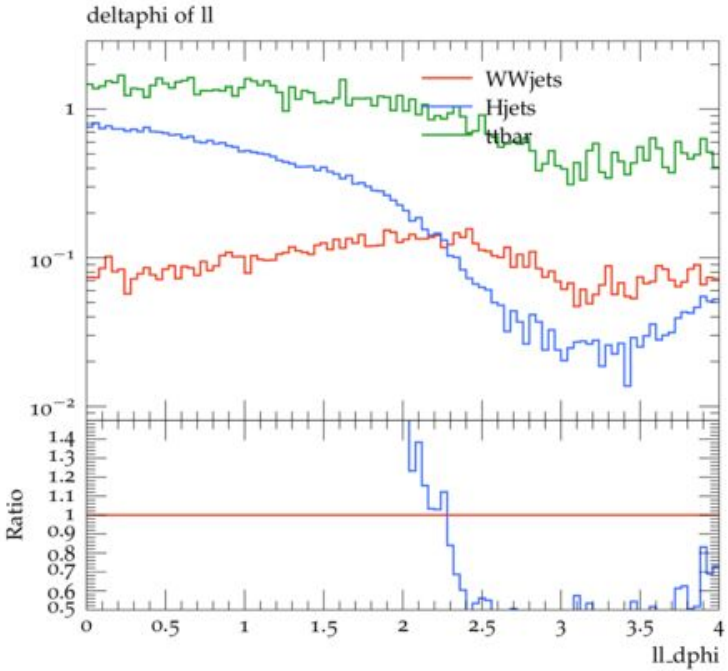

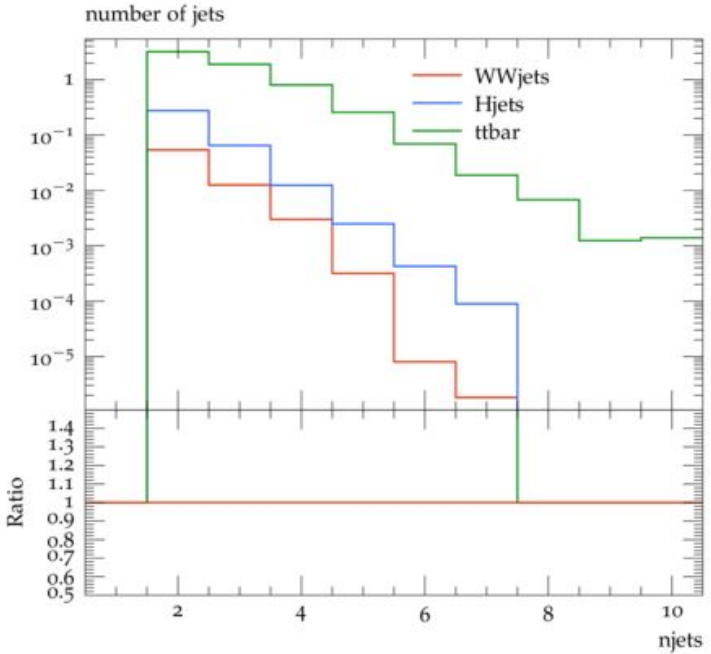

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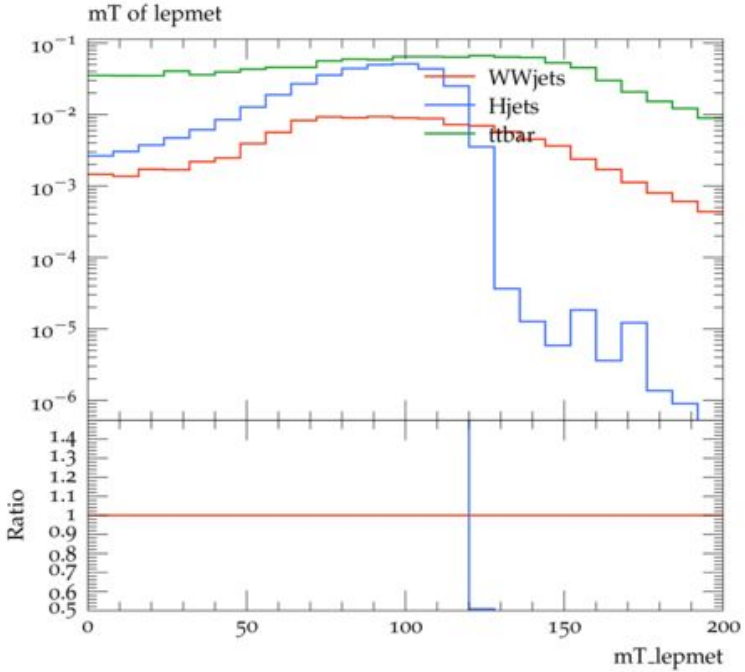

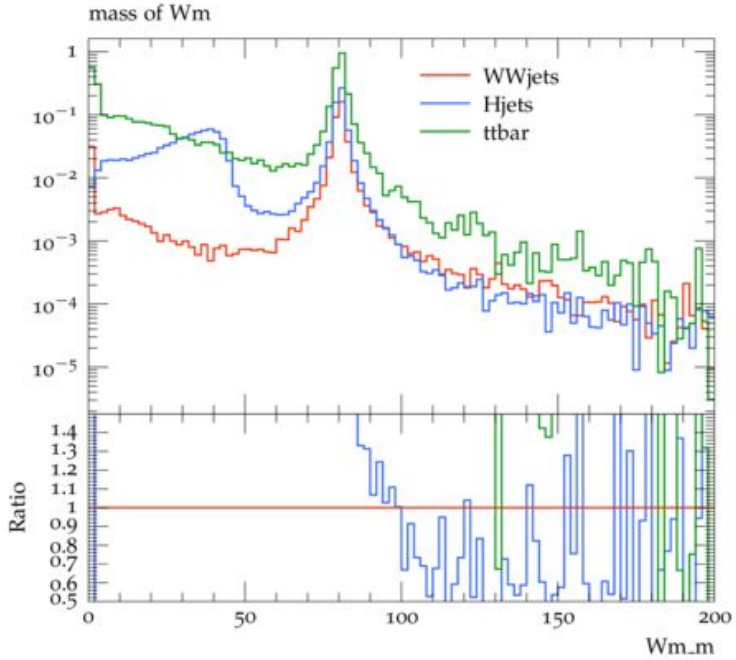

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- Rivet routine is all working fine , of course modification can be and will be done in future !
- Various potential variables : reflects the signal (Higgs) and background (WW) separations clearly .

What's next ?

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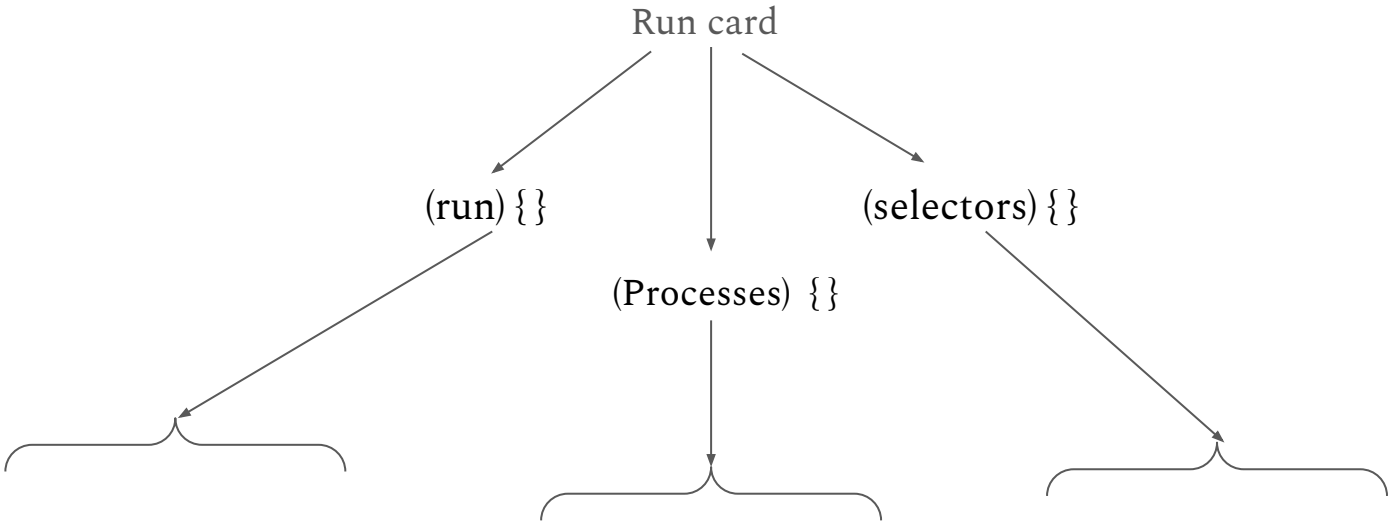
- To explore other possible variables e.g. angular variables : b/w decay planes , leptons-lepton , lepton-jet etc .
- ML approach for the maximum separation between signal and background .
- Compare the SHERPA samples with PYTHIA samples (already being used in HWW analyses) .


Thank
you

Backup !

Sherpa : We use single run card , Run.dat here which consists of following sub sections



All the general settings are implemented here for ex: number of events , beam settings , tags , njtets settings , matrix element settings etc.

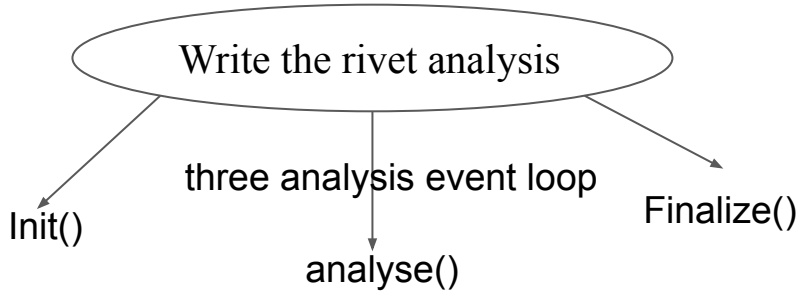
Definition of the process that is under consideration for ex :

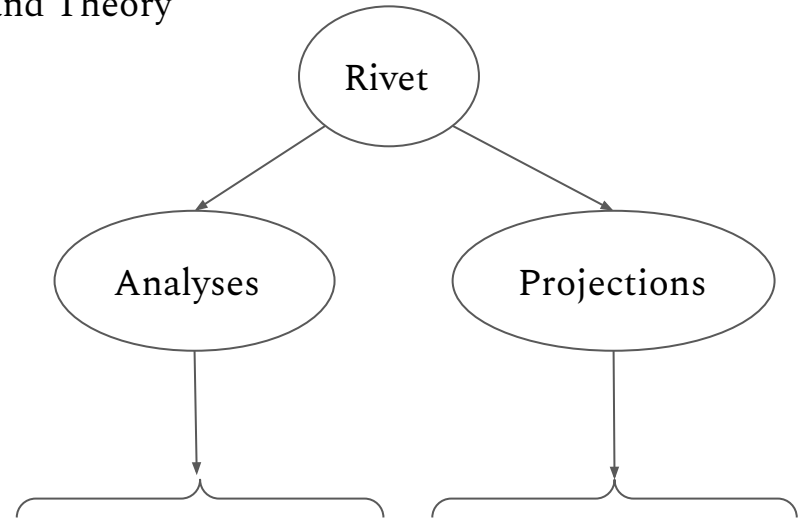
Process 93 93 → 25 93{NJET};
pp → higgs + njets

If needed phase space cuts to be implemented are provided here

Rivet : Robust Independent Validation of Experiment and Theory

Command line that I tried using :
rivet --list-analyses - provide the list of analyses .





rivet-mkanalysis Analysis_name

Analysis_name.cc Analysis_name.info Analysis_name.plot

rivet-buildplugin Analysis_name.cc

routines : implement published experiment analyses

Calculate the properties from an Event , for ex : charge of the particle , multiplicity etc. Rivet is pre equipped with projection classes eg , FinalState - get the final state particles etc.

Short exercise :
wget http://www.hepforge.org/archive/rivet/Z-hadronic-LEP.hepmc
rivet Z-hadronic-LEP.hepmc -a SLD_2002_S4869273
rivet-mkhtml --mc-errs Rivet.yoda:"MC Simulation"

Higgs+jets sample

```
(run){
 % general settings
 EVENTS  ; ERROR 0.1;

 % tags and settings for scale definitions
 FSF:=1.0; RSF:=1.0; QSF:=1.0;
 SCALES STRICT_METS{FSF*MU_F2}{RSF*MU_R2}{QSF*MU_Q2};

 % tags for process setup
 LJET:=1,2; NJET:=1; QCUT:=30.;

 % tags and settings for ME generators
 ME_SIGNAL_GENERATOR Comix Amegic Internal OpenLoops;
 EVENT_GENERATION_MODE Weighted;

 % settings for hard decays
 HARD_DECAYS On;
% enforce decay in WW*[->lnu]
  HDH_STATUS[25,24,-12,11]=2;
  HDH_STATUS[25,24,-14,13]=2;
  HDH_STATUS[25,-24,12,-11]=2;
  HDH_STATUS[25,-24,14,-13]=2;
% enforce decay of W to l nu
  HDH_STATUS[24,12,-11]=2;
  HDH_STATUS[24,14,-13]=2;
  HDH_STATUS[-24,-12,11]=2;
  HDH_STATUS[-24,-14,13]=2;
  HDH_BR_WEIGHTS 0;

 % model parameters
 MODEL HEFT;
 MASS[25] 125.; WIDTH[25] 0.;

 % collider setup
 BEAM_1 2212; BEAM_ENERGY_1 6500;
 BEAM_2 2212; BEAM_ENERGY_2 6500;

 % finite top mass effects
 KFACTOR GGH;
 OL_IGNORE_MODEL 1;
 OL_PARAMETERS preset 2 allowed_libs pph2,pphj2,pphjj2 psp_tolerance 1.0e-7;
}(run);

(processes){
 Process 93 93 -> 25 93{NJET};
 Order (*,0,1); CKKW sqr(QCUT/E_CMS);
 NLO_QCD_Mode MC@NLO {LJET};
 Loop_Generator Internal {LJET};
 ME_Generator Amegic {LJET};
 RS_ME_Generator Comix {LJET};
 End process;
}(processes);
```

ttbar sample :

```
(run){
  EVENTS 10; ERROR 0.99;
  %scales, tags for scale variations
  FSF:=1.; RSF:=1.; QSF:=1.;
  SCALES STRICT_METS{FSF*MU_F2}{RSF*MU_R2}{QSF*MU_Q2};
  CORE_SCALE TTBar;
  EXCLUSIVE_CLUSTER_MODE 1;
  METS_BBAR_MODE=5
  NLO_CSS_PSMODE=1

% collider setup
  BEAM_1 2212; BEAM_ENERGY_1 = 6500.;
  BEAM_2 2212; BEAM_ENERGY_2 = 6500.;

  %tags for process setup
  NJET:=4; LJET:=2,3; QCUT:=30.;

  %me generator settings
  ME_SIGNAL_GENERATOR Comix Amegic LOOPGEN;
  LOOPGEN:=OpenLoops;
  OL_PARAMETERS=ew_scheme 2 ew_renorm_scheme 1
  ASSOCIATED_CONTRIBUTIONS_VARIATIONS=EW EW|LO1 EW|LO1|LO2
EW|LO1|LO2|LO3;
  CSS_REWEIGHT=1
  REWEIGHT_SPLITTING_ALPHAS_SCALES 1
  REWEIGHT_SPLITTING_PDF_SCALES 1
  CSS_REWEIGHT_SCALE_CUTOFF=5.0
  HEPMC_INCLUDE_ME_ONLY_VARIATIONS=1

  INTEGRATION_ERROR=0.05;
```

```
%decay settings
HARD_DECAYS On; HARD_SPIN_CORRELATIONS 1;
  HDH_STATUS[24,12,-11]=2
  HDH_STATUS[24,14,-13]=2
  HDH_STATUS[24,16,-15]=2
  HDH_STATUS[-24,-12,11]=2
  HDH_STATUS[-24,-14,13]=2
  HDH_STATUS[-24,-16,15]=2
  STABLE[24] 0; STABLE[6] 0; WIDTH[6] 0;
}(run)

(processes){
  Process : 93 93 ->  6 -6 93{NJET};
  NLO_QCD_Mode 3 {LJET}; CKKW sqr(QCUT/E_CMS);
  ME_Generator Amegic {LJET};
  RS_ME_Generator Comix {LJET};
  Loop_Generator LOOPGEN;
  Associated_Contributions EW|LO1|LO2|LO3 {LJET};
  Order (*,0);
  Enhance_Observable
VAR{log10(max(sqrt(H_T2)-PPerp(p[2])-PPerp(p[3]),(PPerp(p[2])+P
Perp(p[3]))/2))}|2|3.3
  End process
}(processes)
```