The POWHEG-BOX-V2/WWJ manual

1 Introduction

The POWHEG-BOX WWJ program [1] can be used to generate the QCD production of W^+W^- + 1 jets events in hadronic collisions, with the W-bosons decaying into leptons or hadrons, to NLO accuracy in QCD, in such a way that matching with a shower program is possible. As in the WW process, in the case of decays into hadrons, NLO corrections to the decay processes are not included. This is unlikely to be necessary: most shower Monte Carlo already do a good job in dressing the W decay with QCD radiation, since W hadronic decays have been fit to LEP2 data. The effect of off-shell singly resonant graphs is fully included. The CKM matrix is by default the Cabibbo matrix. The calculation is performed in the four-flavour scheme. Therefore it is mandatory to use a four-flavour PDF, as reminded in the template input cards.

If the W-bosons decay into leptons of the same flavour (e.g. $e^+e^-\nu_e\bar{\nu}_e$), then the ZZJ production of this signal should be considered separately. Interference between these two processes is negligible (see ref. [2], where the same interference is considered without the extra jet) and is not included. This document describes the input parameters that are specific to this implementation. The parameters that are common to all `POWHEG BOX` implementation are given in the `POWHEG-BOX-V2/Docs` directory.

When the MINLO option is switched on, the WWJ generator becomes NLO accurate also for inclusive W^+W^- production. Furthermore, when the NNLOPS option is also switched one, a on-the-flight reweighting to NNLO (fully differential in the Born phase space) is performed.

2 Generation of events

In the WWJ directory do

```
$ make pwhg_main
```

Then do (for example)

```
$ cd testrun-lhc
$ ../pwhg_main
```

At the end of the run, the file `pwgevents.lhe` will contain events for W-pair production in association with one jet in the Les Houches format. In order to shower them with PYTHIA:

```
$ make main-PYTHIA-lhef
$ cd test
$ ../main-PYTHIA-lhef
```

However, because the program is numerically intensive, we do not recommend to run it without the POWHEG parallel-feature version switched on, as described in detail in ref. [3]. A template input card can be found in the testrun-wwj-parallel directory. In the testrun-minlo-parallel directory, instead, we provide a template input card to perform a run with the MINLO option activated.

3 Input parameters

Parameters in powheg.input that are specific to WW pair production in association with one jet are listed in the following:

```
runningscale 0    !  (default 0), 0 = fixed scale 2M_W,
                  !  1 == M(WW), 2 == M_{T,W+} + M_{T,W-}
minlo 0           !  (default 0) if 1 turn on the MINLO option

nnlops 0          !  (default 0) if 1 turn on the NNLOPS option
```

Note that, MINLO overwrites any other running scale choice. The NNLOPS works only if the MINLO option is on. Finally, if MINLO is off one needs a Born suppression factor. Alternatively, once could implement cuts in the phase-space generation to make the cross-section finite.

The NNLOPS option is new in the WWJ code and it allows to reweight to the NNLO result on the flight. This option is not yet present in other NNLOPS codes (Higgs, Drell Yan, associated Higgs production). The on-the-flight reweighting to the NNLO WW is performed using precomputed NNLO tables obtained with the MATRIX code [5] and with WWJ-MINLO [1]. The setup of the NNLO and MINLO is described in detail in ref. [4]. If one wishes to reweight using a different PDF set, or a different collider energy, one might want to generate new MINLO and NNLO reweighting tables. Note however that the reweighing factor should be relatively insensitive to input parameters.
Several decay modes can be selected by an appropriate flag in the powheg.input file:

```
e+e- 1                  !    only electrons
mu+mu- 1                !    only muons
tau+tau- 1              !    only taus
leptonic_notau 1        !    both W's go into leptons (but not τ)
leptonic 1              !    both W's go into leptons
hadronic 1              !    both W's go into hadrons
semileptonic 1          !    one W goes into hadrons, one into leptons
semileptonic_notau 1    !    one W goes into hadrons, one into leptons (but not τ)
e+mu- 1                 !    W+ decays to electrons, W- to muons
mu+e- 1                 !    W- decays to electrons, W+ to muons
```

More conditions can be easily added, by editing the `alloweddec` function in the `init_processes.f` file. If no condition is specified in the input card, the default decay channel is assumed, namely `e+mu-`.

As a final remark, we note that in ref. [1] we found that closed fermion loops slow down the calculation considerably, yet provide no sizable effect in any distribution that we considered (within our numerical accuracy). Hence, we also provide the possibility to run the code without including closed fermion loops. This can be achieved by setting the variable `GOSAMDIR` to `GoSamlib_nofboxes` in the Makefile, and recompiling the code from scratch.

References

[1] K. Hamilton, T. Melia, P. F. Monni, E. Re and G. Zanderighi, arXiv:1606.07062 [hep-ph].

[2] T. Melia, P. Nason, R. Rontsch and G. Zanderighi, JHEP **1111** (2011) 078 doi:10.1007/JHEP11(2011)078 [arXiv:1107.5051 [hep-ph]].

[3] POWHEG-BOX-V2/Docs/V2-paper.pdf

[4] E. Re, M. Wiesemann and G. Zanderighi, arXiv:1805.09857 [hep-ph].

[5] M. Grazzini, S. Kallweit and M. Wiesemann, arXiv:1711.06631 [hep-ph].