

# The POWHEG-BOX-V2 ZZ manual

## 1 Introduction

The POWHEG-BOX-V2/ZZ program [1] can be used to generate the QCD production of  $ZZ$  events in hadronic collisions, with the  $Z$  bosons decaying into leptons, neutrinos or quarks, at NLO accuracy in QCD, in such a way that matching with a full shower program is possible. It is based upon the calculation of refs. [2], [3], [4]. The effect of  $Z$ - $\gamma$  interference, as well as the effect of off-shell singly resonant graphs, are fully included in the calculation. In case of decays into hadrons, NLO corrections to the decay processes are not included. This is unlikely to be necessary: most shower Monte Carlo do already a good job in dressing the  $W$  decay with QCD radiation, since  $W$  hadronic decays have been fit to LEP2 data.

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 manual in the POWHEG-BOX-V2/Docs directory.

## 2 Generation of events

Do

```
$ cd POWHEG-BOX-V2/ZZ
```

```
$ make pwhg_main
```

Then do (for example)

```
$ cd test
```

```
$ ../pwhg_main
```

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

```
$ cd POWHEG-BOX-V2/ZZ
```

```
$ make main-PYTHIA-lhef
```

```
$ cd test
```

```
$ ../main-PYTHIA-lhef
```

## 3 Input parameters

Parameters in `powheg.input` that are specific to  $ZZ$  pair production:

```
semileptonic 1 ! one Z goes to hadrons, one goes to leptons
```

```
only-e 1      ! leptons can only be electrons
```

```
only-mu 1     ! leptons can only be muons
```

```
only-tau 1    ! leptons can only be taus
```

```
e-mu 1       ! one goes into e+e-, one in mu+mu-
```

```
e-tau 1      ! one goes into e+e-, one in tau+tau-
```

```
mu-tau 1     ! one goes into mu+mu-, one in tau+tau-
```

```
leptonic 1    ! both Z go into charged leptons
```

```
leptons-nu 1  ! one Z goes into neutrinos, the other to leptons
```

```
hadrons-nu 1  ! one Z goes into neutrinos, the other to hadrons
```

More conditions can be easily added, by editing the `alloweddec` function in the `init_processes.f` file. Notice that conditions must all be fulfilled. Thus, for example, `only-e` and `leptonic` both set to 1 (and no other keyword) means decays into four electrons. As another example, if both `semileptonic` and `leptonic` appear, you get no events. If no conditions are specified, you get all possible decays. Other options specific of the  $ZZ$  process are

```

mllmin 50          ! minimum mass of charged lepton-antilepton or
                   ! quark-antiquark pairs in decays is 50 GeV
zerowidth 0        ! If 1 (true) use zerowidth approximation (default 0)
withinterference 1 ! If 1 (true) include interference for identical leptons
                   ! (default 1)
dronly  0          ! If 1 (true) include only double resonant contributions
                   ! (default 0)

```

Notice that in case of decays into equal charged particles, the `mllmin` cut is applied to the two possible pairings. If `zerowidth` is absent or equal to zero, the  $Z$ 's are given finite width,  $Z$ - $\gamma$  interference is accounted for. Singly resonant graphs are also included by default, unless the `dronly` flag is set to 1.

## Bibliography

- [1] T. Melia, P. Nason, R. Rontsch, and G. Zanderighi,  *$W+W$ -,  $WZ$  and  $ZZ$  production in the POWHEG BOX*, *JHEP* **1111** (2011) 078, [[1107.5051](#)].
- [2] L. J. Dixon, Z. Kunszt, and A. Signer, *Helicity amplitudes for  $O(\alpha_s)$  production of  $W^+ W^-$ ,  $W^\pm Z$ ,  $ZZ$ ,  $W^\pm \gamma$ , or  $Z\gamma$  pairs at hadron colliders*, *Nucl.Phys.* **B531** (1998) 3–23, [[hep-ph/9803250](#)].
- [3] J. M. Campbell and R. K. Ellis, *An Update on vector boson pair production at hadron colliders*, *Phys.Rev.* **D60** (1999) 113006, [[hep-ph/9905386](#)].
- [4] J. M. Campbell, R. K. Ellis, and C. Williams, *Vector boson pair production at the LHC*, *JHEP* **1107** (2011) 018, [[1105.0020](#)].