

The Z/γ^* EW NLO & QCD production in the POWHEG-BOX-V2 user manual

Luca Barzè

PH-TH Department, CERN, CH-1211 Geneva 23, Switzerland

E-mail: Luca.Barze@cern.ch

Guido Montagna

Dipartimento di Fisica, Università di Pavia and INFN, Sezione di Pavia,

Via A. Bassi 6, 27100 Pavia, Italy

E-mail: Guido.Montagna@pv.infn.it

Paolo Nason

INFN, Sezione di Milano-Bicocca, Piazza della Scienza 3, 20126 Milan, Italy

E-mail: Paolo.Nason@mib.infn.it

Oreste Nicrosini

INFN, Sezione di Pavia, Via A. Bassi 6, 27100 Pavia, Italy

E-mail: Oreste.Nicrosini@pv.infn.it

Fulvio Piccinini

INFN, Sezione di Pavia, Via A. Bassi 6, 27100 Pavia, Italy

E-mail: Fulvio.Piccinini@pv.infn.it

Alessandro Vicini

Dipartimento di Fisica, Università di Milano and INFN, Sezione di Milano,

Via Celoria 16, I-20133 Milano, Italy

E-mail: Alessandro.Vicini@mi.infn.it

ABSTRACT: This note documents the use of the package POWHEG-BOX-V2 for Z/γ^* production processes including QCD and ElectroWeak NLO corrections. Results can be easily interfaced to shower Monte Carlo programs, in such a way that both NLO and shower accuracy are maintained.

KEYWORDS: POWHEG, Shower Monte Carlo, NLO, Electroweak.

Contents

1. Introduction	1
2. Generation of events	1
3. Process specific input parameters	2

1. Introduction

The POWHEG BOX program is a framework for implementing NLO calculations in Shower Monte Carlo programs according to the POWHEG method. An explanation of the method and a discussion of how the code is organized can be found in Refs. [1, 2, 3]. The code is distributed according to the “MCNET GUIDELINES for Event Generator Authors and Users” and can be found at the web page

<http://powhegbox.mib.infn.it>.

This program is an implementation of the Drell-Yan NLO cross sections $pp \rightarrow Z/\gamma^* \rightarrow \ell^+ \ell^-$ including QCD and ElectroWeak (EW) radiative corrections. A detailed description of the implementation can be found in Ref. [4]. In order to run the POWHEG BOX program, we recommend the reader to start from the POWHEG BOX user manual, which contains all the information and settings that are common between all subprocesses. In this note we focus on the settings and parameters specific to the Z/γ^* implementation.

2. Generation of events

Build the executable

```
$ cd POWHEG-BOX-V2/Z_ew-BMNNPV
```

```
$ make pwhg_main
```

Then do (for example)

```
$ cd runtest-lhc-8TeV
```

```
$ ../pwhg_main
```

At the end of the run, the file `pwgevents.lhe` will contain 100000 events for $Z/\gamma^* \rightarrow e^+ e^-$ in the Les Houches format. In order to shower them with PYTHIA6 do

```
$ cd POWHEG-BOX-V2/Z_ew-BMNNPV
```

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

```
$ cd runtest-lhc-8TeV
$ ../main-PYTHIA-lhef
```

If you prefer to shower the event with PYTHIA8 do

```
$ cd POWHEG-BOX-V2/Z_ew-BMNNPV
$ make main-PYTHIA8-lhef
$ cd runtest-lhc-8TeV
$ ../main-PYTHIA-lhef
```

3. Process specific input parameters

Mandatory parameters are those needed to select the final state leptonic species coming from the vector-boson:

```
vdecaymode 11 ! code for selected Z decay
              ! (11(-11): electronic; 13(-13): muonic; 15(-15): tauonic)
```

The decay $Z \rightarrow \nu\bar{\nu}$ is not handled in the present version.

Together with the mandatory parameters, the POWHEG BOX input facility allows for an easy setting of EW and run parameters, by explicitly adding the relevant lines to the input card. If one of the following entries is not present in the input card the reported default value is assumed. In any case, these parameters are printed in the output of the program, so their values can be easily tracked down.

```
Wmass      80.398          ! W mass in GeV
Wwidth     2.141           ! W width in GeV
Zmass      91.1876         ! Z mass in GeV
Zwidth     2.4952          ! Z width in GeV
alphaem    0.00729735254   ! em coupling alpha(0)
gmu        1.16637d-5      ! Fermi constant in GeV^-2
Hmass      120.            ! Higgs mass in GeV
Tmass      172.9           ! Top mass in GeV
Bmass      4.6             ! B quark mass in GeV
Cmass      1.2             ! C quark mass in GeV
Smass      0.15            ! S quark mass in GeV
Umass      0.06983         ! U quark mass in GeV
Dmass      0.06984         ! D quark mass in GeV
Elmass     0.005109989     ! Electron mass in GeV
Mumass     0.105658369     ! Mu mass in GeV
Taumass    1.77699         ! Tau mass in GeV
```

The following parameter limits from below the virtuality of the Z boson:

```
mass_low 20          ! Z virtuality > mass_low in GeV
```

If absent, it is set to 30 GeV. In order to avoid edge effects, the lower limit `mass_low` should be more inclusive w.r.t. cuts applied at the analysis level. Notice that, if photons are generated, the Z virtuality is not necessarily the mass of the dilepton.

```
runningscale 0      ! choice for ren and fac scales in Bbar integration
                    0: fixed scale M_Z
                    1: running scale  $\ell^+\ell^-$  inv mass
```

With running scale, a minimum cutoff of 5 GeV is imposed on $m(\ell^+\ell^-)$.

```
scheme 1! choice for EW NLO scheme calculation
          0: Alpha(0)
          1: Alpha(M_Z)
          2: G_mu
```

The CKM mixing matrix is assumed diagonal in the EW NLO corrections.

The EW radiative corrections can be calculated according to three different schemes: the $\alpha(0)$ scheme, where the input parameters are $\alpha(0)$, M_W and M_Z ; the $\alpha(M_Z^2)$ scheme, where the input parameters are $\alpha(M_Z^2)$, M_W and M_Z (with this scheme the value of the parameter `alphaem_z` should be specified); the G_μ scheme, where the input parameters are G_μ , M_W and M_Z .

The EW corrections can be switched off by setting

```
no_ew 1 ! default 0
```

and the strong corrections can be switched off by setting

```
no_strong 1 ! default 0
```

This last option is just to check EW corrections at the NLO level (i.e., the Les Houches events do not have much meaning).

The program can be interfaced to both PYTHIA6 and PYTHIA8, by doing

```
make main-PYTHIA-lhef
for PYTHIA6 and
make main-PYTHIA8-lhef.
for PYTHIA8.
```

In the case of PYTHIA6 one can also optionally switch off photon radiation from PYTHIA6 and use PHOTOS [5] instead. This is done by setting:

```
use_photos 1 ! default 0
in the powheg.input file.
```

The PHOTOS source code is included in the POWHEG BOX.

For photon final state radiation a comment is in order. According to the POWHEG method, the radiation by the shower has to be generated from a starting scale given by the hard-

est p_T tried at the matrix element level (the variable `scalup` written in the event file `pwgevents.lhe`). This is true also in the case that both QCD and QED radiation are present, as detailed in Ref. [4] . Both `PYTHIA6` and `PYTHIA8` do not use this starting scale for the generation of QED final state radiation from the Z . Hence, in order to avoid double counting of QED radiation, a veto algorithm is necessary. The same problem is present also using `PHOTOS`. This algorithm is provided automatically in the files `main-PYTHIA-lhef.f` and `scalupveto.f`. The same algorithm is implemented for `PYTHIA8`. In this case, however, the user can optionally adopt the internal algorithm of `PYTHIA8`, which is switched on by setting:

```
py8veto 1 ! default 0
```

in the `powheg.input` file.

References

- [1] P. Nason, “A new method for combining NLO QCD with shower Monte Carlo algorithms,” *JHEP* **0411** (2004) 040 [arXiv:hep-ph/0409146].
- [2] S. Frixione, P. Nason and C. Oleari, “Matching NLO QCD computations with Parton Shower simulations: the POWHEG method,” *JHEP* **0711** (2007) 070 [arXiv:0709.2092 [hep-ph]].
- [3] S. Alioli, P. Nason, C. Oleari and E. Re, “A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX,” [arXiv:1002.2581 [hep-ph]].
- [4] L. Barzè, G. Montagna, P. Nason, O. Nicrosini, F. Piccinini and A. Vicini, “paper in preparation”.
- [5] P. Golonka and Z. Was, *Eur. Phys. J. C* **45** (2006) 97 [hep-ph/0506026].