The POWHEG BOX user manual:
Z/γ^* EW NLO & QCD production

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ABSTRACT: This note documents the use of the package POWHEG BOX 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

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

$$\texttt{http://powhegbox.mib.infn.it}.$$

This program is an implementation of the Drell-Yan NLO cross sections $pp \to Z/\gamma^* \to \ell^+\ell^-$ 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/ZEW
$ make pwhg_main
```
Then do (for example)
```
$ cd test-el
$ ../pwhg_main
```
At the end of the run, the file `pwgevents.lhe` will contain 100000 events for $Z/\gamma^* \to e^+e^-$ in the Les Houches format. In order to shower them with `PYTHIA` do

```
$ cd POWHEG-BOX/ZEW
$ make main-PYTHIA-lhef
$ cd test-el
$ ../main-PYTHIA-lhef
```

3. Process specific input parameters

For the EW NLO Z/γ^* production, it is required to activate the `easlight` option, to enable the new final state radiation mapping necessary to describe the final state collinear radiation.

Other 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 $Z \to \nu\bar{\nu}$ 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)
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

masswindow_low 10  !  M_Z > Zmass - masswindow_low * Zwidth
masswindow_high 10 !  M_Z < Zmass + masswindow_high * Zwidth
```

The following two parameters are useful to generate events efficiently far away from the Z peak:

```
masslow 800            !  M_Z > masslow in GeV
masshigh 2000           !  M_Z < masshigh in GeV
```

In order to avoid edge effects, the lower limit `masslow` should be more inclusive w.r.t. cuts applied at the analysis level

```
runningscale 0    !  choice for ren and fac scales in Bbar integration
                           0:   fixed scale M_Z
                           1:   running scale ℓ⁺ℓ⁻ 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_μ
```

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.

Higher order QED corrections are simulated by means of `PHOTOS` [5] used in the exponentiated mode (`IEXP=.TRUE.`). An interface to the code is provided in the file `main-PYTHIA.f` and the photon cascade information is stored in the `common/hepeup`.

The `PHOTOS` source code is included in the `POWHEG BOX`.

References

[1] P. Nason, "A new method for combining NLO QCD with shower Monte Carlo algorithms," JHEP **0411** (2004) 040 [arXiv:hep-ph/0409146].

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[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].