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`POWHEG BOX` 1.99-beta

The POWHEG BOX user manual: Higgs boson production through gluon fusion in the MSSM

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Abstract: This note documents the use of the package `POWHEG BOX` for Higgs boson production trough gluon fusion in the MSSM. 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.

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

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

This program is an implementation of the NLO cross section for Higgs boson production via gluon fusion process, in the MSSM, in the POWHEG formalism of refs. [1, 2]. It is based over the work done by *Alioli et al* [9]. The supported processes are the production of the light CP even scalar h, of the heavy CP even scalar H and of the pseudoscalar A. This implementation provides the exact treatment in the amplitude of the quark and of the squark masses; it also provides the evaluation of the diagrams involving the quark-squark-gluino vertices, which are approximated by different mass expansions, as described in refs.[17, 18, 19]. MSSM parameters are A detailed description of the implementation can be found on ref. [20].

Spin correlations of Higgs boson decay products are not included, being it a scalar. This issue can be safely left to the subsequent Shower Monte Carlo program. Finite Higgs boson width effects are accounted for.

The code, that can be found in the POWHEG-BOX/gg_H_MSSM subdirectory is based on the subtraction scheme by Frixione, Kunszt and Signer implemented in the POWHEG BOX, rather than on the scheme discussed in the paper [9]. Please cite it anyhow if you use the program.

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 $gg \to \phi \ \ (\phi = h, H, A)$ implementation.

2. System requirements

Feynhiggs version ¿= 2.8.0 is required to compile and use this MC event generator.

3. Generation of events

Build the executable

```
$ cd POWHEG-BOX/gg_H_MSSM
$ make pwhg_main
```

Then do (for example)

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

At the end of the run, the file `pwgevents.lhe` will contain 100000 events for $gg \to H$ in the Les Houches format.

In order to shower them with `PYTHIA` (for example) do

```
$ cd POWHEG-BOX/gg_H_MSSM
$ make main-PYTHIA-lhef
$ cd testrun-lhc
$ ../main-PYTHIA-lhef
```

4. Process specific input parameters

The input parameters for POWHEG are separated into two files: one is the standard powheg.input and the others differs according to the renormalization scheme selected for the MSSM parameters. Currently we implement an On-Shell and a $\overline{\mathrm{DR}}$ scheme.

4.1 Common configuration file: powheg.input

The common parameters, defined in 'powheg.input' are:

```
zerowidth 1 !  Control if the Higgs boson is to be produced on-shell or not:
1 = On-Shell; 0 = Off-shell with Breit-Wigner
hwidth 10 !  Higgs width, dummy value, you should change it if you do off-shell
production
bwhape 1 !  BW shape:  1/2/3
masswindow 10d0 !(default 10d0) number of widths around hmass in the BW for
an off-shell Higgs boson
ew 0 !  ew = 0 disable EW corrections, ew = 1 enable EW corrections
fastew 1 !  fast ew corrections evaluations by mass sampling
gfermi 0.116637D-04 !  GF
hdecaywidth 0 !  use HDECAY computed width
hdecaymode -1 !  PDG code for first decay product of the higgs
!  allowed values are:  0 all decay channels open
!  1-6 d dbar, u ubar,..., t tbar (as in HERWIG)
! 7-9 e+ e-, mu+ mu-, tau+ tau-
!  10 W+W-
!  11 ZZ
! 12 gamma gamma
```

```
runningscale 0 !  Use running scale
!  **** Mandatory parameters for the MSSM model ****
higgstype 1 !  CP-even, neutral, higgs type:  1 = light higgs; 2 = heavy higgs;
3 = pseudoscalar
scheme 2 !  Renormalization scheme.  2 = OS (Feynhiggs), 1 = DRBAR (Softsusy)
!  **** Optional parameters for the MSSM model ****
nosquarks 0 !  1 = No scalars, 0/not defined = scalars enabled
lhsquarks 0 !  1 = Scalars contribution are taken in the infinite mass limit,
0 = full mass dependence
!  *** Parameters for DRBAR scheme mssmmbatmh 0 !  when massren = 1, 1 = mb(mh)
is used (from mssm-param-mh.slha), 0 = mb(M_susy) is used
!  *** Parameters for the OS scheme !  bottommass 4.75d0 !  optional, if not
defined default to one obtained with one-loop scheme change from mb(mb) fhdecaywidth
0 !  If 1 get the total Higgs decay width directly from Feynhiggs FHslhaflag
0 !  If 0 read input param from powheg-fh.in, otherwise from powheg-fh.slha
```

4.2 Specific configuration files for the OS scheme

The POWHEG implementation, enabled by the 'massren 2' option in the powheg.input file, in the OS scheme uses the FeynHiggs API to calculate the MSSM parameters used in the program. MSSM specific input for Feynhiggs can be provided in two ways, where the behaviour is controlled by the 'FHslhaflag' flag in the powheg.input. If 'FHslhaflag' is set to 0, the input parameters are read from a file named 'powheg-fh.in'. The syntax for this file is exactly the same as the one of Feynhiggs, since it is read by POWHEG using the FH API. A minimal example is given by:

```
AlfasMZ 0.119
MT 172.5
MB 4.213
MW 80.398
MZ 91.1876
GF 0.116637D-4 MSusy 1000
MA0 1000
TB 10
Abs(M_2) 200
Abs(M_3) 800
Abs(MUE) 200
Abs(Xt) 2000
```

After inizialition, POWHEG will write the results from FeynHiggs in an SLHA file called 'powheg-fh-output.slha' for use by other programs (i.e. parton showers MC).

If the 'bottommass' keyword is specified in the powheg.input file, POWHEG will use this value as the OS bottom mass.

4.3 Specific configuration files for the $\overline{DR}$ scheme

The $\overline{DR}$ scheme is used by setting 'massren 1' in the powheg.input file. In this configuration POWHEG reads the MSSMparameters from an SLHA file generated in the $\overline{DR}$ scheme by the user favorite program. The file should be named 'mssm-param.slha'.

If the 'mssmmbatmh 1' is set in the POWHEG configuration file, another SLHA configuration file, names 'mssm-param-mh.slha', with the scale of the running parameters set at m_h , is required to be produced by the users.

4.4 General considerations

The running of α_S is evaluated at two loop order, correctly matching, at flavour thresholds, different definitions that depends on the number of flavours that can be considered light at the renormalization scale.

Examples of `powheg.input` files are given in the subdirectories `gg_H_MSSM/testrun-tev` and `gg_H_MSSM/testrun-lhc`. In all examples, the choice of the parameters that control the grid generation is such that a reasonably small fraction of negative weights is generated, so they can be run as they are. We remind the reader that these negative weights are only due to our choice of generating $\tilde{B}$ instead of $\bar{B}$. They indeed correspond to phase space points where NLO corrections are bigger than LO contributions. Had we performed the integration over the full radiation phase space these negative weights would have disappeared completely.

In case one is interfacing to `HERWIG` or `PYTHIA` SMC programs, we provide a facility to select the Higgs boson decay products in these programs :

```
hdecaymode 12     !  code for selection of Higgs boson decay products:
                  !  -1 the Higgs boson is left undecayed by the SMC
                  !  0 all decay channels are open
                  !  1-6 d dbar, u ubar,..., t tbar (as in HERWIG)
                  !  7-9 e+ e-, mu+ mu-, tau+ tau-
                  !  10, 11, 12 W+W-, ZZ, gamma gamma
```

Together with the mandatory parameters, the `POWHEG BOX` input facility allows for an easy setting of run parameters, by explicitly adding the relevant lines to the input card. In case 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.

```
masswindow 10d0 !(default 10d0) number of widths around hmass in the BW for
an off-shell Higgs boson
runningscale 0 !  choice for ren and fac scales in Bbar integration
                                 0:  fixed scale M_H
                                 1:  running scale inv mass H
```

Of particular importance are the following parameters:

- `hhfact 100d0 ! (default no dumping factor) dump factor for high-pt radiation: > 0 dumpfac=h**2/(pt2+h**2)` controls how much of real contribution enters in the `POWHEG` Sudakov form factor. By default all real contributions are included, but this may lead to a NNLO mismatch in the higher Higgs boson p_{T} distribution tail, with respect to fixed order NLO results. This actually brings `POWHEG BOX` results closer to NNLO ones, but if one want to switch-off this feature it's possible to use a reduced real contribution $R^{\mathrm{red}} = R\times$ `dumpfact` in the Sudakov and to generate the remaining $R\times$(1-`dumpfact`) part without suppression, as documented in Sec. 4.3 of ref. [9].

- `zerowidth 1` (default 0 = false) enforce the calculation in the Higgs zero width approximation.

- `bwshape 1` (default 1) choose the functional form of the Breit-Wigner along which the Higgs virtuality is distributed, in case of the zero width approximation has not been chosen. Allowed values are 1 for a BW with a running width, 2 for a fixed width.

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