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POWHEG BOX 1.0

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

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Abstract: This note documents the use of the package POWHEG BOX for Higgs boson production trough gluon fusion. 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, first evaluated in refs. [6, 7, 8], in the POWHEG formalism of refs. [1, 2]. A detailed description of the implementation can be found on ref. [9]. We allow either to retain the full top-mass dependence in the leading order contribution, either to perform the calculation of NLO terms in the large top-mass limit. 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 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 $gg \to H$ implementation.

2. Generation of events

Build the executable

```
$ cd POWHEG-BOX/gg_H
$ 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` do

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

3. Process specific input parameters

The mandatory parameters are

```
gfermi 0.116639D-04 !  Fermi constant
hmass 120 !  mass of Higgs boson in GeV
hwidth 0.003605 !  width of Higgs boson in GeV
topmass 171.3 !  top quark mass in GeV
```

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/testrun-tev` and `gg_H/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_low 10 !  M_H > Hmass - masswindow_low * Hwidth
masswindow_high 10 !  M_H < Hmass + masswindow_high * Hwidth
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:

- `largemtlim 3` (default 3) controls how the large top-mass approximation is enforced. The default behaviour is to evaluate the LO contributions with the full mass dependence and the NLO contributions in the large top mass limit. These are then reweighted by a top-mass correction factor $B_{(m_t)}/B_{(m_t \to \infty)}$, given by the ratio of the LO result in the theory with finite quark masses over the result in the effective theory, where heavy quarks in the loop have been integrated out. This correction factor is evaluated on a event-by-event basis at the actual Higgs boson virtuality, if the zero width approximation is not enforced (see below). Setting this parameter to 0 one fixes this correction factor to be always evaluated at the Higgs boson mass. Setting this parameter to 1 the correction factor is instead omitted and the both the LO and NLO contributions are all evaluated in the large top mass limit. Setting it to 2 the correction factor is again omitted but the LO contributions are evaluated with the full top-mass dependence

- `includebloop 1` (default 0) Setting this parameter to 1 the correction factor for the `largemtlim 0` or`largemtlim 3` cases will include also the contributions coming from the diagrams with a loop of bottom quarks.

  The mass of the bottom quark can be set via the `bmass` token in the POWHEG BOX input file. If not provided, a default value of $m_b = 4.55\text{GeV}$ is assumed. This token has no effect if used in combination with the `largemtlim 1` or`largemtlim 2` choices.

- `hfact 100d0 !  (default no dumping factor) dump factor for high-pt radiation: > 0 dumpfac=hfact**2/(pt2+hfact**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 $R^{\text{red}} = R\times$ `dumpfact` in the Sudakov and to generate the remaining $R\times(1\text{-}\texttt{dumpfact})$ 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 2` (default 1) choose the functional form of the Breit-Wigner along which the Higgs virtuality is distributed, in case the zero width approximation has not been chosen. Allowed values are 1 for a BW with a running width, 2 for a fixed width Γ_H and 3 for the complex-pole scheme according to Passarino et al.

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