Preprint typeset in JHEP style - PAPER VERSION

July 20, 2012
POWHEG BOX 1.99-beta

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

Simone Alioli
Deutsches Elektronen-Synchrotron DESY
Platanenallee 6, D-15738 Zeuthen, Germany
E-mail: simone.alioli@desy.de

Paolo Nason
INFN, Sezione di Milano-Bicocca, Piazza della Scienza 3, 20126 Milan, Italy
E-mail: Paolo.Nason@mib.infn.it

Carlo Oleari
Università di Milano-Bicocca and INFN, Sezione di Milano-Bicocca
Piazza della Scienza 3, 20126 Milan, Italy
E-mail: Carlo.Oleari@mib.infn.it

Emanuele Re
Institute for Particle Physics Phenomenology, Department of Physics
University of Durham, Durham, DH1 3LE, UK
E-mail: emanuele.re@durham.ac.uk

Emanuele Angelo Bagnaschi
LPTHE, 4, Place Jussieu, F-75252 Paris, France
E-mail: bagnaschi@lpthe.jussieu.fr

Giuseppe Degrassi
Dipartimento di Fisica, Universit di Roma Tre and INFN, sezione di Roma Tre
Via della Vasca Navale 84, I-00146, Rome, Italy
E-mail: degrassi@fis.uniroma3.it

Alessandro Vicini
Dipartimento di Fisica, Universit di Milano and INFN, sezione di Milano
Via Celoria 16, I-20133 Milano, Italy
E-mail: alessandro.vicini@mi.infn.it

Pietro Slavich
LPTHE, 4, Place Jussieu, F-75252 Paris, France
E-mail: slavich@lpthe.jussieu.fr

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, in the SM and in the MSSM, in the POWHEG formalism of refs. [1, 2]. It is based over the work done by *Alioli et al* [9]. This implementation provides the exact treatment of the top and bottom masses in the amplitude. A detailed description of the implementation can be found on ref. [17]. Please note that the MSSM is not officialy supported yet.

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_with-finite-masses` 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_with-finite-masses`
`$ 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_with-finite-masses
$ make main-PYTHIA-lhef
$ cd testrun-lhc
$ ../main-PYTHIA-lhef
```

3. Process specific input parameters

3.1 SM

The mandatory parameters are

```
model 0 !  model:  0 = SM (See note1)
massren 0 !  0 = OS, 1 = MSBAR, 2 = DRBAR
gfermi 0.1166397-04 !  Fermi constant
hmass 120 !  mass of Higgs boson in GeV
hwidth 0.003605 !  width of Higgs boson in GeV
topmass 173.1 !  top quark mass in GeV
ew 0 !  If 1 enable EW corrections
```

Optional parameters are

```
bottomass 4.75d0 !  bottom quark mass in GeV (enabled if defined)
charmass 1.15d0 !  charm quark mass in GeV (enabled if defined)
hdecay 0 !  If 1 read the total decay width from br.sm2 produced by HDECAY
```

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_with-finite-masses/testrun-tev` and `gg_H_with-finite-masses/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 and 3 for Passarino's complex pole scheme.

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