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POWHEG BOX 1.0

The POWHEG BOX user manual: Single-top s- and t-channel processes

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Abstract: This note documents the use of the package POWHEG BOX for the single-top s- and t-channel production processes. 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.

In the following we will focus on the implementation of single-top (s- and t-channel) production, whose source files can be found in the POWHEG-BOX/ST_sch and POWHEG-BOX/ST_tch subdirectories.

This program is an implementation of the NLO cross section calculated in [4] in the POWHEG formalism of refs. [1, 2]. A detailed description of the implementation can be found in ref. [5]. Spin correlations of the top-quark decay products are included with a method analogous to the one described in [6], and the relevant matrix elements for the full decayed amplitudes were obtained using MadGraph [7].[1]

In this note we give all the necessary information to run the program.

[1] The only difference of the BOX implementation with respect to the one described in [5] is the treatment of finite width effects. In the BOX program, we decided to calculate the production cross section keeping always the value of the top-quark offshellness fixed and equal to the mass value. Finite-width effects are included a posteriori, at the same stage of top decay-products generation.

2. Installation

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 single-top s- and t-channel implementations.

In the following, we will describe how to run the s-channel code. Same considerations hold also for the t-channel one: in fact, the structure of the two codes (and the relevant files) is similar. Explicit instructions will be given when there are relevant differences.

3. Generation of events and showering

The executable is built with the following commands

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

In the testrun folder, there are several examples of input files. For example, you can start a run doing

```
$ cd testrun
$ ../pwhg_main
```

The input file read in this case is powheg.input and at the end a file named pwgevents.lhe will contain 100000 events for single top s-channel production at the LHC, in the Les Houches format. To shower them with PYTHIA do

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

Similar commands will run the HERWIG shower.

4. Process specific input parameters

```
facscfact 1 !  factorization scale factor:  mufact=muref*facscfact
renscfact 1 !  renormalization scale factor:  muren=muref*renscfact
```

Factorization and renormalization scale factors appearing here have to do with the computation of the inclusive cross section (i.e. the $\bar{B}$ function [1, 2, 5]), and can be varied by a factor of order 1 to study scale dependence. The natural choice for this process is the mass of the top-quark. We choose to perform the NLO calculation keeping these scales fixed.

The experienced user can change this setting modifying the `set_fac_ren_scales` routine.

It follows a description of parameters which are relevant for this production process:

- If the fraction of negative weights is large, one may increase `foldcsi`, `foldy`, `foldphi`. Allowed values are 1, 2, 5, 10, 25, 50. The speed of the program is inversely proportional to the product of these numbers, so that a reasonable compromise should be found. Our experiences tell us that, even at LHC energies, the fraction of negative weights in $\bar{B}$ calculation is such that the numbers provided in the examples need not to be changed. For the t- channel case, it is recommended to leave the default foldings on the csi and y variables.[2]

- For single-top, it is recommended to activate the `withdamp` option, to enable the Born-zero damping factor.

- For the t- channel case, it is recommended to leave the default value for `iymax`, to obtain a good efficiency in the radiation generation.

Other parameters are those specifically related to single-top processes: from revision 1.0, some of these parameters are mandatory (the program stops if they are missing), other are optional (default values are assigned in `init_couplings.f`, but are overwritten if the token is found uncommented in the input file, as in previous versions).

For the production step, the relevant parameters are:

```
!  mandatory production parameters
ttype 1          !  1 for t, -1 for tbar
topmass 175.0    !  top mass
```

where the value of `ttype` is used to decide if top or antitop quarks will be produced and `topmass` set the top-quark mass.

In the current released version, top-quark decay products are always generated by `POWHEG`, accordingly to a procedure very similar to the one of ref. [6]. Therefore, the following parameters are mandatory too:

```
!  mandatory parameters used in decay generation
topdecaymode 10000 !  decay mode:  the 5 digits correspond to the following
                   !  top-decay channels (l,mu,tau,u,c)
                   !  0 means close, 1 open
tdec/elbranching 0.108 !  W electronic branching fraction
```

[2] 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.

where the value of the `topdecaymode` token is formed by five digits, each representing the maximum number of the following particles at the (parton level) decay of the t ($\bar{t}$) quark: $e^{\pm}$, $\mu^{\pm}$, $\tau^{\pm}$, $\overset{(-)}{u}$, $\overset{(-)}{c}$. Thus, for example, 10000 means $t \to e^{+}\nu_e b$, 11100 means all semileptonic decays, 00011 means fully hadronic.

The optional parameters are listed below. Their meaning is self-explanatory. We remind that it is not allowed to set any entry of the CKM matrix exactly equal to zero.

```
!  optional production parameters
!  (defaults defined in init_couplings.f)
#wmass 80.4               !  w mass
#sthw2 0.23113            !  (sin(theta_W))**2
#alphaem_inv 127.011989   !  1/alphaem
#CKM_Vud 0.9740           !  CKM matrix entries ...
#CKM_Vus 0.2225
#CKM_Vub 0.000001
#CKM_Vcd 0.2225
#CKM_Vcs 0.9740
#CKM_Vcb 0.000001
#CKM_Vtd 0.000001
#CKM_Vts 0.000001
#CKM_Vtb 1.0

!  optional parameters used in decay generation
!  (defaults defined in init_couplings.f)
#topwidth 1.7         !  top width
#wwidth 2.141         !  w width
#tdec/emass 0.000511  !  e mass
#tdec/mumass 0.1056   !  mu mass
#tdec/taumass 1.777   !  tau mass
```

5. Generation of a sample with t and $\bar{t}$ events

The user can be interested in the generation of a sample where both top and antitop events appear. To this purpose, a script and a dedicated executable have been included. The script is named `merge_ttb.sh` and can be found in the directory `testrun`. It can be run in any subfolder of `ST_sch`. Three inputs are mandatory: the first two are the prefixes of the input files used to generate t and $\bar{t}$ events. The third input has to be an integer and correspond to the total number of events that the final *merged* sample will contain. The script has to be run twice, using a positive integer value at the first call and its opposite afterward. Therefore, for example, to produce a sample of 10000 events at Tevatron, starting from the input files `tev_st_s_t-powheg.input` and `tev_st_s_tb-powheg.input`, the invocation lines should be as follows:

```
$ sh merge_ttb.sh tev_st_s_t tev_st_s_tb 10000
```

and then

```
$ sh merge_ttb.sh tev_st_s_t tev_st_s_tb -10000
```

Few remarks are needed:

- it is responsibility of the user to check that the 2 input files are equal. The `ttype` tokens have to be different, obviously.
- the two values of `numevts` are not really used: the program re-calculate the needed values as a function of the t and $\bar{t}$ cross sections and of the total number of events to be generated.
- the final event file is always named `t_tb_sample-events.lhe`. In the header section it also contains a copy of the two input files used to generate it, for cross-checking purposes

References

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