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HERWIG 6.5 Release Note

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Abstract

A new release of the Monte Carlo program HERWIG (version 6.5) is now available. The main new features are: support for the Les Houches interface to matrix element generators; additional SM and MSSM Higgs processes in lepton collisions; additional matrix elements for the spin correlation algorithm; a new version of the ISAWIG interface; interface to the MC@NLO program for gauge boson pair production in hadron collisions. This is planned to be the last major release of Fortran HERWIG. Future developments will be implemented in a new C++ event generator, HERWIG++.

Contents

1 Introduction

The last major public version (6.2) of HERWIG was reported in detail in [1]. The new features of version 6.3 and 6.4 are described in refs. [2] and [3], respectively. In this note we describe the main modifications and new features included in the latest public version, 6.5.

Please refer to [1] and to the present paper if using version 6.5 of the program. When running MSSM processes starting from version 6.1, please add reference to [4].

The program, together with other useful files and information, can be obtained from the following web site:

`http://hepwww.rl.ac.uk/theory/seymour/herwig/`

This will be mirrored at CERN:

`http://home.cern.ch/seymour/herwig/`

It is anticipated that version 6.5, with minor modifications in the series 6.5xx, will be the *last Fortran version* of HERWIG. Substantial physics improvements will be included in the new C++ event generator HERWIG++ [5], to be released in 2003.

2 Les Houches interface

We now include support for the interface between parton level generators and HERWIG using the Les Houches Accord as described in [6]. In general we have tried to code the interface in such a way that from the user point of view it behaves in the same way as that already included in PYTHIA [7].

The interface operates in the following way. If the `IPROC` code is set negative then HERWIG assumes that the user wants an external hard process using the Les Houches accord.

If this option is used the initialization will call the routine `UPINIT` to initialize the external hard process; this name is the same as that used by PYTHIA. This routine should set the values of the run parameters in the Les Houches run common block.

After the initialization during the event generation phase the routine UPEVNT (again this name is the same as that used by PYTHIA) is called. This routine should fill the event common block as described in [6].

Dummy copies of both these routines are supplied with HERWIG and should be deleted and replaced if you are using this option. Due to the internal structure of HERWIG two new parameters are needed to control the interface, in addition to those in the Les Houches common block. The logical input variable[1] LHSOFT [.TRUE] controls the generation of the soft underlying event; the default is to generate a soft underlying event and so LHSOFT must be set .FALSE. for lepton-lepton processes. The second variable LHGLSF [.FALSE.] controls the treatment of colour self-connected gluons, which may occur with some methods of colour decomposition. The default is to kill events with self-connected gluons whereas if LHGLSF = .TRUE. an information-only warning is issued instead.

We have not included full support for the interface. In particular

- It is assumed that all events have two particles of status IDUP=–1;
- We do not support the status codes –2 and –9;
- The treatment of the code IDUP=3 is the same as IDUP=2, i.e. all intermediate resonances have their masses preserved.

These restrictions are the same as those imposed by PYTHIA. If you have any problems with the interface or need the options we have not yet supported please let us know.

It should also be noted that while the interface has been tested with Standard Model processes, for example all the processes in ALPGEN [8], it is less well tested for SUSY processes.

3 New SM and MSSM Higgs processes

SM and MSSM Higgs production in association with fermion pairs in lepton-lepton collisions is now available. These processes were introduced in [9] and their phenomenological relevance was discussed in [10]. The relevant IPROC codes are given in table 1.

Two new subroutines, HWHIGE and HWH2HE, had to be included. Fermion masses are retained in the final state according to the HERWIG defaults. The same values appear in the Yukawa couplings. Notice that in the case of charged Higgs boson production the Cabibbo-Kobayashi-Maskawa mixing matrix has been assumed to be diagonal. Furthermore, due to the rather different phase space distribution of the final state products, all processes can only be produced separately, not collectively. Initial- and final-state radiation (both QED and QCD) and beamsstrahlung are included via the usual HERWIG algorithms. Finally notice that the use of the IPROC series 1000 and 1100 for $\ell^+\ell^-$ processes required some internal modification to HERWIG, which was originally designed to generate leptonic processes only for IPROC < 1000. Now we assume an $\ell^+\ell^-$ process whenever IPROC < 1300. These modifications have no implications for the traditional user, but may affect more knowledgeable ones who have edited previous versions of the main HERWIG code.

[1] Default values for input variables are shown in square brackets.

IPROC	Process
1000+ID	$\ell^+\ell^- \to t\,\bar{t}\,H^0_{\rm SM}$ (ID as in IPROC=300+ID)
1110+IQ	$\ell^+\ell^- \to q\,\bar{q}\,h^0$ (IQ as in IPROC=100+IQ)
1116+IL	$\ell^+\ell^- \to \ell^+\ell^- h^0$ (IL=1,2,3 for e, μ, τ)
1120+IQ	$\ell^+\ell^- \to q\,\bar{q}\,H^0$ (IQ as in IPROC=100+IQ)
1126+IL	$\ell^+\ell^- \to \ell^+\ell^- H^0$ (IL=1,2,3 for e, μ, τ)
1130+IQ	$\ell^+\ell^- \to q\,\bar{q}\,A^0$ (IQ as in IPROC=100+IQ)
1136+IL	$\ell^+\ell^- \to \ell^+\ell^- A^0$ (IL=1,2,3 for e, μ, τ)
1140	$\ell^+\ell^- \to d\,\bar{u}\,H^+ +$ c.c.
1141	$\ell^+\ell^- \to s\,\bar{c}\,H^+ +$ c.c.
1142	$\ell^+\ell^- \to b\,\bar{t}\,H^+ +$ c.c.
1143	$\ell^+\ell^- \to e\,\bar{\nu}_e H^+ +$ c.c.
1144	$\ell^+\ell^- \to \mu\,\bar{\nu}_\mu H^+ +$ c.c.
1145	$\ell^+\ell^- \to \tau\,\bar{\nu}_\tau H^+ +$ c.c.

Table 1: New SM and MSSM Higgs processes.

4 Spin correlations in R-parity violating decays

When we included spin correlations in HERWIG6.4 [11] we did not include either R-parity violating decays or decays producing gravitinos in the algorithm. This led to HERWIG stopping when such decays were included. This of course could be stopped by switching the spin correlations off, i.e. `SYSPIN=.FALSE.`. We have now included the relevant matrix elements for R-parity violating decays and hard processes and decays producing gravitinos. At the same time we have made changes so that at both the initialization and event generation stages many of the terminal warnings which were caused by the code not having the correct matrix elements are now information-only warnings. If you still get terminal error messages from any of the spin correlation routines please let us know.

5 Other interfaces

5.1 ISAWIG

To coincide with the release of HERWIG 6.5 we have produced a new version of the ISAWIG interface to ISAJET for the calculation of MSSM spectra and decay rates. Due to stability problems with the Oxford web-server we have moved the web-page to Cambridge. The new address is

`http://www.hep.phy.cam.ac.uk/~richardn/HERWIG/ISAWIG/`

At the moment the old page will redirect users here but we cannot be sure how long this will continue.

Since the original version of ISAWIG there have been a number of new versions of ISAJET, often with changes in the sizes of the common blocks from which we extract the information we need. This has necessitated periodical updating of the code to run with the most recent version of ISAJET, with the result that the code could no longer be run with older versions. However, the Snowmass points and slopes [12] are defined with ISAJET version 7.58 and so we can no longer continue in this way and still be able to generate these points. Therefore, starting with the new ISAWIG version 1.2, we are using C preprocessing so that users can define the version of ISAJET they are using at compile time. When compiling the main ISAWIG code and the modified SUGRUN and SSRUN programs the following compiler options should be specified:

- `-DISAJET758` to use ISAJET7.58,
- `-DISAJET763` to use ISAJET7.63.

The default at the moment is to compile code to run with ISAJET7.64. In the future this will change so that the most recent version of ISAJET becomes the default but we will continue to support the older versions.

5.2 HDECAY

There has also been a new release of the HDECAY package [13], version 3. In order to support this version, and the previous version 2.0, we are also using C preprocessing to control the version of HDECAY used. In order to achieve this the HDECAY interface code has been merged with the main ISAWIG program. The following options should be used when compiling ISAWIG if you are using HDECAY:

- `-DHDECAY2` if you are using version 2 of HDECAY
- `-DHDECAY3` if you are using version 3 of HDECAY.

As before the default is to compile a dummy routine. If you are using HDECAY you must link with a version of the HDECAY code which has the main HDECAY program removed.

5.3 MC@NLO

The program MC@NLO [14] generates events with

- exclusive rates and distributions accurate to next-to-leading order when expanded in α_s;
- multiple soft/collinear parton emission generated by HERWIG parton showering;
- hadronization according to the HERWIG cluster model.

At present only the processes of gauge boson pair production in hadron ($h = p$ or $\bar{p}$) collisions are implemented in MC@NLO, making use of the HERWIG process codes in table 2.

`IPROC`	Process
2850	$h\,h \to W^+W^-X$
2860	$h\,h \to Z^0Z^0X$
2870	$h\,h \to W^+Z^0X$
2880	$h\,h \to W^-Z^0X$

Table 2: MC@NLO diboson processes.

To use these codes, one must delete the dummy HERWIG subroutine `HWHVVJ` and replace it by the one in the MC@NLO package. This will then read and process an input file of parton configurations prepared by MC@NLO. For further details see the MC@NLO web page:

`http://www.hep.phy.cam.ac.uk/theory/webber/MCatNLO/`

Implementation of other processes, such as heavy quark production, in MC@NLO is in progress [15]. These future development will make use of the Les Houches interface discussed in sect. 2, rather than special process codes.

6 Miscellaneous changes and corrections

- A new logical input variable, `PRESPL` [`.TRUE.`], has been introduced to control whether the longitudinal momentum (`PRESPL = .TRUE.`), or rapidity (`PRESPL = .FALSE.`), of the hard process centre-of-mass is preserved in hadron collisions after initial-state parton showering. At present the only function of this variable is to allow users to study the effects of momentum reshuffling, which is necessary after showering to compensate for jet masses. In future, it is anticipated that setting `PRESPL=.FALSE.` will simplify the treatment of other processes in MC@NLO.
- A bug has been fixed in the backward evolution in the logical structure structure of an `IF` statement controlling the branching. This was preventing the forced branching to valence partons and caused many of the `HWSBRN`=104 warnings. Users should find the number of such warnings is significantly reduced.
- When polarization effects in lepton collisions were added a bug was introduced in squark pair production which has now been fixed.
- A bug in the matrix element for $q\,\bar{q} \to g\,H^0_{\rm SM}$ (`IPROC`=2300 etc.) has been corrected.
- The effects of off-shell WW and ZZ decays of the SM Higgs boson are now included in the generated weights of $2 \to 3$ processes.

Acknowledgements

Since this is expected to be the last (Fortran) HERWIG release note, we would like to take this opportunity to thank again all those colleagues and users who have contributed to the development of the program, whether by providing code, suggesting improvements or reporting problems. Thanks also to those who worked so hard to establish the Les Houches accord, which should make it possible to expand the application of Fortran HERWIG to new processes without (much) further intervention by the authors. Meanwhile, many of us will be transferring our main efforts to HERWIG++, in preparation for the new era of object-oriented event generation.

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