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## HERWIG 6.4 Release Note

G. Corcella

*Max Planck Institute für Physik, Munich*

*E-mail: corcella@mppmu.mpg.de*

I.G. Knowles

*Department of Physics and Astronomy, University of Edinburgh*

*E-mail: iknowles@supanet.com*

G. Marchesini

*Dipartimento di Fisica, Università di Milano-Bicocca, and I.N.F.N., Sezione di Milano*

*E-mail: Giuseppe.Marchesini@mi.infn.it*

S. Moretti

*Theory Division, CERN, and Institute for Particle Physics Phenomenology, University of Durham*

*E-mail: stefano.moretti@cern.ch*

K. Odagiri

*Theory Division, KEK*

*E-mail: odagirik@post.kek.jp*

P. Richardson

*Department of Applied Mathematics and Theoretical Physics and  
Cavendish Laboratory, University of Cambridge*

*E-mail: richardn@hep.phy.cam.ac.uk*

M.H. Seymour

*Department of Physics and Astronomy, University of Manchester*

*E-mail: M.Seymour@r1.ac.uk*

B.R. Webber

*Cavendish Laboratory, University of Cambridge*

*E-mail: webber@hep.phy.cam.ac.uk*

### Abstract

A new release of the Monte Carlo program HERWIG (version 6.4) is now available. The main new features are: spin correlations between the production and decay of heavy fermions, i.e. top quarks,  $\tau$  leptons and SUSY particles; polarization effects in SUSY production processes in lepton-lepton collisions; an interface to TAUOLA for  $\tau$  decays; MSSM Higgs processes in lepton-lepton collisions.

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## 1 Introduction

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

Please refer to [1] and to the present paper if using version 6.4 of the program. When running MSSM processes starting from version 6.1, please add reference to [3].

### 1.1 Availability

The new 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 temporarily be mirrored at CERN for the next few weeks:

<http://home.cern.ch/seymour/herwig/>

## 2 Spin correlations

Spin correlation effects have been added in processes where top quarks,  $\tau$  leptons and SUSY particles are produced, as described in [4]. At the moment the effects are only calculated for the production of these particles in the following processes: `IPROC=100-199`, `IPROC=700-799`, `IPROC=1300-1399`, `IPROC=1400-1499`, `IPROC=1500-1599`, `IPROC=1700-1799`, `IPROC=2000-2099`, `IPROC=2800-2825`, `IPROC=3000-3030`. However, if these particles are produced in other processes, the spin correlation algorithm will still be used to perform their decays. The correlations are also included for the decay of the MSSM Higgs bosons, regardless of how they are produced.

The spin correlations are controlled by the logical variable<sup>1</sup> `SYSPIN [.TRUE.]` which switches the correlations on. If required the correlations are initialized by the new routine `HWISPN`. This routine initializes the two, three and four body matrix elements.

The three and four body matrix elements can be used separately to generate the decay distributions without spin correlation effects. These are switched on by the switches `THREEB [.TRUE.]` for three body decay and `FOURB [.FALSE.]` for four body decays. The four body decays

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<sup>1</sup>Default values for input variables are shown in square brackets.

are only important in SUSY Higgs studies, and have small branching ratios. However, they take some time to initialize and are therefore switched off by default.

The initialization of the spin correlations and/or decay matrix elements can be time consuming and we have therefore included an option to read/write the information. The information is written to unit LWDEC [88] and read from LRDEC [0]. If either are zero the data is not written/read. If IPRINT=2 then information on the branching ratios for the decay modes and the maximum weights for the matrix elements is outputted.

**Important note:** If the spin correlation (SYSPIN) or matrix element switches (THREEB, FOURB) are .TRUE., then the matrix element codes (NME entries) for the decays concerned are not used; the calculated matrix elements are used instead.

For top decays via the weak matrix element, when SYSPIN=.TRUE. the spin correlation algorithm uses the helicity amplitudes to perform the decay, whereas when SYSPIN=.FALSE. the spin averaged matrix element is used.

Top decay to either a real or virtual Higgs boson is not currently implemented in the spin correlation algorithm and therefore the spin correlations should be switched off, SYSPIN=.FALSE., if you wish to study this decay process.

## 2.1 Polarized lepton beams

The effect of polarization for incoming leptonic beams in MSSM SUSY processes has also been included. These effects are included both in the production of SUSY particles and via the spin correlation algorithm in their decays.

## 3 New MSSM Higgs processes

The following MSSM Higgs production processes in  $\ell^+\ell^-$  collisions have been added ( $\ell = e, \mu$ ):

IPROC	Process
910	$\ell^+\ell^- \rightarrow \nu_e \bar{\nu}_e h^0 + e^+ e^- h^0$
920	$\ell^+\ell^- \rightarrow \nu_e \bar{\nu}_e H^0 + e^+ e^- H^0$
960	$\ell^+\ell^- \rightarrow Z^0 h^0$
970	$\ell^+\ell^- \rightarrow Z^0 H^0$
955	$\ell^+\ell^- \rightarrow H^+ H^-$
965	$\ell^+\ell^- \rightarrow A^0 h^0$
975	$\ell^+\ell^- \rightarrow A^0 H^0$

For the last three, a new subroutine has been introduced, HWHIHH, whereas the first four make use of the implementation of their SM counterparts, which are based on the subroutines HWHIGW and HWHIGZ.

## 4 TAUOLA interface

An interface to the TAUOLA decay package has been added. To use this interface, the dummy subroutines DEXAY, INIETC, INIMAS, INIPHX, INITDK, PHOINI, PHOTOS must be deleted, and the parameter TAUDC ['HERWIG'] must be set to 'TAUOLA'. You should then link to both TAUOLA

and PHOTOS. The easiest way to do this is to obtain the TAUOLA/PHOTOS versioning system from

<http://wasm.home.cern.ch/wasm/test.html>

and produce a version with the correct size of the HEPEVT common block. This system will provide a JETSET demo. The code for this, apart from the JETSET main program and interface, can then be linked to HERWIG (with the above changes) instead of JETSET.

This interface uses the information from the spin density matrices to select the helicity of the decaying  $\tau$  leptons if the spin correlation algorithm is being used; otherwise the helicity of the decaying  $\tau$  is averaged over.

## 5 Miscellaneous corrections

Corrections have been made affecting the following:

- Gaugino pair production in hadron collisions: a bug affecting the sign of the centre-of-mass collision angle was corrected.
- Gaugino/squark production: a bug in the matrix element was corrected.
- MSSM Higgs production in hadron-hadron via vector-vector fusion: a bug inducing the use of the mass of the SM Higgs as hard scale of the subprocess as well as its label in the IDHW array has now been taken care of.
- Gauge boson pair production:
  - A bug in testing the error code after the initial state shower has been corrected.
  - The scale has been changed to the parton-parton centre-of-mass energy from the average of the produced boson masses, which was used in the previous version.
  - The  $W^+$  and  $W^-$  were interchanged in hadronic  $W^+W^-$  production. This has been corrected.
- Pion Beams. The default MRS nucleon structure functions were used without warning in pion scattering. If you wish to simulate pion scattering either the older NSTRU=1,2 pion sets or PDFLIB should be used.

## References

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