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Herwig++ 2.2 Release Note

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Abstract

A new release of the Monte Carlo program Herwig++ (version 2.2) is now available. This version includes a number of improvements including: matrix elements for the production of an electroweak gauge boson, $W^{\pm}$ and Z^0, in association with a jet; several new processes for Higgs production in association with an electroweak gauge boson; and the matrix element correction for QCD radiation in Higgs production via gluon fusion.

Contents

1 Introduction

The last major public version (2.1) of Herwig++, is described in great detail in [1]. This release note therefore only lists the changes which have been made since the last release (2.1). The manual has been updated to reflect these changes and this release note is only intended to highlight these new features and the other minor changes made since the last version.

Please refer to [1] and the present paper if using version 2.2 of the program.

The main new features of this version are the inclusion of matrix elements for the production of an electroweak gauge boson, $W^{\pm}$ and Z^0, in association with a jet in hadron-hadron collisions, the addition of matrix elements for the production of an electroweak gauge boson, $W^{\pm}$ and Z^0, in association with the Higgs boson in both lepton-lepton and hadron-hadron collisions, and the matrix element correction for the production of QCD radiation in Higgs production via $gg \to h^0$. In addition a number of other changes, such as the inclusion of the option of a saturation model for the small-x PDF and a restructuring of the library structure, have been made and a number of bugs have been fixed.

1.1 Availability

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

`http://hepforge.cedar.ac.uk/herwig/`

In order to improve our response to user queries, all problems and requests for user support should be reported via the bug tracker on our wiki. Requests for an account to submit tickets and modify the wiki should be sent to `herwig@projects.hepforge.org`.

Herwig++ is released under the GNU General Public License (GPL) version 2 and the MCnet guidelines for the distribution and usage of event generator software in an academic setting, which are distributed together with the source, and can also be obtained from

`http://www.montecarlonet.org/index.php?p=Publications/Guidelines`

2 New Matrix Elements

A number of new matrix elements are included in this release:

- the MEPP2WJet and MEPP2ZJet classes for the simulation of $W^{\pm}$ and Z^0 production in association with a hard jet in hadron-hadron collisions;
- the MEPP2WH and MEPP2ZH classes for the simulation of $W^{\pm}$ and Z^0 production in association with a Higgs boson in hadron-hadron collisions;
- the MEee2ZH class for the production of a Higgs boson in association with a Z^0 boson in e^+e^- collisions.

3 Higgs Matrix Element Correction

The matrix element correction for $gg \to h^0$ has been included using the same approach as for the Drell-Yan production of a $W^{\pm}$ or Z^0 boson. The p_T spectra of Higgs bosons with masses

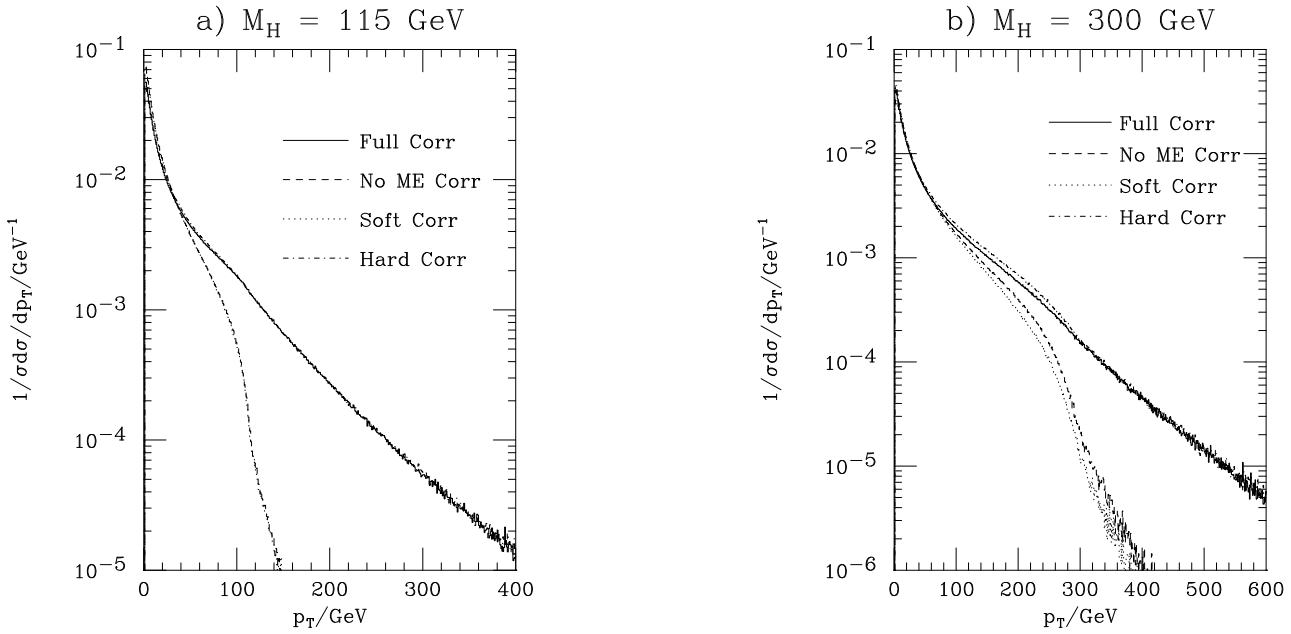

Figure 1: The transverse momentum of the Higgs boson at the LHC for a Higgs boson with mass a) 115 GeV and b) 300 GeV. The results of the full correction (solid), no correction (dashed), only the soft matrix element correction to radiation generated by the parton shower (dotted), and the hard correction filling the 'dead' region not filled by the parton shower (dot-dashed) are shown.

of 115 GeV and 300 GeV are shown in Fig. 1. Only the $gg \to h^0 g$, $qg \to h^0 q$ and $\bar{q}g \to h^0 \bar{q}$ partonic processes are included in the matrix element correction as these are the only processes which have a parton-shower interpretation. The $q\bar{q} \to h^0 g$ process should therefore be included as an additional hard process with no cut on the p_T of the outgoing gluon if all the partonic processes are required, in general this process gives a very small contribution.

4 Other Changes

A number of other more minor changes have been made. The following changes have been made to improve the physics simulation:

- A new class implementing a saturation model for the PDFs has been included.
- A number of additional options for HepMC output have been added, including the units to be used for energies and distances.
- The decays of the Σ_b baryons have been changed so that only the decays $\Sigma_b \to \pi \Lambda_b$ are included.
- A number of bugs in the hadronization have been fixed necessitating the retuning of the default hadronization parameters to LEP and B-factory data. The parameters for the underlying event have also been retuned.
- The option of not building the BSM models has been added, by default all the models are built.

- The particles for specific new physics models have now been moved to the files specifying the models.
- The Higgs width is now automatically recalculated from its mass and the limits on the off-shell mass are taken to be proportional to the width.
- The option of generating intrinsic p_T according to an inverse quadratic distribution has been added.

The following bugs have been fixed:

- A major bug in the splitting function for $g \to gg$ branchings in the initial state which lead to too little radiation being generated from incoming gluons has been fixed.
- The scale of the veto on the production of radiation in the parton shower has been changed from the p_T of the particles in the hard process to their transverse mass, this has a significant effect for top production.
- Intrinsic p_T is no longer generated for the secondary scattering processes generated using the multiple parton-parton scattering model.
- The directions of hadrons containing a quark from the perturbative stage of event were not correctly smeared, this has been corrected.
- A bug in the selection of the hadrons in cluster decays which lead to K_L^0 rather than K_0 and $\bar{K}_0$ mesons being produced has been fixed. A related problem which prevented more than one meson which has the same flavour composition and mass being produced has also been fixed.
- A problem with the matrix element correction for top decay in rare cases where the off-shell W boson mass is large has been fixed.
- A workaround for problems with the built-in gcc `abs` function has been added.
- In order to fix some problems with the positions of particles we no longer include displacements for intermediates particles produced before the hadrons produced in the hadronization phase, all or which are assumed to be produced at the origin.
- The limits on the off-shell mass of BSM particles is now set by default when the width is calculated or read from an input file.
- In BSM models the branching ratios for Higgs decays are now correctly reset from the SM values.
- A number of problems related to initializing and running the generator using the `Herwig++ read` command have been fixed.
- The handling of problems when the unweighting of the matrix element in the generation of multiple parton-parton scattering fails has been improved.
- Loop protection has been added to the four-body decays in the Kinematics class to prevent rare cases where an extremely large number of iterations were required. By default these decays now use the MAMBO algorithm to avoid this problem.
- The value of π used in various AnalysisHandlers are now consistently set using the value Constants::pi.

5 Summary

Herwig++ 2.2 is the third version of the Herwig++ program with a complete simulation of hadron-hadron physics and contains incremental changes with respect to the previous version. The program has been extensively tested against a large number of observables from LEP, Tevatron and B factories. All the features needed for realistic studies for hadron-hadron collisions are now present and we look forward to feedback and input from users, especially from the Tevatron and LHC experiments.

Our next major milestone is the release of version 3.0 which will be at least as complete as HERWIG in all aspects of LHC and linear collider simulation. Following the release of Herwig++ 3.0 we expect that support for the FORTRAN program will cease.

Acknowledgements

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References

[1] M. Bahr *et. al.*, *Herwig++ Physics and Manual*, `arXiv:0803.0883`.