I review the current status and future plans of the HERWIG collaboration.

1 Introduction

HERWIG is a Monte Carlo event generator for simulation of hadronic final states in lepton–lepton, lepton–hadron and hadron–hadron collisions. It incorporates important colour coherence effects in the final state and initial state parton showers, as well as in heavy quark processes and the hard process generation. It uses the cluster hadronization model and a cluster-based simulation of the underlying event. While earlier versions concentrated on QCD and a few other SM processes, recent versions contain a vast library of MSSM and other BSM processes. A review of current Monte Carlo event generators including HERWIG can be found in.

We are currently in a period of intense activity, finalizing the HERWIG program and writing a completely new event generator, HERWIG++. In this very short contribution, I can do little more than mention the areas of progress and provide references to sources of more details.

2 HERWIG version 6.5

HERWIG version 6.5 was released in October 2002. Its main new features were an interface to the Les Houches Accord event format, the hooks needed by the MC@NLO package and various bug fixes and minor improvements. It was advertised as the final fortran version of HERWIG before work switched to HERWIG++.

Despite this, the period since then has seen intense development with several new subversion releases and new features, most notably version 6.505, which featured an improved interface to the Jimmy generator for multiparton interactions, which I will discuss in more detail shortly. The most recent version is 6.507, which can be obtained from the HERWIG web site.
Development of fortran HERWIG is now slowing, and the only new feature still foreseen is the implementation of matrix element corrections to the production of Higgs bosons, both SM and MSSM, preliminary versions of which have been discussed in [15]. Beyond this, the HERWIG collaboration has made a commitment to all running (and ceased) experiments to support their use of HERWIG throughout their lifetimes. Due to lack of manpower, making the same promise to the LHC experiments would divert too much effort away from support of HERWIG++, and we will only support their use of HERWIG until we believe that HERWIG++ is a stable alternative for production running.

3 Jimmy

Early versions of the Jimmy model [16] generated jet events in photoproduction using a multiparton interaction picture. The recent update [17] enables it to work efficiently as a generator of underlying events in high $E_T$ jet events and other hard processes in hadron–hadron collisions for the first time. For a given pdf set, the main adjustable parameters are $P_{T\text{Jim}}$, the minimum transverse momentum of partonic scattering, and $JMRAD(73)$, related to the effective proton radius. Varying these one is able to get a good description of the CDF data [18] and other data held in the JetWeb database [19] that are sensitive to underlying event effects in hard process events. However, a poor description of minimum bias data in which there is no hard scale is still obtained. This is probably due to the fact that $P_{T\text{Jim}}$ is a hard cutoff and there is no soft component below it; preliminary attempts to rectify this are encouraging [20]. It is interesting to note that with tunings that give equally good descriptions of current data, Jimmy predicts twice as much underlying event activity as PYTHIA at the LHC.

4 HERWIG++

The HERWIG program is now more than ten times the size it was when it was designed and is maintained by a collaboration of about ten authors. Its structure has become too unwieldy to maintain reliably and is too rigid to incorporate many of the physics improvements that have occurred to us recently. We therefore took the decision to write a completely new event generator, HERWIG++, [21] retaining the main features of HERWIG, angular ordering and cluster hadronization, but with a completely new design offering more flexible and scalable development, with the aim to have a reliable product throughout the lifetime of the LHC experiments.

Use of ThePEG At around the same time, the developers of PYTHIA took a similar decision [22] and started work [23] on PYTHIA 7, a replacement for PYTHIA. As part of this project, an extremely powerful framework for the administration of event generation was developed [24]. In order for this to be used by other Monte Carlo packages, it has been separated off as an independent Toolkit for high energy Physics Event Generation, ThePEG [25]. HERWIG++ is based on ThePEG, which offers a number of advantages: the administrative overhead is shared, while retaining completely independent physics implementations; users only need to learn to use one framework to use several different event generators; and can (with care!) mix modules from different event generators simply by selecting the appropriate components from the toolkit.

Hard Interactions A small library of basic $2 \to 2$ processes is built in to ThePEG, a few more will be implemented in HERWIG++ using a new HELAS-like structure that has already been implemented, but we do not foresee ever developing a hard process library to the extent that we did in HERWIG. Instead, the plan is to provide a clean interface to external codes to generate the majority of hard processes: interfaces to AMEGIC++ and a Les Houches accord file reader already exist. Of course MC@NLO- and CKKW-style matrix element+parton shower matchings are also planned.

Parton Showers A completely new parton shower algorithm has been designed [26], based on the quasi-collinear limit [27] which gives a smooth suppression of forward radiation from massive
partons, rather than a sharp dead-cone as in HERWIG. It also has advantages for matrix element
matching, as it gives a smooth coverage of the soft limit, with the emission region from colour-
connected jet pairs just touching, with no overlap or missing region. The new algorithm has
been used for an interesting study of the theoretical uncertainties in Sudakov form factors.

**Cluster Hadronization** The hadronization model is largely a rewrite, but with an improved
treatment of the baryon sector, inspired by, but slightly different from, the one of Kupco.

**Phenomenology for $e^+e^-$ Annihilation** The above components, together with a treatment
of secondary decays that for the moment is an exact copy of HERWIG’s, are sufficient to give full
simulation of $e^+e^-$ annihilation events. The first phenomenological study was made in
Although not a complete parameter tune, a first attempt yields a similar overall description
of $Z^0$ decays to HERWIG, with significant improvements in the yields of identified baryons.
Particularly significant is the description of B meson production – in HERWIG heavy and light
quark events could not be simultaneously well described, always yielding tension in parameter
tunings, but in HERWIG++ the perturbative cutoff largely determines the B fragmentation
function and its best-fit value also gives a good description of light-quark event shapes.

**Current Developments** Work is under way on the extension to hadron collisions. A simple
model of the underlying event exists and a new model based on Jimmy plus a soft component
is planned. The initial state parton shower exists, but needs further development and testing.
A complete description of simple processes like Drell–Yan is anticipated for this summer.

A complete rewrite of the secondary decays is under way, with more sophisticated treatments
of almost all decay modes: a general treatment of the spin structure and spin correlations;
interference between hadronic resonances and non-resonant diagrams; and specialized decayers
for important special cases. The decay tables themselves are stored in an external xml database
and a direct link with the CEDAR project is planned. At present 448 particles with 2607
decay modes have been incorporated, loosely based on the particle data group tables. The new
database allows the many massages that are needed, for example to make branching fractions
add up to 100%, to be documented, with a star-rating system for how trustworthy they are.

**Future Outlook** We plan to complete the implementation and testing of initial state showers
this summer and release a preliminary version to the LHC experiments. Next will come 2-jet
production in hadron collisions and the first serious comparisons with Tevatron data. Devel-
opment will continue on secondary decays and start on a multiparton interaction model of the
underlying event and CKKW-type matching to mutijet matrix elements. HERWIG++ will be
a stable alternative to HERWIG for first LHC analyses, allowing us a platform from which to
further develop the theoretical framework.

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