Introduction to the Monte Carlo Models session

Jonathan M. Butterworth[1], *Torbjörn Sjöstrand*[2]
[1]Department of Physics and Astronomy, University College London
[2]Department of Theoretical Physics, Lund University

There is hardly any area of hadron collider physics where event generators play such a central a role as they do for the exploration of MPI. One reason is that MPI, although extending well into the perturbative region, have their biggest impact close to, or inside, the nonperturbative regime. Another is that MPI studies by necessity probe *all* the main physics aspects of hadron colliders in an nontrivial admixture, including multiple partonic collisions, initial- and final-state radiation, beam remnant structure, colour flow issues, the impact-parameter picture, and hadronization.

If the study of MPI has for the first time become fashionable within the particle physics community, it is in large part owing to the interplay between experimental studies and Monte Carlo modelling and tuning in recent years. Specifically, the CDF studies, already reviewed by Rick Field, have largely relied on the availability of generators that could provide a framework for the interpretation of the data. One case in point is that a unified description of mimimum-bias and underlying-event physics comes about quite naturally in MPI-based Monte Carlo implementations. Conversely, the renewed interest in improving and tuning models that have lain dormant for many years would not have happened without the influx of new data to digest.

The session on Monte Carlo Models collects talks within two areas. Firstly presentations of several of the main generators, with an overview of new ideas and current status. Secondly presentations of new tunes of these generators, which also introduce new tools that allow a more systematic approach to the whole tuning effort. But it should be emphasized that event generators are central to many other studies presented at this meeting, in particular in sessions I and II.

Since it is all too easy to get carried away by the “Yes, we can” spirit that exists in the MPI community nowadays, in this introduction we would still like to remind the reader that many tough issues remain poorly understood and modelled. Thus there is still scope for significant improvements in the future, driven both by theoretical insights and experimental studies. Several such topics made for corridor talk during the meeting, but are maybe not so well represented in the individual writeups, so here are a few examples:

- How to model and measure multi-parton density functions, that depend on multiple flavour choices and multiple x and Q^2 scales?
- How does close-packing of partons in the initial state, especially at small x, tie in with the functioning of the colour screening mechanism?
- Currently implemented MC models of MPI assume a factorisation between the x-dependence and impact-parameter profile of the incoming hadrons. Can this assumption be relaxed, and if so how large would the effect be?
- Can the presence of rescattering events, i.e. where an incoming parton scatters twice or more, be established experimentally, given that the natural signal of three outgoing jets competes with a large QCD bremsstrahlung background?

- Can the initial-state branchings intertwine several $2 \to 2$ processes that are seemingly separate, and if so how?
- A large amount of colour reconnection is favoured by the tunes of PYTHIA to $\langle p_\perp \rangle(n_{\mathrm{charged}})$ data; but is this the correct interpretation and, if so, what is the physics and what are the rules that govern colour reconnection?
- To what extent can colour reconnection also affect the pattern of perturbative QCD radiation? Can e.g. two dipoles each stretched between a final-state parton and (the hole left behind by) an initial-state one transform into a single dipole between the two final-state partons?
- Does the dense-packing of colour-field "strings" in central collisions induce states that border on a quark-gluon plasma?
- Does the hadronization of these topologies give rise to a dense hadron gas within which final-state rescatterings occur?
- Given the above uncertainties, can we still assume that the composition of different particle species should be the same in hadronic collisions as in e^+e^- ones?
- How big a baryon-flow from the beam remnants to the central region should we expect?
- How far can eikonal models be trusted to correctly relate different event topologies, including diffractive ones? Is maybe instead colour reconnection the proper way to think about the emergence of diffractive topologies?
- When tuning, how should the relative importance of various data be judged? When are discrepancies due to poor physics or to poorly documented data? How can we avoid overtuning, *i.e.* avoid forcing the model to fit the data even if the data contain physics not included in the model? (Many experimental working groups and applications apply pressure to fit the data at any cost.)
- Can meaningful uncertainties be attached to MC tunes, in particular for MPI? How far can particular physical effects be ruled out, or shown unambiguously to be present, based upon such tunes?

In summary, the pride of recent successes should not blind us to the challenges ahead. The LHC may well have surprises in store for us.