Introduction

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As for the previous HERA-LHC workshop, the main goals of the WG5 working group during 2006–2008 were: 1) To examine and improve Monte Carlo models for the LHC data using the experience and ideas from the HERA experiments; 2) To develop analysis frameworks to be used to tune and validate Monte Carlo models; 3) To review and further develop data analysis tools, common interfaces and libraries, which have their origin at HERA and can be useful for studies at the LHC.

Over the past few years, the working group has covered various aspects of data analysis tools and Monte Carlo models, from the conceptually simple ideas through technically detailed projects. Below we will briefly discuss several topics covered by the participants of the WG5 working group.

1 Monte Carlo event generators

There has been considerable progress in the development of Monte Carlo event generators during this workshop. In the working group, we had a very broad coverage of almost all existing Monte Carlo event generators which are expected to be used at the LHC. We have particularly discussed the developments of ALPGEN, PYTHIA8 , HERWIG++, CASCADE, MC@NLO, THEPEG and Forward Physics Monte Carlo (FPMC) [1, 2]. A lot of progress has been made in different areas of simulation.

On the perturbative level, the matching of parton showers with high order matrix elements was discussed and developed extensively. The matching of high jet multiplicity matrix elements with multiple parton shower emissions was discussed as well as matching parton showers with complete next–to–leading order calculations.

The most important question for this workshop was whether we had the necessary tools for the LHC era and whether there was something that HERA could still contribute. Several new Monte Carlo event generators, such as PYTHIA 8, HERWIG++ and SHERPA, are completely new programs, all written in C++, that partly aim to be the successors of the FORTRAN event generators that had already been widely used at HERA. These Monte Carlo models are not just simple rewrites of the existing codes: as was discussed, in many respects, the simulation of the underlying physics in such Monte Carlo models is more sophisticated than in the previous FORTRAN-based versions. New parton shower models, new models for the underlying event and a more sophisticated simulation of the non–perturbative hadronization was discussed. A lot of emphasis has been put on the discussion of underlying event physics as some progress in understanding was expected from the latest HERA results. Details will be discussed in the following section.

In addition to a pure technical description of the progress made in the development of such models, we had several studies showing the relevance and importance of these models to the LHC physics, especially for the direct photons (γ+jet), top-pair production, Wt and the forward-jet physics [2, 3]. We have learned that the current event generators work satisfactorily for the description of HERA data, but the LHC experiments will substantially increase the demands on the physics models implemented in such models.

2 Multiple Parton Interactions in Monte Carlo generators

In the years '80, the evidence for Double Scattering (DS) phenomena in the high-p_T phenomenology of hadron colliders [4] suggested the extension of the same perturbative picture to the soft regime, giving rise to the first implementation of the Multiple Parton Interaction (MPI) processes in a QCD Monte Carlo model [5] which was very successful in reproducing the UA5 charged multiplicity distributions [6].

On top of the general Minimum Bias (MB) observables these MPI models turn out to be particularly adequate to describe the Underlying Event (UE) physics at Tevatron [7], in particular they partly account for the pedestal effect (i.e. the enhancement of the Underlying Event activity with the energy scale of the interaction) as the effect of an increased probability of multiple partonic interactions in case a hard collision has taken place. A second important effect that can contribute to the pedestal effect is the increase in initial state radiation associated to the presence of a hard scattering.

Examples of MPI models are implemented in the general purpose simulation programs PYTHIA [8], HERWIG/JIMMY [9, 10] and SHERPA [11]. Other successful descriptions of UE and MB at hadron colliders are achieved by alternative approaches like PHOJET [12], which was designed to describe rapidity gaps and diffractive physics (relying on both perturbative QCD and Dual Parton Models). The most recent PYTHIA versions [13] adopt an optional alternative description of the colliding partons in terms of correlated multi-parton distribution functions of flavours, colors and longitudinal momenta.

From the contributions to the MC and multi-jet working groups of this HERA/LHC workshop, it is clear that the MPI are currently experiencing a growing popularity and are presently widely invoked to account for observations that would not be explained otherwise.

While preparing the ground for the traditional DS, MB and UE measurements at the LHC along the Tevatron experience (also complemented with the recent UE HERA results), new feasibility studies are proposed which in perspective will constitute a challenge to the performances of the MPI models: the usage of jet clustering algorithms providing an automated estimation of the UE activity, the investigation of the mini-jet structure of the MB events, the estimation of large pseudo-rapidity activity correlations, the connection between the partonic cross sections and the rapidity gap suppression in the hard diffractive events.

At the same time, the implementation of the MPI effects in the Monte Carlo models is quickly proceeding through an increasing level of sophistication and complexity that has already a deep impact on the analysis strategies at the LHC. For example new MC tools like PYTHIA8 and HERWIG++ can now be used in order to estimate complementary Standard Model backgrounds to searches coming from DS.

Further progress in the description of the MPI might be achieved with the introduction of a dynamical quantum description of the interacting hadrons, providing also a modeling of the diffractive interactions in the same context.

3 Introduction to Monte Carlo validation and analysis tools

The RIVET library, a successor to the successful HERA-oriented generator-analysis library, HZ-TOOL, is getting to be popular at the LHC for validating the performance of event generator and tuning [14]. Unlike FORTRAN-based HZTOOL, RIVET is written in object-oriented C++, and it is primarily a library which can be used from within any analysis framework.

For Monte Carlo tuning, the so-called PROFESSOR system [14] was recently successfully used for PYTHIA6 tuning. This led to a substantial improvement on the existing default tune, thus it can greatly aid the setup of new generators for LHC studies.

In this working group, we have moved beyond Monte Carlo specific validation tools. As an example, jHepWork analysis framework [15] presented at this working group can be considered as a multi-platform alternative to ROOT since it was written in Java. The framework can be useful for both experimentalists and theorists.

4 Conclusions

The presented proceedings describe the results of the work performed in the WG5 working group over several years between 2006–2008. Hopefully, we have provided a correct balance between experimental and theoretical results. As conveners of this working group, we were impressed by the quality and diversity of the presented results. The high quality of the presentations stimulated lively discussions often leading to new ideas and insights into the working group topics.

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