Working group: Multi-Jet final states and energy flows

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Abstract

We present a summary of the activities of the *Multi-Jet final states and energy flows* Working Group of the *HERA and the LHC workshop*, 2007-2008. Among the more specific topics considered were the status of and recent progress in higher order calculations, both in fixed perturbative expansions and in resummed approaches, recent progress in the description of jets, including the description of forward jets, new calculations performed using k_T-factorization and new determinations of unintegrated parton densities.

1 Introduction

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The activities of Working Group 2, *Multi-Jet Final States and Energy Flows*, have covered a broad range of topics, encompassing both theoretical and experimental advances in understanding the hadronic final state at high energies. Much of this work will be of significant benefit in preparing to fully exploit the LHC physics potential. We focus here on progress in the field since the last proceedings of this workshop [1, 2].

From a theoretical point of view, a good understanding of the Standard Model (SM) is of the utmost importance in order to be able to unravel and disentangle possible New Physics effects. In addition, the study of the Standard Model is important in its own right, especially in the QCD sector where the strong coupling in many cases prevents us from making reliable predictions. Recently, considerable progress has been made in the area of higher order calculations in perturbative QCD. Some developments are discussed in the contributions of Sec. [3]. Typically, these fixed-order calculations are sufficient to describe inclusive observables, such as cross sections or transverse momentum (p_t) spectra at sufficiently high scales. However, more exclusive observables, such as event-shape distributions, require that one rearranges the perturbative expansion and that one resums leading and next-to-leading logarithmic terms to all orders in perturbation theory. This technology is today already well-developed both in terms of analytical calculations and in terms of numerical implementations in parton shower Monte Carlos. We report on further recent progress in the understanding and development of such resummed calculations in Sec. [4].

The development and use of jet algorithms plays a key role in the study of hadronic final states. Indeed jets are an essential tool for a variety of studies, such as top reconstruction, mass measurements and searches for Higgs and new physics. Furthermore, they are instrumental for QCD studies, e. g. for inclusive-jet measurements, which in turn constitute an important input for parton density determinations. By clustering particles into jets, jet algorithms reduce complicated multi-particle events in simple final states with few jets. This procedure and the way particles are recombined together (e.g. the E- or P-scheme) is fundamentally non-unique. This freedom can be exploited to extract information from jets. The rapid, recent development of fast, infrared- and collinear-safe cone and clustering algorithms, is discussed in Sec. [5]. Also considered are the issues of jet-finding, reconstruction and calibration currently being developed by the LHC experimental collaborations. Recent work on defining jet-quality measures, designed to quantify the performance of jet algorithms, is also presented.

In Sec. [6] we focus our attention to the k_T-factorization approach, which may be the key to fully understand the hadronic final states at the LHC. Although the standard collinear factorization should hold for the description of jets at very high scales, we expect it to break down at somewhat smaller scales and low x, and the use of k_T-factorization and unintegrated parton densities will become essential. This is an area where we have learned a lot from HERA results, and where we may learn more still from data yet to be analyzed.

A major difficulty in describing final states at high energies is the treatment of multi-parton interactions. There is no doubt that, due to the high density of small-x partons, the events at the LHC will contain several semi-hard parton–parton scatterings. Indeed such events have already been studied at the Tevatron, and models including this feature are need in order to describe *e.g.* the underlying events in photo-production at HERA. Although models for multi-parton interactions exist, there are many uncertainties, and the differences in the predictions for the LHC are large. Most of the work on multi-parton interactions in the workshop was presented in joint sessions with the Monte Carlo tools working group, and the corresponding contribution to these proceedings are presented in the section of this working group [7].

In Sec. [8], reviews some recent experimental results from HERA which are of interest for future LHC studies, concentrating particularly on isolated photon and jet production, including the effects of multi-parton interactions and the underlying event.

Finally we take a look at processes at even higher parton densities, such as those occurring in heavy ion collisions. Here it is important to consider not only the productions of jets, and possible effects of gluon saturation, but also the propagation of the hard partons through a dense medium. A couple of issues related to such interactions at high densities are discussed in Sec. [9].

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