Introduction to Parton Distribution Functions

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Abstract

We provide an assessment of the impact of parton distributions on the determination of LHC processes, and of the accuracy with which parton distribution functions (PDFs) can be extracted from data, in particular from current and forthcoming HERA experiments. We give an overview of reference LHC processes and their associated PDF uncertainties, and study in detail W and Z production at the LHC. We discuss the precision which may be obtained from the analysis of existing HERA data, tests of consistency of HERA data from different experiments, and the combination of these data. We determine further improvements on PDFs which may be obtained from future HERA data (including measurements of F_L), and from combining present and future HERA data with present and future hadron collider data. We review the current status of knowledge of higher (NNLO) QCD corrections to perturbative evolution and deep-inelastic scattering, and provide reference results for their impact on parton evolution, and we briefly examine non-perturbative models for parton distributions. We discuss the state-of-the art in global parton fits, we assess the impact on them of various kinds of data and of theoretical corrections, by providing benchmarks of Alekhin and MRST parton distributions and a CTEQ analysis of parton fit stability, and we briefly present proposals for alternative approaches to parton fitting. We summarize the status of large and small x resummation, by providing estimates of the impact of large x resummation on parton fits, and a comparison of different approaches to small x resummation, for which we also discuss numerical techniques.

The physics of parton distributions, especially within the context of deep-inelastic scattering (DIS), has been an active subject of detailed theoretical and experimental investigations since the origins of perturbative quantum chromodynamics (QCD), which, thanks to asymptotic freedom, allows one to determine perturbatively their scale dependence [1–5].

Since the advent of HERA, much progress has been made in determining the Parton Distribution Functions (PDFs) of the proton. A good knowledge of the PDFs is vital in order to make predictions for both Standard Model and beyond the Standard Model processes at hadronic colliders, specifically the LHC. Furthermore, PDFs must be known as precisely as possible in order to maximize the discovery potential for new physics at the LHC. Conversely, LHC data will lead to an improvement in the knowledge of PDFs.

The main aim of this document is to provide a state-of-the art assessment of the impact of parton distributions on the determination of LHC processes, and of the accuracy with which parton distributions can be extracted from data, in particular current and forthcoming HERA data.

In Ref. [6] we set the stage by providing an overview of relevant LHC processes and a discussion of their experimental and theoretical accuracy. In Ref. [7] we turn to the experimental determination of PDFs, and in particular examine the improvements to be expected from forthcoming measurements at HERA, as well as from analysis methods which allow one to combine HERA data with each other, and also with data from existing (Tevatron) and forthcoming (LHC) hadron colliders. In Ref. [8] we discuss the state of the art in the extraction of parton distributions of the data by first reviewing recent progress in higher-order QCD corrections and their impact on the extraction of PDFs, and then discussing and comparing the determination of PDFs from global fits. Finally, in Ref. [9] we summarize the current status of resummed QCD computations which are not yet used in parton fits, but could lead to an improvement in the theoretical precision of PDF determinations.

In addition to summarizing the state of the art, we also provide several new results, benchmarks and predictions obtained within the framework of the HERA–LHC workshop.

Acknowledgements

References

[1] Gross, D. J. and Wilczek, F., Phys. Rev. Lett. **30**, 1343 (1973).

[2] Politzer, H. D., Phys. Rev. Lett. **30**, 1346 (1973).

[3] Gross, D. J. and Wilczek, F., Phys. Rev. **D8**, 3633 (1973).

[4] Georgi, H. and Politzer, H. D., Phys. Rev. **D9**, 416 (1974).

[5] Gross, D. J. and Wilczek, F., Phys. Rev. **D9**, 980 (1974).

[6] M. Dittmar et al., *LHC final states and their potential experimental and theoretical accuracies*. These proceedings.

[7] A. Glazov et al., *Experimental determination of parton distributions*. These proceedings.

[8] A. Glazov et al., *Glap evolution and parton fits*. These proceedings.

[9] G. Altarelli et al., *Resummation*. These proceedings.