

## Introduction

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## Abstract

We provide an assessment of the state of the art in various issues related to experimental measurements, phenomenological methods and theoretical results relevant for the determination of parton distribution functions (PDFs) and their uncertainties, with the specific aim of providing benchmarks of different existing approaches and results in view of their application to physics at the LHC.

We discuss higher order corrections, we review and compare different approaches to small  $x$  resummation, and we assess the possible relevance of parton saturation in the determination of PDFs at HERA and its possible study in LHC processes. We provide various benchmarks of PDF fits, with the specific aim of studying issues of error propagation, non-gaussian uncertainties, choice of functional forms of PDFs, and combination of data from different experiments and different processes. We study the impact of combined HERA (ZEUS-H1) structure function data, their impact on PDF uncertainties, and their implications for the computation of standard candle processes, and we review the recent  $F_L$  determination at HERA. Finally, we compare and assess methods for luminosity measurements at the LHC and the impact of PDFs on them.

With the start of data-taking at the LHC getting closer, the importance of a detailed understanding of the physics of parton distributions (PDFs) has increased considerably, along with the awareness of the LHC community for the importance of the issues related to it. Clearly, the main reason why PDFs are important at the LHC is that at a hadron collider a detailed understanding of PDFs is needed in order to obtain accurate predictions for both signal and background processes. Indeed, for many physical processes at the LHC, PDFs are the dominant source of uncertainty. On the other hand, an accurate control of PDF uncertainties allows one to use selected processes as “standard candles”, for instance in the determination of luminosities. However, this also means that experimentation at the LHC will provide a considerable amount of new experimental information on PDFs, and it will enable us to test the adequacy of their current theoretical understanding.

The main aim of this document is to provide a state of the art assessment of our understanding of PDFs at the dawn of the LHC. Since the previous HERA-LHC workshop [1], we have witnessed several important directions of progress in the physics of PDFs. On the theoretical side there has been conclusive progress in extending the treatment of perturbative QCD beyond the current default, namely, the next-to-leading perturbative order. On the phenomenological side there has been a joint effort between experimental and theoretical groups involved in the extraction of PDFs, specifically from global fits, in agreeing on common procedures, benchmarks and standards. On the experimental side, new improved results from the HERA runs are being finalized: these include both the construction of a joint determination of structure function which combines the result of the ZEUS and H1 experiments, and the first direct measurements of the structure function  $F_L$  which have been made possible by running HERA at a reduced proton beam energy in 2007. Also, the LHC experiments (ATLAS, CMS and LHCb) are now assessing

the use of standard candle processes for luminosity measurements.

All these issues are discussed in this document. In each case, our main goal has been to provide as much as possible a joint treatment by the various groups involved, as well as a comparison of different approaches and benchmarking of results. In particular, in Sect. [2], after briefly reviewing (Sect. [3]) the current status of higher-order calculations for DIS, we provide (Sect. [4]) detailed comparisons of techniques and results of different existing approaches to small  $x$  resummation, and then we summarize (Sect. [5]) the current status of studies of parton saturation at HERA, their possible impact on current PDF extraction and the prospects of future studies at the LHC. In Sect. [6] we discuss methods and results for the benchmarking of PDF fits: with specific reference to two benchmark fits based on a common agreed set of data, we discuss issues related to error propagation and non-gaussian errors, to the choice of functional form and corresponding bias, to possible incompatibilities between different data sets. In Sect. [7] we turn to recent progress in the extraction of PDFs from HERA data, specifically the impact of combined ZEUS-H1 structure function data on PDF determination and the ensuing calculation of  $W$  and  $Z$  cross-sections (Sect. [8]) and the recent first determination of the structure function  $F_L$  (Sect. [9]). In Sect. [10] we discuss and compare luminosity measurements based on absolute proton-proton luminosity measurements to those based on the use of standard candle processes, and the impact on all of them of PDF uncertainties. Finally, in Sect. [11] we present the PDF4LHC initiative, which will provide a framework for the continuation of PDF studies for the LHC.

*Note:* Most of the contributions to this workshop are the result of collaboration between various groups. The common set of authors given for each section or subsection has read and approved the entire content of that section or subsection; however, when a subset of these authors is given for a specific part of the section or subsection, they are responsible for it.

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