PROTON STRUCTURE MEASUREMENTS AT HERA

D. LONTKOVSKYI ON BEHALF OF THE H1 AND ZEUS COLLABORATIONS
DESY, Notkestrasse 85,
22607 Hamburg, Germany

A QCD analysis HERAPDF1.7 of the combined HERA inclusive neutral and charged current deep inelastic scattering data, including reduced proton energy data as well as charm and jet production data is presented. Predictions for different observables at LHC energies based on proton parton density functions (PDFs) extracted from the HERA data only are competitive with predictions based on parton distributions extracted from more diverse processes. The program for determination of the proton PDFs HERAFITTER is also presented.

1 Introduction

The precision of predictions of the Standard Model processes in high energy experiments with protons is often limited by the precision of the proton PDFs, therefore an accurate extraction of the pPDFs is vital. The measurements from HERA provide one of the main sources of information about the proton structure. The phase space coverage by the HERA experiments is complementary to the one by fixed target experiments and overlaps with the Tevatron and the LHC. The HERA PDF sets are based on using HERA data only. So far the HERAPDF1.5 [1,2] provides the reference set. It is based on the combined HERAI and preliminary combined HERAII inclusive neutral current (NC) and charged current (CC) data [1,2]. The kinematic range of the combined HERA data is $0.045 < Q^2 < 30000$ GeV^2 and $6 \times 10^{-5} < x < 0.65$. In the HERAPDF1.6 [3] set jet production data from H1 and ZEUS are used in addition. This allowed a simultaneous PDF and $\alpha_s(M_Z)$ fit with good precision. Here a new PDF set HERAPDF1.7 [4] is presented, exploiting a large variety of different data and processes at HERA. In addition to the data used for HERAPDF1.6 it also uses combined preliminary $F_2^{c\bar{c}}$ data [5] and combined NC data from runs with lower proton energy.

2 QCD analysis settings

The QCD analysis procedure can be summarised as follows. At the starting scale below the charm mass threshold the proton PDFs are parametrised as functions of x. The following flavour decomposition is used: the valence distributions xu_v and xd_v; the gluon distribution xg; the u-type and d-type sea quark distributions $x\bar{U} = x\bar{u}, x\bar{D} = x\bar{d} + x\bar{s}$. These PDFs are then evolved to higher scales using the NLO DGLAP equations, by means of the QCDNUM program [6]. The predictions for the observables are computed by the convolution of the evolved PDFs with perturbative coefficient functions. Heavy flavours were treated in the general mass variable flavour number scheme [7]. In case of jet observables the FastNLO [8] convolution engine was used. It has been shown in previous studies [2,3] that more data allow for more flexible gluon

and sea quark PDF parametrisatons, therefore the flexible 14 parameters fit of HERAPDF1.5f was adopted in this analysis.

3 Results and predictions

The result of the HERAPDF1.7 fit is presented in Fig. 1. A detailed error analysis was performed in order to obtain the best estimate for the PDF uncertainties. The consistency of the combined measurements allows the estimation of experimental uncertainties on the proton PDFs by a $\delta\chi^2 = 1$ tolerance criterion. Variations of the strangeness fraction, charm and bottom quark masses, minimal Q^2 of the measurements account for the model uncertainty. The variation of the starting scale of the evolution and modification of the PDFs parametrisations is included in the parametrisation uncertainty. The experimental uncertainty accounts for the precision of the data. The HERAPDF1.7 fit is also compared to the previous proton PDF determination HERAPDF1.6 in Fig. 1. It is found that additional data used in HERAPDF1.7 prefers a slightly softer gluon distribution, however the difference between different HERAPDF sets is within the PDF uncertainty.

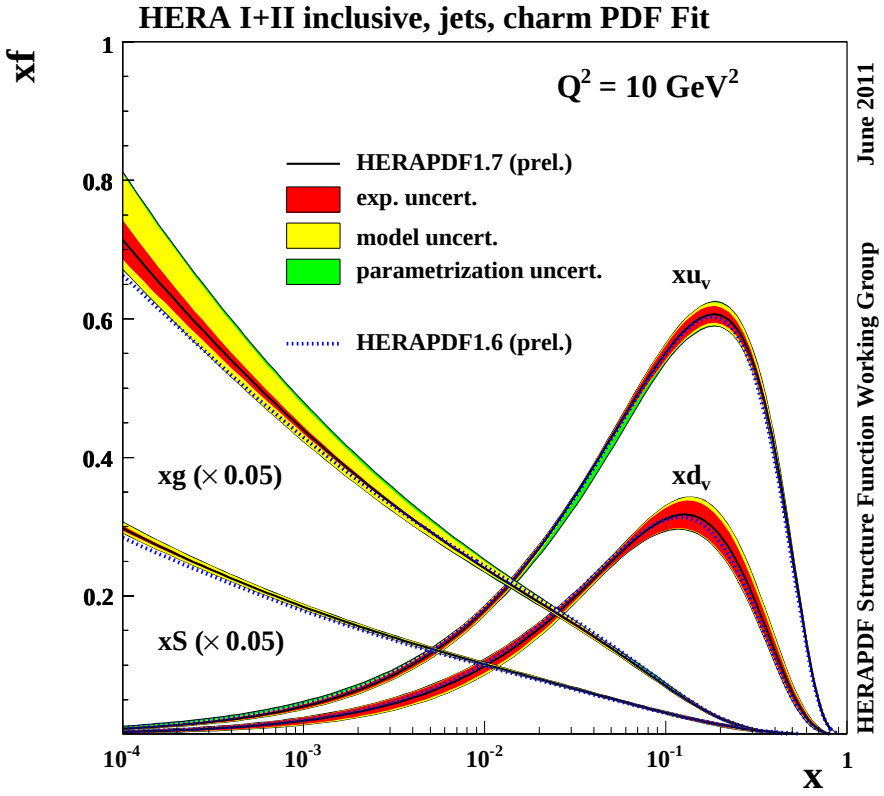
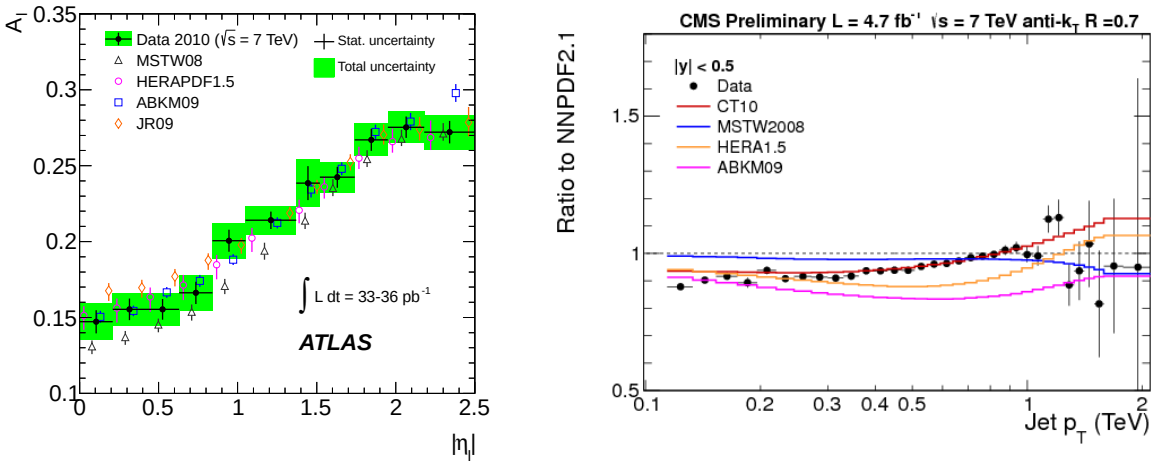


Figure 1: The proton PDFs HERAPDF1.7 at $Q^2 = 10$ GeV^2 extracted from a fit to the data and compared to the HERAPDF1.6. Solid and dashed lines represent central values of the HERAPDF 1.7 and HERAPDF 1.6 fits, respectively. The bands represent various contributions to the PDFs uncertainties.

The predictions based on HERAPDFs as well as those from other PDF fitter groups have been confronted with the recent measurements at the LHC. Exemplary results [9,10] from ATLAS and CMS are shown in Fig. 2. The predictions are found to be in reasonable agreement with the data.



(a) (b)

Figure 2: Measured W charge asymmetry at ATLAS as a function of lepton pseudorapidity $|\eta_l|$ compared with theoretical predictions calculated to NNLO and based on different proton PDF sets (a). Ratio of CMS inclusive jet cross section to NLO predictions based on different proton PDF sets for $|y| < 0.5$ (b)

4 HERAFITTER project

Various measurements at the LHC will reach a precision allowing further constrains on the proton PDFs. The aim of the HERAFITTER project is to provide the necessary infrastructure for PDF studies. The framework covers processes from a wide area: ep (inclusive DIS, jets), $p\bar{p}$ (jets, Drell-Yan) with a clear possibility to extend to new processes and theories. An open source program for the PDF determination HERAFITTER is available [11].

5 Summary

The NLO QCD analysis HERAPDF1.7 of extended datasets of measurements from HERA experiments provides a new precise determination of the proton PDFs. This determination is consistent with previous determinations at HERA and has smaller uncertainty. The predictions based on different variants of HERAPDF provide a reasonable description of different observables at the LHC energy. The new open source project HERAFITTER combines all necessary ingredients for further theoretical and experimental studies of the proton PDFs in advent of new precise measurements by LHC experiments.

References

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