Testing sensitivity of parton distributions to CMS jet data using HERAfitter

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Abstract

During 2015 Summer Students Programme HERAfitter platform was used to analyse inclusive Deep Inelastic Scattering data from HERA experiments [1]-[6] as well as recent data from CMS [7]-[8]. Several results announced in HERAfitter publication in June [1] were repeated, in particular fit with free α_s for HERA inclusive + HERA charm + HERA jets data gave the α_s value of $\alpha_s = 0.1183 \pm 0.0009$ (experimental uncertainty). Fit with free α_s for HERA inclusive + CMS jets gave $\alpha_s > 0.123$, which is higher than expected and must be investigated further.

1 Introduction

Main objects studied during Summer Students Programme were Parton Distributions Functions (PDFs). PDF is defined as a function $F_p(x)$ which gives probability of finding parton with longitudinal momentum fraction x.

PDFs are crucial when one wants to calculate theoretical cross-section for processes involving scattering on protons and compare them to experimental data. Parton distribution functions uncertainties are often dominating uncertainties of cross-sections and other variables describing processes at colliders like Tevatron, LHC and HERA. DIS data collected in HERA experiments are currently the core of every PDF extraction.

The HERAFitter is a framework able to extract PDFs and carry many extensive studies connected with parton distribution. It was firstly designed for data from HERA but currently is widely used with Tevatron and LHC data.

2 HERAfitter framework

HERAfitter can be used to determine parton distribution functions (PDFs). These are needed to calculate cross sections for ep, pp or $p\bar{p}$ collideras. They are also required for analyzing data collected at the LHC and future colliders.

In the Figure 1 there is a schematic structure of HERAfitter. HERAfitter was used with data files both from HERA experiments and from CMS. Several input theory parameters were also modified to check how it would change quality of the fit.

Each fit was run using information from three files: steering.txt, minuit.in.txt and ewparam.txt. In file steering.txt user determines datafiles which will be used for fit, sets strong coupling constant α_s and chooses between a few theoretical options, such as heavy flavor scheme and χ^2 definition. In minuit.in.txt one can set input value of minimisation parameters and choose which of them should be constant during fit and which should be freed so that HERAfitter calculates their optimal value. In ewparam.txt electroweak parameters, such as W and Z boson masses, are set.

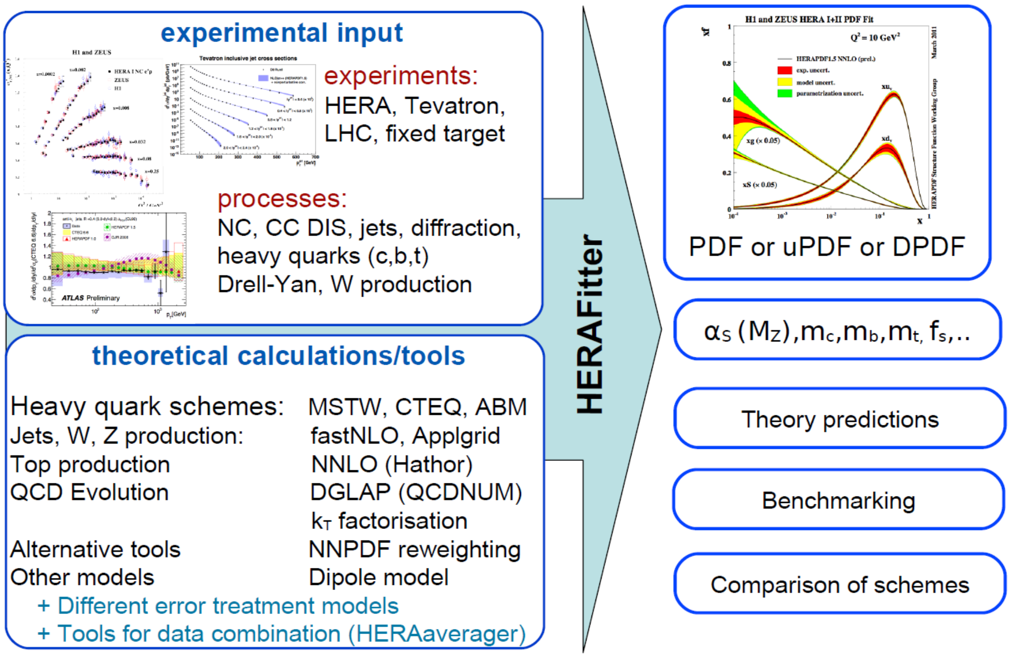

Figure 1: Scheme of HERAfitter program.

3 HERAPDF2.0 parton distributions

At the beginning of Summer Program the main goal was to recreate some results from recent publication [1], in particular plot of parton distribution functions HERAPDF2.0 next to leading order (NLO) at $\mu_f^2 = 10$ GeV^2 (shown in the Fig. 2).

In order to find model and parametrisation uncertainites of PDFs HERAfitter was run with variations of main parameters and model assumptions, as shown in Table 1. For the nominal fit all parameters were set to the standard value. For each variation only one parameter in the fit was changed from the standard value. Altogether eleven fits were run. Received parton distribuition functions for the up and down quarks (valence and sea) are shown in Fig. 3.

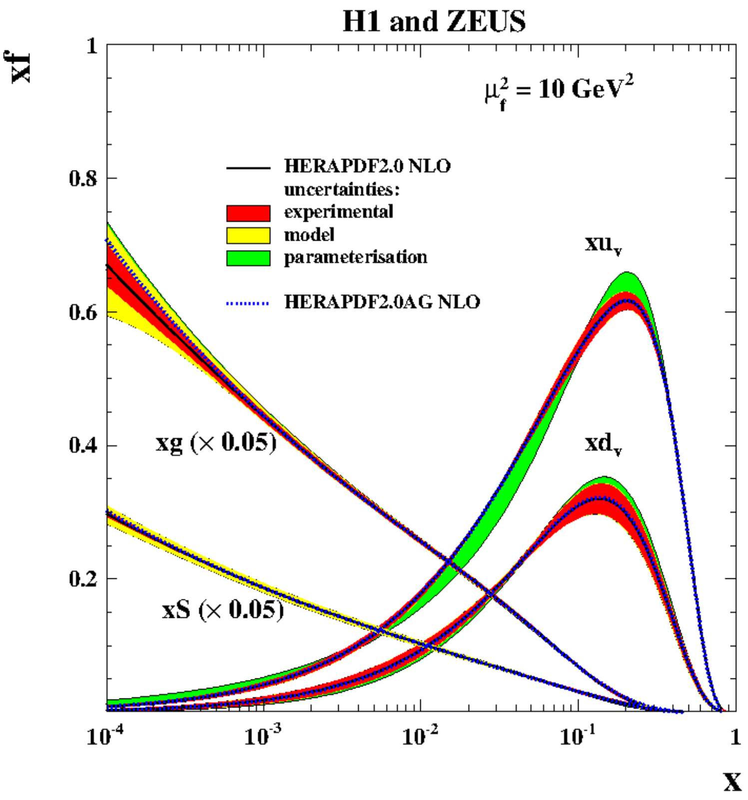

Figure 2: Example of calculated parton distribution functions (publication).

Variation	Standard Value	Lower Limit	Upper Limit
Q^2_{min} [GeV^2]	3.5	2.5	5.0
M_c (NLO) [GeV]	1.47	1.41	1.53
M_b [GeV]	4.5	4.25	4.75
f_s	0.4	0.3	0.5
μ_{f_0} [GeV]	1.9	1.6	2.2

Table 1: Input parameters for HERAPDF2.0 fits and the variations considered to evaluate model and parametrisation (μ_{f_0}) uncertainites.

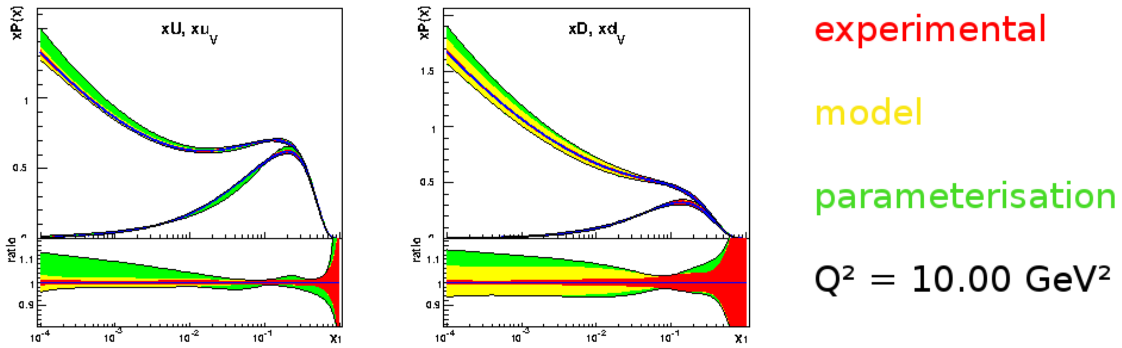

Figure 3: Example of calculated parton distribution functions (fit produced during Summer Programme).

After that an impact on PDFs given by including HERA jets data ([1], [4]-[6]) was studied. The main point was to run HERAfitter for the same datafiles with different α_s values, that is - to make *scan* of α_s and look at the quality of the fit using χ^2. This procedure was repeated for two data sets: HERA inclusive data and HERA inclusive + HERA charm + HERA jets data. Figure 4 (taken from HERAPDF2.0 studies [1]) shows that adding jet data increases sensitivity of the fit to α_s value. Results shown in Fig. 5 are in agreement with those in the publication [1].

Finally the fit with free α_s for HERA inclusive + HERA charm + HERA jets data was processed. Fitted parameters are in agreement with values in the publication, in particular $\alpha_s = 0.1183 \pm 0.0009$ (experimental uncertainty).

4 Further constrains on PDFs from CMS jet data

The most important point of work was using HERAfitter to analyse data from CMS jets. At first a scan of α_s was done using following data files:

- HERA inclusive [2] + CMS 2.76 TeV jets data [7],
- HERA inclusive + CMS 8 TeV jets data [8],
- HERA inclusive + CMS 2.76 TeV jets + CMS 8 TeV jets data.

Results are presented in Fig. 6. Again one can easily see that addtional data allows for more accurate determining strong coupling constant.

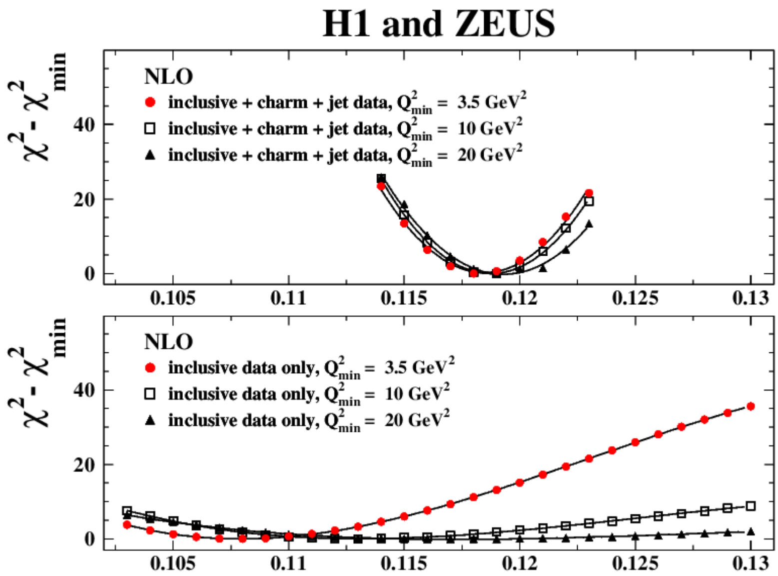

Figure 4: Scan of strong coupling constant from publication.

By checking fitted parabola's widht in $\Delta\alpha_s$ corresponding to $\Delta\chi^2 = 1$ it is possible to determine which data (HERA charm + jets or CMS jets) are more sensitive to α_s scan (Fig. 7). In case of HERA inclusive data + all CMS jets data one gets $\Delta\alpha_s = 0.00107$, while for HERA inclusive + charm + jets data $\Delta\alpha_s = 0.00095$, which shows that HERA charm + jets are slightly more sensitive to α_s. Including all datafiles (HERA inclusive + charm + jets data + all CMS jets data) makes the fit most sensitive to α_s scan (Fig. 8). In this case $\Delta\alpha_s = 0.00074$, increasing the sensitivity further.

Bigger sensitivity to α_s scan corresponds to smaller experimental uncertainty of PDFs. In the Fig. 9 relative uncertainty of distribution functions of down valence quark and gluon are presented. Additional CMS jets data clearly decrease PDF relative uncertainty for most of the studied x range in gluon distribution function.

4.1 Constraining α_s

The last task was to compare fitted α_s value and its uncertainty for several datafile sets (Fig. 10). One can see that for HERA inclusive + charm + jets data α_s is close to the global average. Adding CMS data shifts fitted strong coupling constant to higher values. It is not sure why this happens, probably it is connected with parameterisation of PDFs. Another conclusion is that

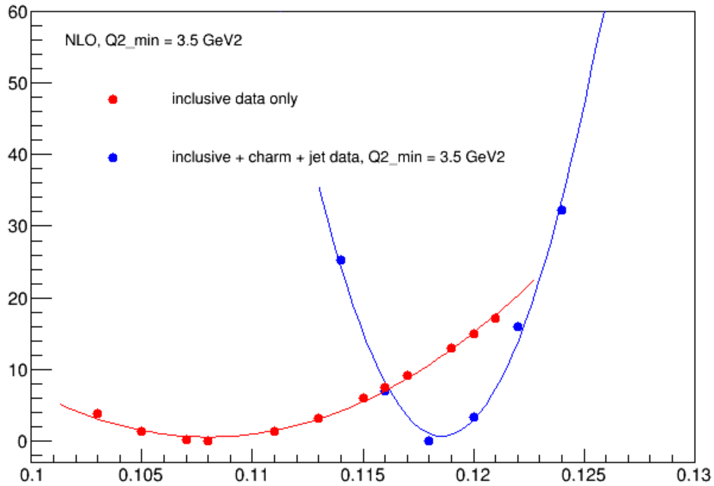

Figure 5: My scan of strong coupling constant.

adding more datafiles always decreases uncertainty of the fit, as one would expect.

5 Summary

During Summer Student Programme several tasks concerning PDFs and sensitivity of parton distributions to CMS jet data were done. A few of them were a repetition of results described in publication [1], with the HERA-PDF2.0 setup for the same data files used, the strong coupling constant α_s was calculated indentically (as well as its experimental uncertainty). The α_s scan was done for seven different data sets, using both HERA and CMS data. It was proven that both HERA and CMS data are sensitive to α_s. Calculations based on CMS data leads to α_s bigger than world average. This result is not well explained yet and will be examined further.

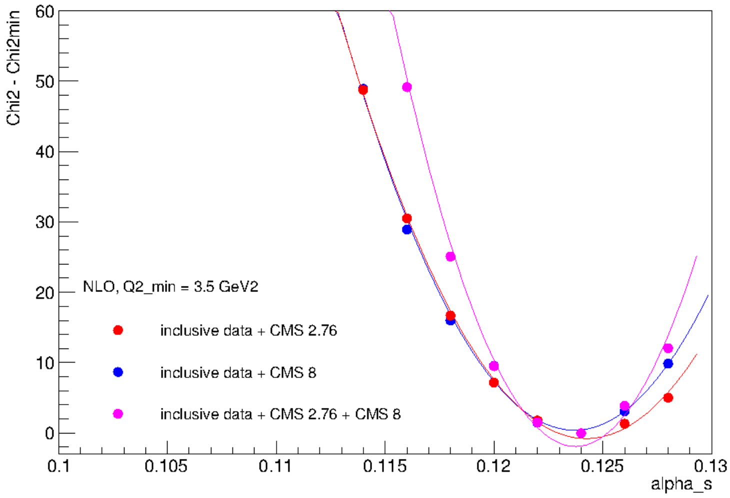

Figure 6: My scan of strong coupling constant for combined data from HERA and CMS.

References

[1] Combination of Measurements of Inclusive Deep Inelastic $e^{\pm}p$ Scattering Cross Sections and QCD Analysis of HERA Data, H1 and ZEUS Collaborations, http://arxiv.org/abs/1506.06042

[2] arXiv:0911.0884 (HERA inclusive data)

[3] arXiv:1211.1182 (HERA charm data)

[4] arXiv:1010.6167 (HERA jets data)

[5] arXiv:0911.5678 (HERA jets data)

[6] arXiv:0707.4057 (HERA jets data)

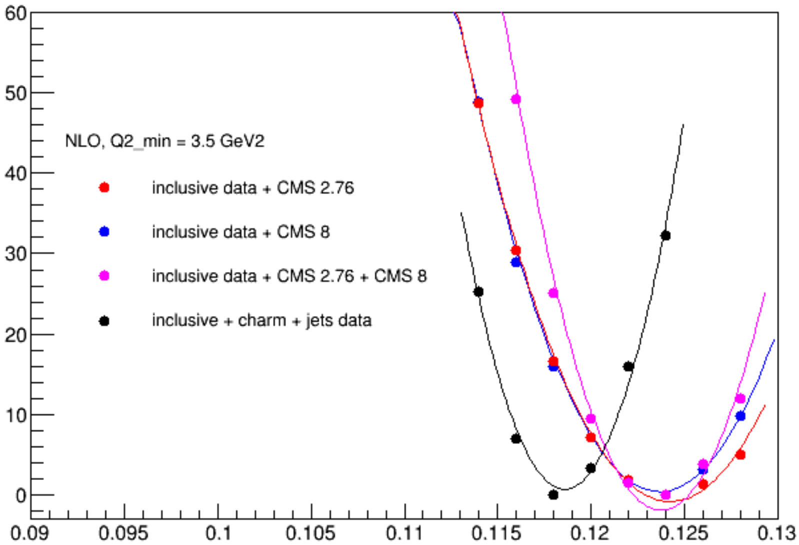

Figure 7: Scan of strong coupling constant for combined data from HERA and CMS.

[7] SMP-14-017 (CMS jets 2.76 data)

[8] SMP-14-023 (CMS jets 8 data)

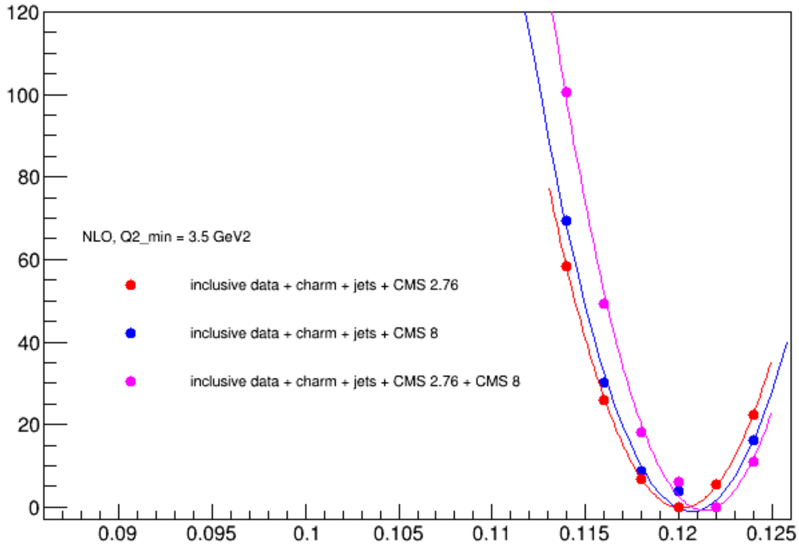

Figure 8: Scan of strong coupling constant for combined data from HERA and CMS.

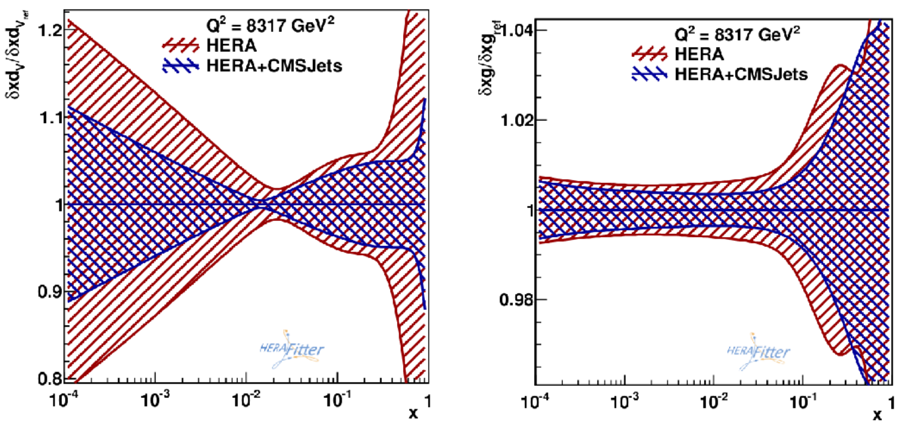

Figure 9: Relative uncertainty of distribution function of down valence quark (left) and gluon (right).

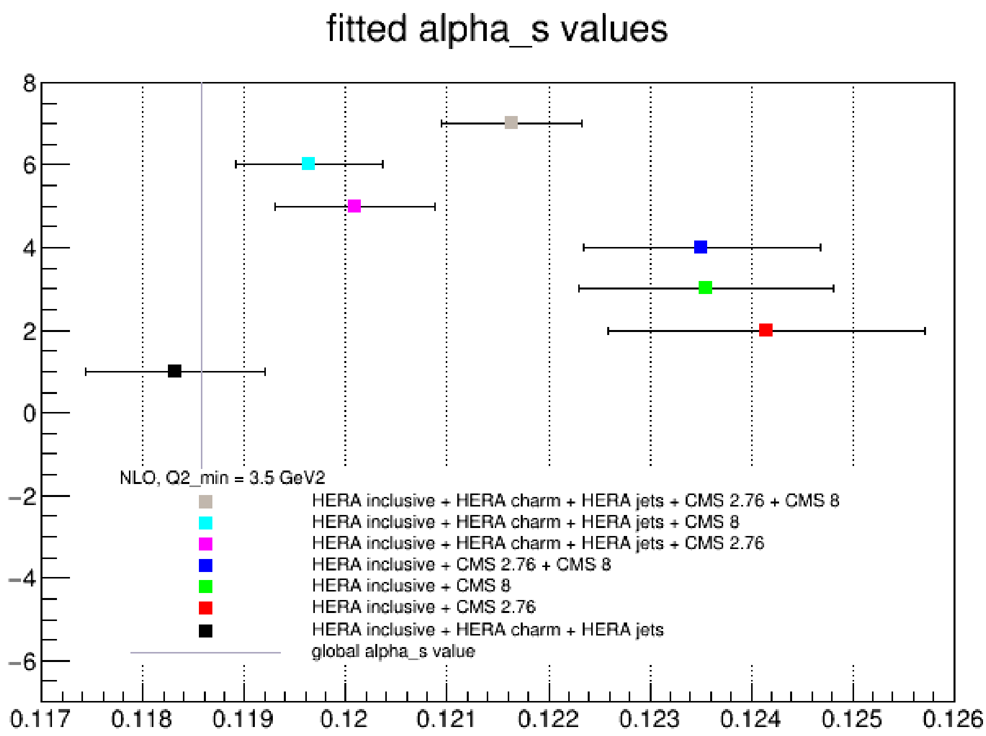

Figure 10: Fitted α_s values for different HERA and CMS data combinations.