PDF studies with LHeC inclusive DIS pseudo-data

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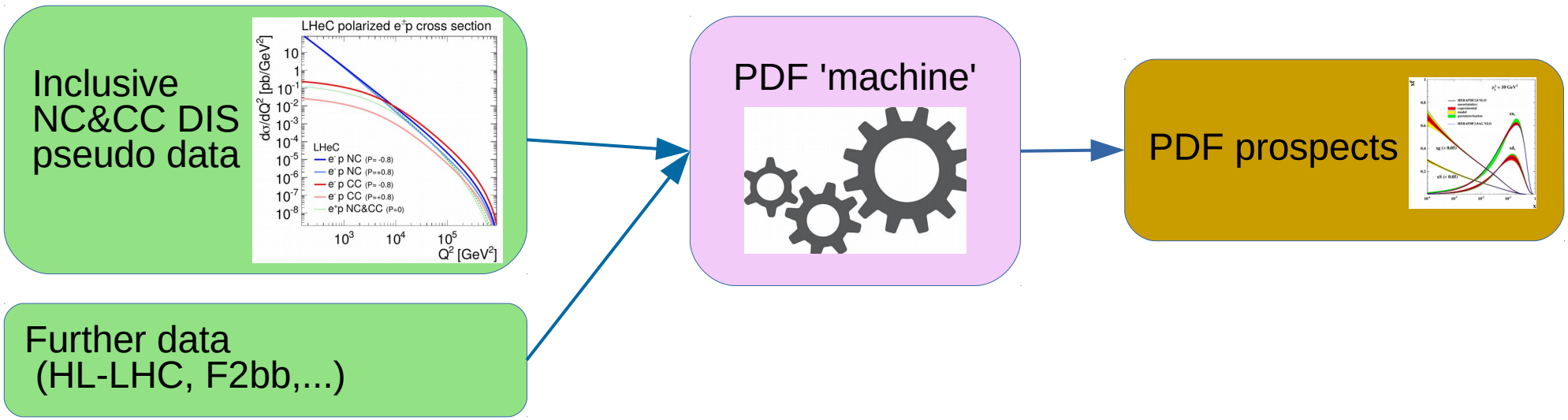
with contributions from M. Klein, F. Giuli, and many more

Introduction

PDF prospects with LHeC pseudo data



PDF 'machine'

- PDF 'fitting' framework
- PDF profiling (MC, Hessian)
- Many many different aspects
- … parameterisations, QCD order, HF, pseudo-data 're-generation', χ^2 definition, error treatment, error propagation, presentation of results, etc...

PDF prospects

- Two ingredients
  1) prospects w/ LHeC data
  2) 'today' (or any other comparison)
- Caveat
  there is nowadays no data in the regime accessible by LHeC: extrapolated uncertainties of present PDFs are often debatable

Goal and methodology

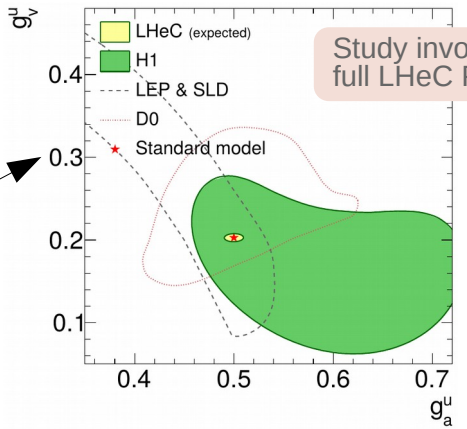
Goal

- Provide an additional independent check
- perform studies, which are otherwise difficult to do

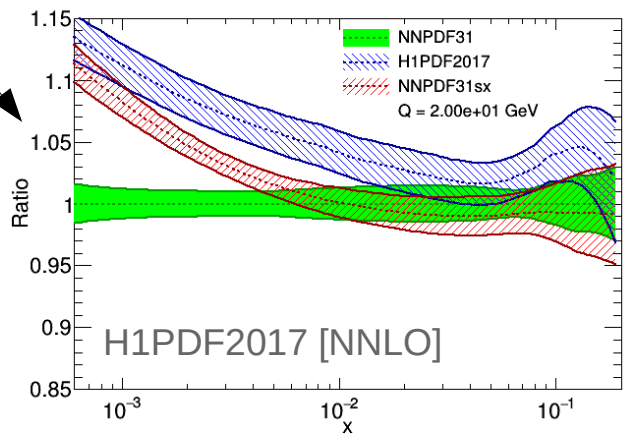
Methodology

- Use Alpos fitting framework
  - flexible and fully object-oriented fitting framework
  - Interfaces to:
    QCDNUM, Apfel, Apfel++, fastNLO, Applgrid, TMinuit, TMinimizer, Apccp, EPRC, CRunDec, …
  - (good) reproduction of HERAPDFs feasible
  - Used for
    - H1PDF2017 [nnlo]
    - LHeC EW studies

LHeC EW studies



Study involves full LHeC PDF fit!



Results involving Alpos

- H1PDF2017 *EPJ C77 (2017), 791*
  NNLO α_s from jets
- H1 electroweak analysis *EPJ C78 (2018), 777*
- α_s from jets *[arXiv:1712.00480]*
- Two-tensor pomeron model *(in prep., prel. EDS2017)*
- LHeC, FCC-eh EW studies *(PoS DIS2017 (2018) 105)*
- diffr. dijets in NNLO *(EPJ C78 (2018), 538)*
- H1 jet analysis *(EPJ C77 (2017) 215)*

Ansatz

PDF parameterisation

- HERA-like PDF parameterisation
  → start with 'simple' parameterisation and extent if needed

$$
\begin{array}{ll}
xg & xg(x) = A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{C'_g} \\
xu_v & xu_v(x) = A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}}(1+E_{u_v}x^2), \\
xd_v & xd_v(x) = A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}}, \\
x\bar{U} & x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}}(1-x)^{C_{\bar{U}}}, \\
x\bar{D} & x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}}(1-x)^{C_{\bar{D}}}
\end{array}
$$

- PDF parameters set similar to H1PDF2017
  → reasonably high gluon also at lower-x values
  → still: include neg.-gluon term, such that gluon uncertainty has additional flexibility at lower-x

- Use most-recent polarised incl. NC & CC DIS ~~data~~ uncertainties from Max
  `http://hep.ph.liv.ac.uk/~mklein/lhecdata/`
  $Q^2 > 3.5\ \mathrm{GeV}^2$, 1005 data points (NC, CC, Low-E)

- Re-calculated pseudo-data σ: NNLO QCD, ZM-VFNS, … (details are not so important)
  χ^2 after minimisation is zero.

- Log-normal based likelihood function
  → relative uncertainties are normal distributed
  → only relative uncertainties are input to fit
  no translation from rel. uncert. to abs. uncert. needed

$$\chi^2 = \sum_{ij} \log \frac{d_i}{\tilde{\sigma}_i} V_{ij}^{-1} \log \frac{d_j}{\tilde{\sigma}_j}$$

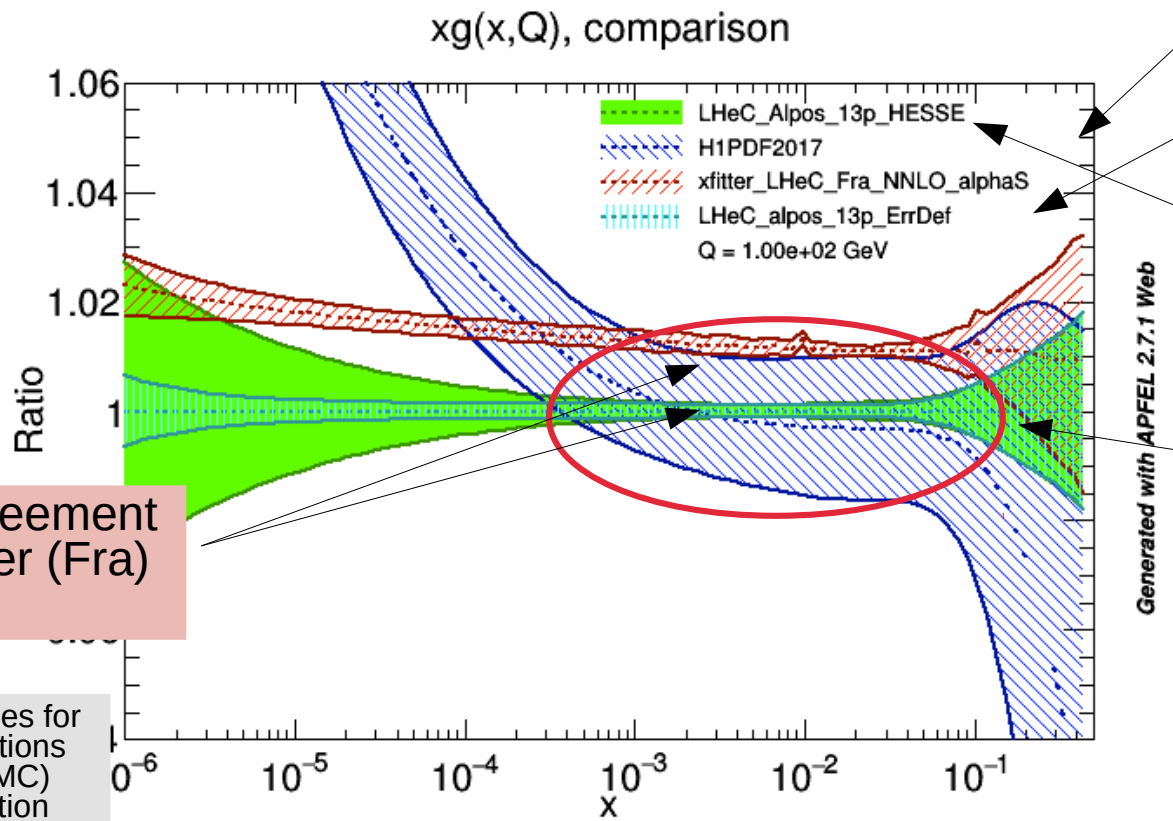
- Hesse uncertainites (linearised to PDF bands)

In short: Linear error propagation of relative uncertainties of LHeC pseudo-data to PDFs (give a certain PDF param.)

Comparison with xfitter

Counter analysis by Fra using xfitter: gluon at Q=100GeV

- Same data (NC, CC DIS)
- same PDF parameters
- everything else supposely a bit differently:
  χ^2, error propagation, HF, order, (some) fit parameters



Fra with xfitter

Alpos with linear error propagation

Alpos with 'offset' method for errors

'Hot spot' with most precise data: result should be fairly independent on many aspects

Excellent agreement between xfitter (Fra) and Alpos

Fra performed studies for different error definitions (hessian, pumplin, MC)
→ see his presentation

H1PDF includes α_s uncertainty

Comparison of fit parameters

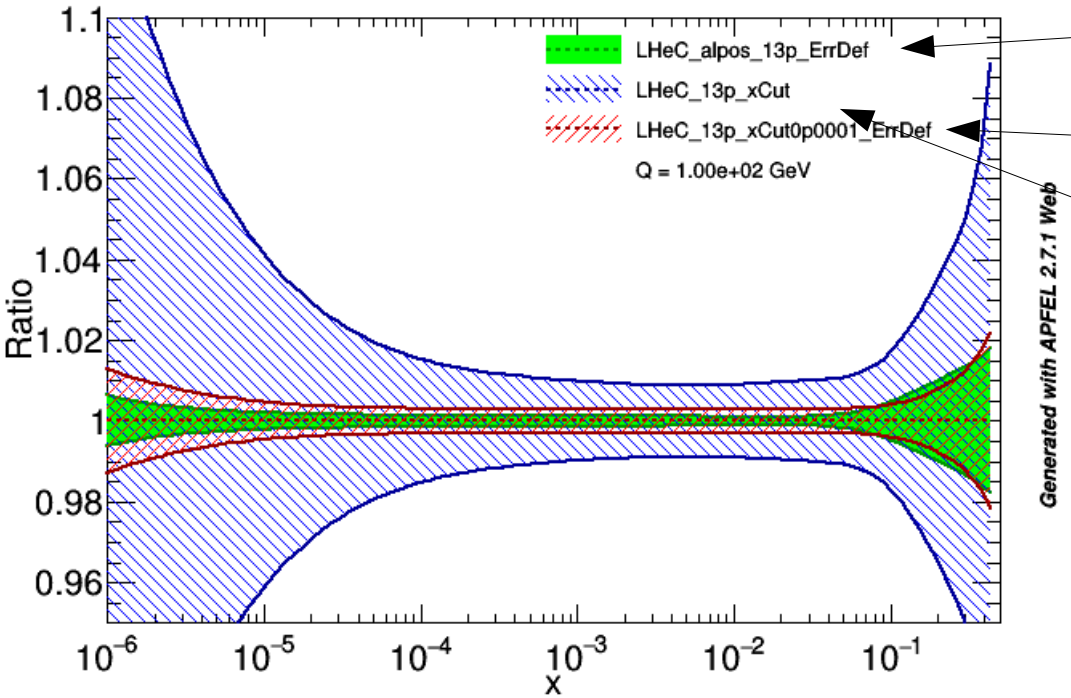
Comparison of fit parameters

Alpos				xfitter			
NO.	NAME	VALUE	ERROR				
NO.	NAME	VALUE	ERROR				
1	PDFQ0_HERA.gB	-1.41932e-01	4.28038e-02	2	Bg	-0.14193	0.43954E-01
2	PDFQ0_HERA.gC	5.43168e+00	1.35211e-01	3	Cg	5.4317	0.14065
3	PDFQ0_HERA.gAP	1.10893e-01	8.55227e-02	7	Aprig	0.11089	0.93281E-01
4	PDFQ0_HERA.gBP	-4.57197e-01	5.10765e-02	8	Bprig	-0.45720	0.55829E-01
5	PDFQ0_HERA.uvB	6.62333e-01	3.70365e-03	12	Buv	0.66233	0.35042E-02
6	PDFQ0_HERA.uvC	4.97721e+00	8.75557e-03	13	Cuv	4.9772	0.85748E-02
7	PDFQ0_HERA.uvE	1.61257e+01	2.03477e-01	15	Euv	16.126	0.19785
8	PDFQ0_HERA.dvB	9.51296e-01	5.73567e-03	22	Bdv	0.95130	0.51711E-02
9	PDFQ0_HERA.dvC	4.87832e+00	2.05283e-02	23	Cdv	4.8783	0.18967E-01
11	PDFQ0_HERA.DbarA	2.53145e-01	2.59597e-03	41	ADbar	0.25315	0.39369E-02
12	PDFQ0_HERA.DbarB	-1.16990e-01	1.19288e-03	42	BDbar	-0.11699	0.16013E-02
13	PDFQ0_HERA.DbarC	1.52941e+01	2.62952e-01	43	CDbar	15.294	0.32839
10	PDFQ0_HERA.UbarC	7.50441e+00	8.56278e-02	33	DUbar	5.8445	0.14556
EXTERNAL ERROR MATRIX.		NDIM= 25	NPAR= 13	101	alphas	0.11800	constant
				102	fs	0.50000	0.75973E-02

- (pretty) good agreement between alpos and xfitter (Fra)

Restricting data in x

Restrict data in x_{Bj} (keeping Q2>3.5GeV^2)



all NC,CC data

0.0001 < x < 0.1

0.001 < x < 0.1

- 'medium' x: almost independent on high-x (x>0.1) and low-x (x<0.0001) though: lower-x (0.0001<x<0.001) with relevant impact
- low-x: prospects are challenging
  - parameterisation must allow for inflation of error band
  - lower-x (0.0001<x<0.001) apparently provides stringent extrapolation constraints in my parameterisation choice
- High-x: similar considerations as for low-x

Correlated vs. uncorrelated uncertainties

Correlation model

- Default fit considers full correlation of all syst. uncertainties of pseudo-data

Study

- Consider all uncertainties as uncorrelated, besides
- Lumi and 'CC-syst' remain correlated

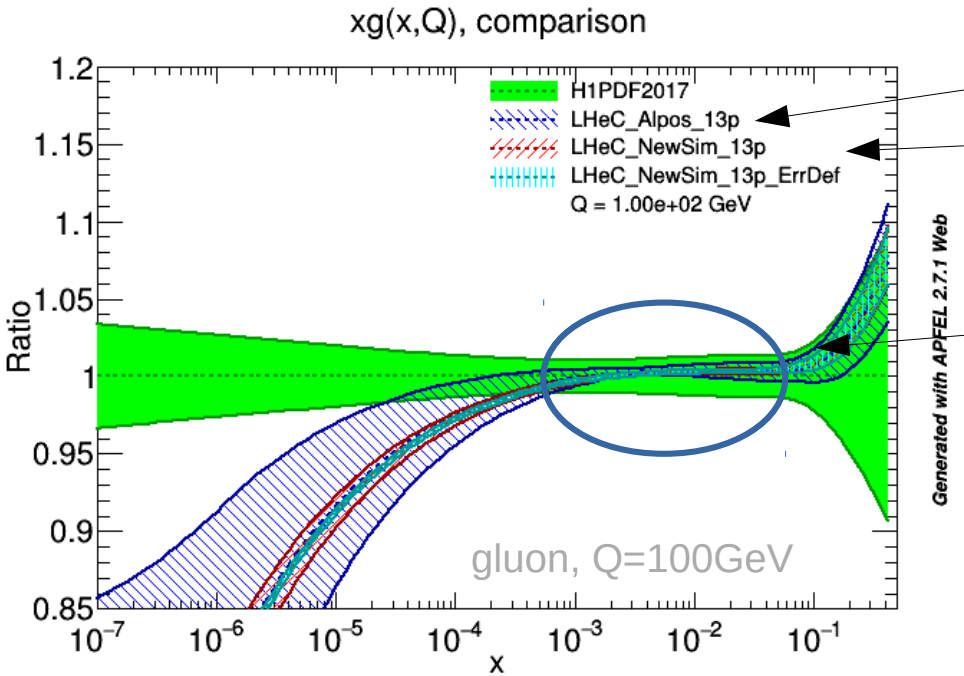
	param_name	value	uncorr	correl.
1	PDFQ0_HERA.gB	-1.41932e-01	6.80604e-02	4.28038e-02
2	PDFQ0_HERA.gC	5.43168e+00	2.08712e-01	1.35211e-01
3	PDFQ0_HERA.gAP	1.10893e-01	1.34979e-01	8.55227e-02
4	PDFQ0_HERA.gBP	-4.57197e-01	8.02945e-02	5.10765e-02
5	PDFQ0_HERA.uvB	6.62333e-01	4.14510e-03	3.70365e-03
6	PDFQ0_HERA.uvC	4.97721e+00	4.42353e-03	8.75557e-03
7	PDFQ0_HERA.uvE	1.61257e+01	2.26209e-01	2.03477e-01
8	PDFQ0_HERA.dvB	9.51296e-01	6.13180e-03	5.73567e-03
9	PDFQ0_HERA.dvC	4.87832e+00	1.97988e-02	2.05283e-02
10	PDFQ0_HERA.UbarC	7.50441e+00	1.24924e-0	8.56278e-02
11	PDFQ0_HERA.DbarA	2.53145e-01	4.36530e-0	2.59597e-03
12	PDFQ0_HERA.DbarB	-1.16990e-01	2.14174e-0	1.19288e-03
13	PDFQ0_HERA.DbarC	1.52941e+01	3.23096e-0	2.62952e-01

→ uncorrelated uncertainties increase uncertainties on fit parameters by about 50%

Study on dataset used

LHeC simulated data evolved…

- Recent simulated data is from 03/2017
  Expects: high lumi, low-E run
- Previous prospects (<03/17) with less optimistic scenario: L~500fb^{-1}
  ….but already with polarised beams



'old' simulation

recent pseudo-data
(linear, and offset error prop)

Reasonable agreement at medium x

Note:
1) H1PDF includes α_s uncertainty
2) H1PDF w/o neg. gluon term
3) H1PDF: uncertainties not valid for x< 1e-4

- high-x and low-x with considerable differences:
  … partially, these can be attributed to flexibilities for PDF parameters

Summary, Conclusions

An independent study for PDF prospects was performed

- Using Alpos fitting framework, as used for EW studies
- Setup similar to xfitter, though with numerous differences

Consistency with xfitter

- Consistency with xfitter is observed for a reference fit to NC&CC DIS LHeC pseudo-data
- … despite numerous differences between the two fitting frameworks

Focus on gluon density

- At medium x: gluon density is fairly independent on parameterisation, pseudo-data version, error propagation technique, parameterisations, etc…
  → excellence reference for the different approaches

- At very-low-x and very-high-x: LHeC prospects are fairly difficult to obtain (not a focus of todays study)
  → care must (already) be taken with reference PDFs

H1 vs. PDF4LHC vs. NNPDF vs. LHeC