xFitter : recent results for gluon PDFs

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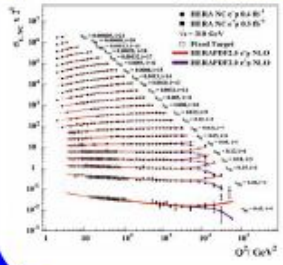
Project overview

xFitter:

- Open source QCD analysis framework for PDF related studies
- Core interface connects together external tools (QCDNUM, APFEL(++), APPLGRID, FastNLO, Hathor) for qcd evolution and theory calculations.
- Enables both complete PDF fits and simplified phenomenological studies of PDF sensitivity to new data

Project overview

Experimental Data



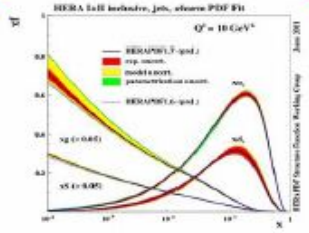
Data: HERA, Tevatron, LHC, fixed target experiments

Processes:
Inclusive DIS, Jets, Drell-Yan, Diffraction, Top production W and Z production

Theory Calculations

HQ Schemes:	MSTW, NNPDF, ABM, ACOT
Jets, W, Z:	FastNLO, ApplGrid
Top:	Hathor
Evolution:	QCDNUM, APFEL, k_T
Other:	NNPDF reweighting TMDs, Dipole Model, ...

xFitter



Parton Distribution Functions:
PDF, Updf, TMD

$\alpha_s(M_Z)$, m_c,m_b,m_t ...

Theoretical Cross Sections

Comparisons to other PDFs (LHAPDF)

Project overview

Several types of χ^2 definitions can be used (D - data, T -theory)

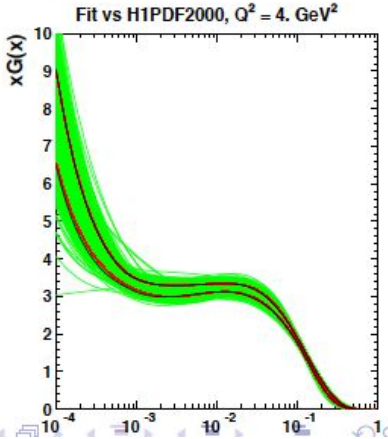
- nuisance parameters: $\chi^2 = \sum_i \frac{(D_i - T_i^*)^2}{(\delta^2_{unc})}, \quad T_i^* = T_i + \sum_j \xi_j \delta_i^{cor,j}$

- covariance matrix: $\chi^2 = \sum_{i,j} (D_j - T_i) Cov^{-1}_{i,j} (D_i - T_j)$

- their mixture

Various types of uncertainty treatment for experimental data:

- Hessian: – nuisance parameters are fitted, χ^2 tolerance > 1 can also be used to account for marginally compatible input data sets
- Offset method – nuisance parameters are applied as 1σ shifts
- Monte Carlo – data points are shifted randomly within 1σ limits to form MC replicas



Project overview

http://xfitter.org

xFitter / DownloadPage

Releases of the xFitter QCD analysis package

- The release notes can be found in this attachment: xFitter_release_notes.pdf .
- Installation script for xFitter together with QCDNUM, APFEL, APPLGRID, LHAPDF install-xFitter-2.0.1
  - New installation script from master branch install-xfitter-master
- Data and theory files can be downloaded from cernbox cernbox

Date	Version	Files	Remarks
 05/2019	**2.0.1 OldFashioned**	xfitter-2.0.1.tgz	update/bug fix to 2.0.0 FrozenFrog
 03/2017	**2.0.0 FrozenFrog**	xfitter-2.0.0.tgz	stable release with decoupled data and theory files

Web access to GIT

- The master version can be viewed and downloaded from https://gitlab.cern.ch/fitters/xfitter.git

Nuclear xFitter
Previous releases

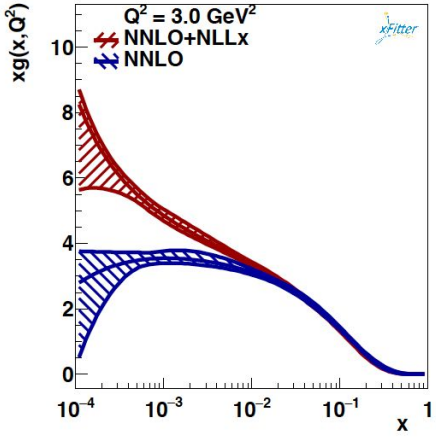
- Releases can downloaded as tgz files. New release last year: 2.0.1 “Old Fashioned”. Mostly bug fix vs 2.0.0 /updates to be compatible with updated external codes
- The data files are still stored on CERNBox. CERN gitlab to get access to the master branch
- Documentation and tutorial correspond to released versions
- For help there is an xfitter-users forum

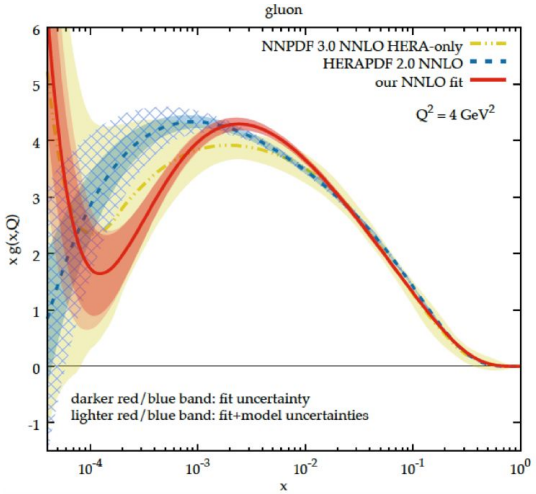
Recent results

Impact of low-x resummation on QCD analysis of HERA data [*Eur.Phys.J.C* 78 (2018) 8, 621]

ln(1/x) resummation for HERA DIS data fits with xFitter reduces low-x and low-Q^2 tension between theory and data. The gluon PDF rises steeply at low-x and low-Q^2 = 2.5 GeV^2 , contrary to simple NLO and NNLO.

+ alternative gluon parametrization for low-x





$$xg(x,\mu_0^2) = A_g\, x^{B_g}(1-x)^{C_g}\left[1 + F_g \log x + G_g \log^2 x\right]$$

$$xu_v(x,\mu_0^2) = A_{u_v}\, x^{B_{u_v}}(1-x)^{C_{u_v}}\left[1 + E_{u_v}x^2 + F_{u_v} \log x + G_{u_v} \log^2 x\right]$$

$$xd_v(x,\mu_0^2) = A_{d_v}\, x^{B_{d_v}}(1-x)^{C_{d_v}}$$

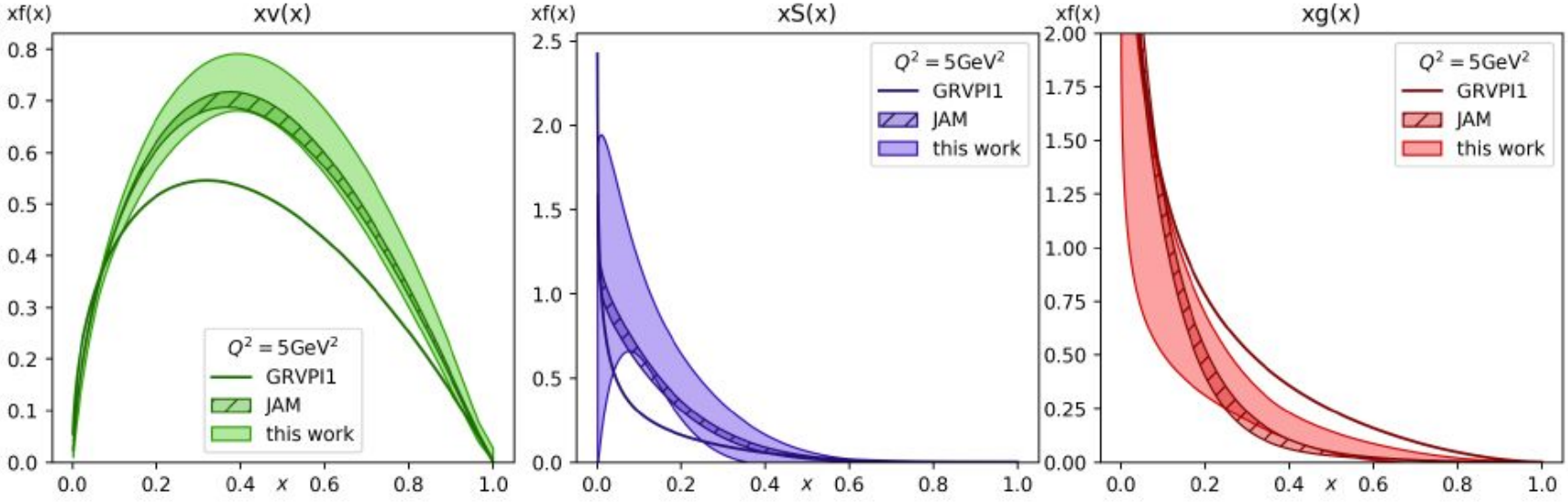
$$x\bar{u}(x,\mu_0^2) = A_{\bar{u}}\, x^{B_{\bar{u}}}(1-x)^{C_{\bar{u}}}\left[1 + D_{\bar{u}}x + F_{\bar{u}} \log x\right]$$

$$x\bar{d}(x,\mu_0^2) = A_{\bar{d}}\, x^{B_{\bar{d}}}(1-x)^{C_{\bar{d}}}\left[1 + D_{\bar{d}}x + F_{\bar{d}} \log x\right],$$

Recent results

[2] Parton Distribution Functions of the Charged Pion Within The xFitter Framework
[Phys. Rev. D 102, 014040 (2020)]

DY and photon production data constrain valence distributions, but not sensitive enough for sea and gluon components.

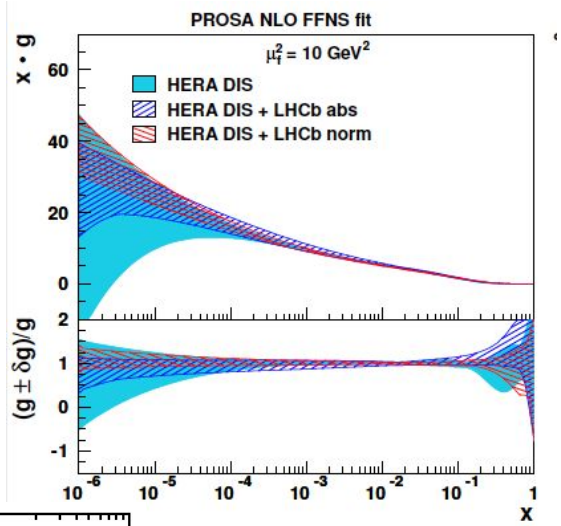


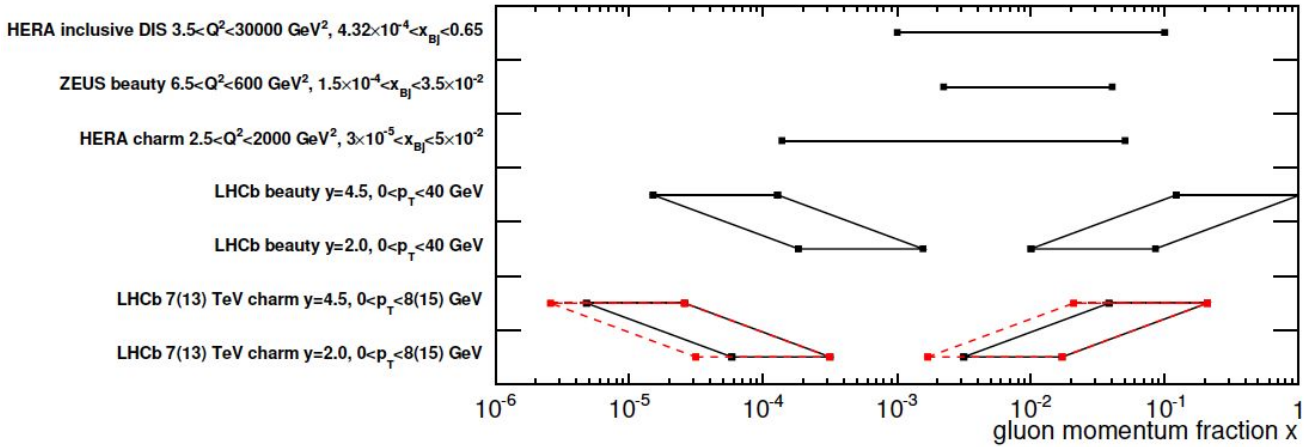
Recent results

PROSA is not a PDF group: collaboration of theorists and experimentalists focused on new ideas [https://prosa.desy.de]. The collaboration is prolific within xFitter for its QCD tools development.

Better low-x (up to $x=10^{-6}$) gluon constraints due to LHCb data, not covered by other experiments

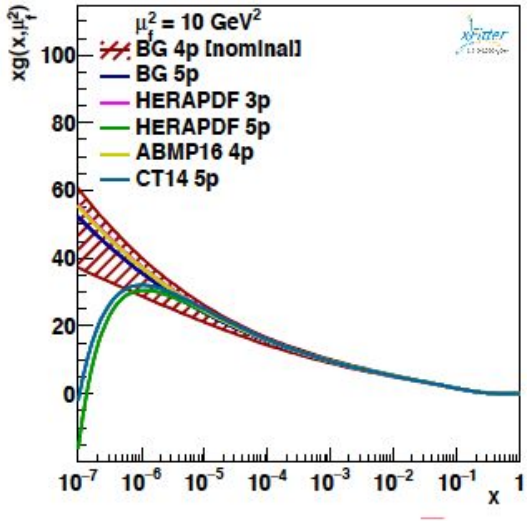
[EPJ C75 (2015) 396, JHEP 2004 (2020) 118]





EPJ C75 (2015) 396

Recent results



We decided to not use parametrisations which produces sharp negative gluon at low x, because:

- they predict negative total charm hadroproduction cross sections at $\sqrt{s} \gtrsim 30$ TeV
- at $x \lesssim 10^{-6}$ gluon is not probed by data directly: it is momentum sum rule which makes it negative

Other parametrisations are consistent with out uncertainty band (some other, like MMHT2014, was not possible to use because of very flexible gluon at high x)

Nominal ($D = E = 0$ for $f = g$):

$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2+F\log x), \quad f = g$$
$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2), \quad f = u_v, d_v, \overline{U}, \overline{D} \qquad (2)$$

$$\begin{aligned}
\text{ABMP16:} \quad & xg(x) = A(1-x)^b x^{a(1+\gamma_1 x)}, \\
\text{CT14:} \quad & xg(x) = Ax^{a_1}(1-x)^{a_2}(e_0(1-y)^2 + e_1(2y(1-y)) + y^2), y = 2\sqrt{x} - x, \\
\text{HERAPDF2.0:} \quad & xg(x) = A_g x^{B_g}(1-x)^{C_g} + A'_g x^{B'_g}(1-x)^{25}, \\
\text{HERAPDF2.0 no flex. } g\text{:} \quad & xg(x) = A_g x^{B_g}(1-x)^{C_g}, \\
\text{BG:} \quad & xg(x) = A_g x^{B_g}(1-x)^{C_g}(1+F_g \log x + G_g \log^2 x),
\end{aligned} \qquad (3)$$

Other research

- xFitter is used by many LHC collaborations to estimate how their results constrain PDFs ([CMS, Eur. Phys. J. C 79 (2019)269], [ATLAS, ATL-PHYS-PUB-2018-017])
- Nuclear PDFs analysis is an actively developed area [M. Walt et al, Phys. Rev. D 100, 096015 (2019)]
- The calculation of TMDs can be included via the APFEL package [*JHEP* 07 (2020) 117]

Summary

- xFitter is an open source QCD analysis tool for PDF determination
- Recent release v2.0.1 with modular theory, evolution and parameterization structure
- The code is actively developed and user support is always provided
- Many interesting results published by the xFitter development team and external research groups
- The tool allows to constrain gluon PDF in proton and nucleus
- SPD physics is a prospective source of data for TMD determination with xFitter