Developments in xFitter

Open Source QCD Fit framework

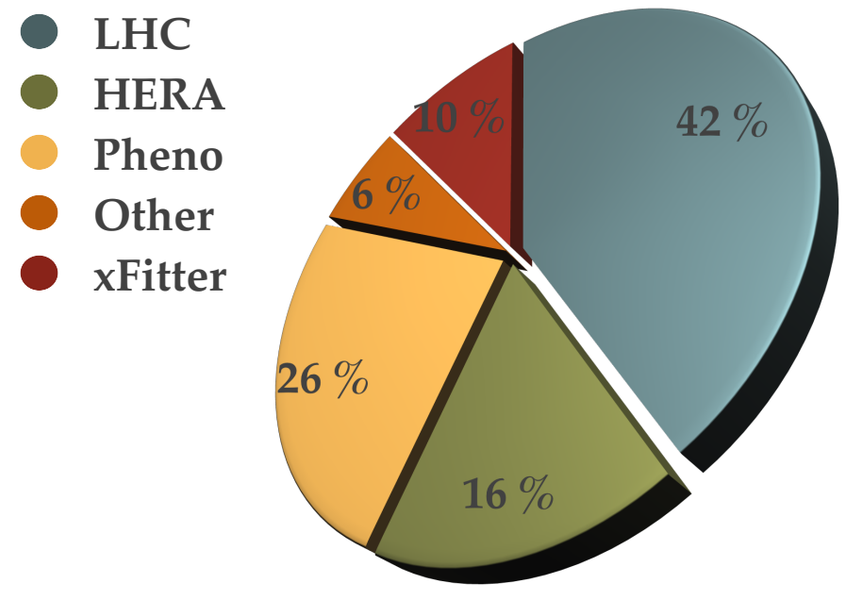
https://www.xfitter.org/xFitter

Voica Radescu
on behalf of the xFitter developers' team

Introductory words:

- **2011 Open Source Revolution:**
  - formerly known as HERAFitter
  - Establishing the first open source QCD Fit Platform which started the wave of sharing QCD fit codes EPJC (2015), 75
  - A team of ~30 developers:
    - LHC / HERA / theory / independent
    - several releases since 2011
    - 31 publications that have used the framework [in total]

synergy between experiment and theory groups



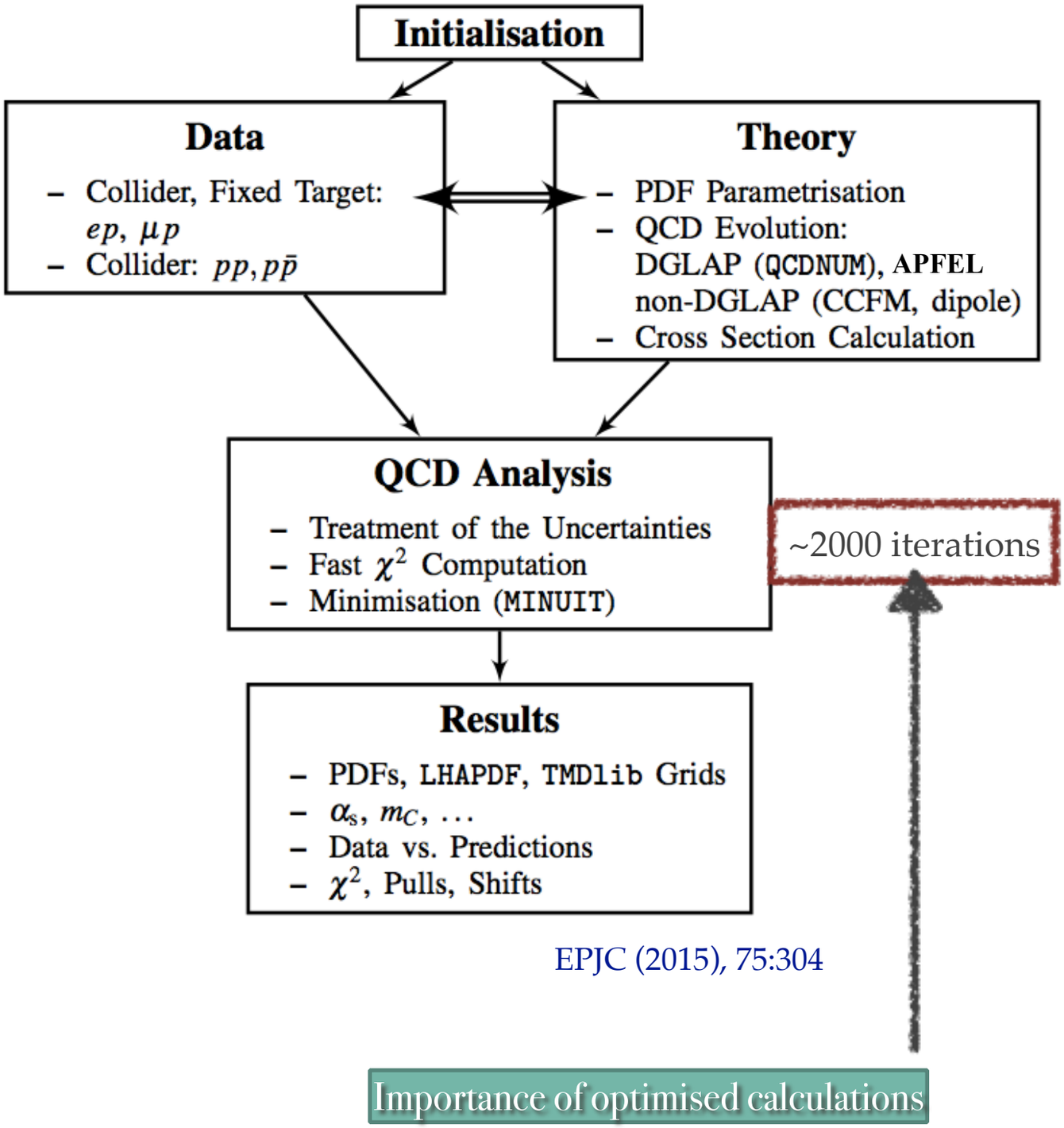
- **provides a unique QCD framework to address theoretical differences:**
  —> benchmark exercises / collaborative efforts / topical studies
- **provides means to the experimentalists to optimise the measurements:**
  —> assess impact / consistency of new data

- **Dedicated studies [xFitter developers]**
  - method in preserving correlation between PDFs extracted at different orders in pQCD EPJC (2014) 74
  - address consistency of Tevatron measurement and evaluate their collective impact on valence EPJC (2015), 75
  - **determination of the running mass in MS scheme** accepted by JHEP

xFitter Project at Glance:

Main Steps for a QCD fit:

- Parametrise PDFs at the starting scale
  - multiple options for functional forms
    - Standard Polynomial, Chebyshev, etc
- Evolve to the scale corresponding to data point
  - QCD(DGLAP) evolution codes [QCDNUM, APFEL]
  - kt ordered evolution, Dipole models, QCD(DGLAP)+QED
- Calculate the cross section
  - various heavy flavour schemes:
    - RT, ACOT, FONLL, FFNS(ABM)
  - fast grid techniques interfaced to DY:
    - APPLGRID, FASTNLO, APFELgrids
- Compare with data via $\chi 2$:
  - multiple forms to account for correlations
- Minimize $\chi 2$ with respect to PDF parameters
  - Profiling, reweighting
  - Fit: MINUIT, data driven regularisation



EPJC (2015), 75:304

Importance of optimised calculations

xFitter release: 1.2.2 [July 2016]

Release xFitter1.2.2.tgz available at: *https://www.xfitter.org/xFitter/xFitter/DownloadPage*

Downloads of xFitter software package

xFitter-1.2.2 release is publicly available.
All the xFitter releases can be accessed HERE.
All the former (HERAFitter) releases can be accessed HERE.
Description: http://arxiv.org/abs/1410.4412

xFitter / DownloadPage

Releases of the xFitter QCD analysis package

- Versioning convention: **i.j.k** with
  - **i** - stable release
  - **j** - beta release
  - **k** - bug fixes.
- 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
- The script to download coupled data and theory files getter-xfitter.sh.

Date	Version	Files	Remarks
07/2016	**1.2.2**	xfitter-1.2.2.tgz	release with decoupled data and theory files
05/2016	**1.2.1**	xfitter-1.2.1.tgz	release with decoupled data and theory files
02/2016	**1.2.0**	xfitter-1.2.0.tgz	release with decoupled data and theory files

Documentation

- A list of datasets which can be downloaded with the help of getter script.
- Manual (under continuous improvement) can be accessed here.
- The **README** file (accessible via the package) gives an explanation for a quick start.
- The **INSTALLATION** file (accessible via the package) provides information for package installation and usage instructions.
- The package is licensed under GNU GPL, please see **LICENCE** for mode details (accessible via the package).

- By default only final combined HERA I+II data are distributed
  - (xfitter-)getter.sh script to download data with corresponding theory files already adjusted for the xfitter format.
- A complete installation script is also provided (tested under different platforms)
- A release note to keep track of changes between releases is included

xFitter on HEPFORGE and access to Data Files

- Home
- Source Code
- List of Data Files
- xFitter Wiki
- xFitter Releases
- Contact

An Open Source QCD Fit Project

Welcome! This site is under development.
(use: xFitter site .)

provides a visualisation of available data sets
adjusted for the xFitter format
(a README is provided as well)

xfitter.hepforge.org/data2.html

Apps Bookmarks ATLAS Experiment herafitter.developer... H1 Fast Navigator

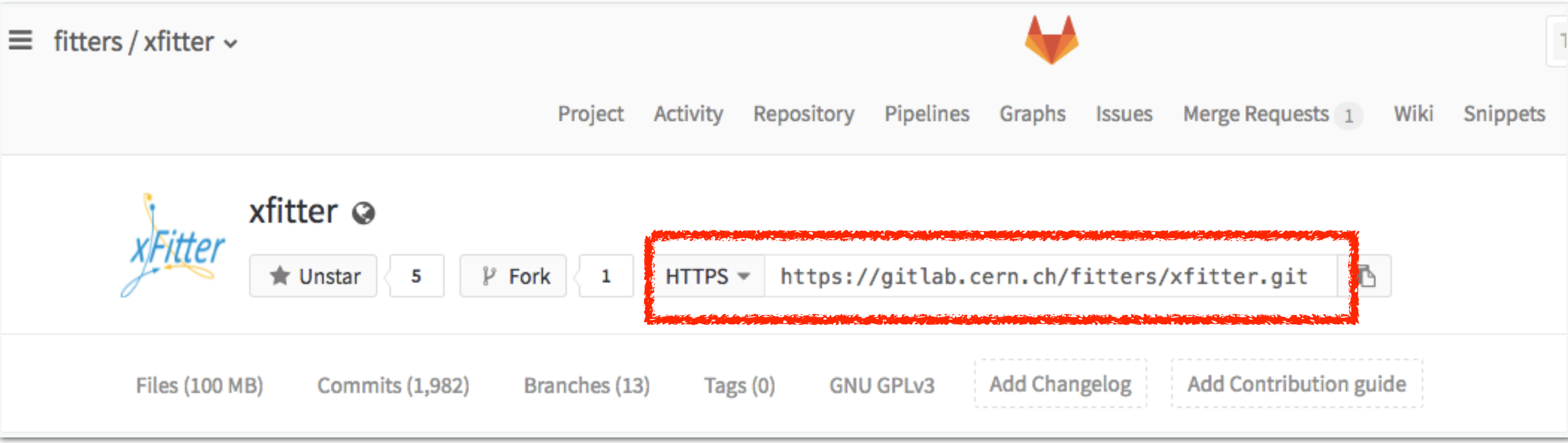
This page contains the list of publicly available experimental data sets (with corresponding theory grids if available) in the xFitter package.

To download data set please click on the arXiv link (and open/save tar.gz file).

No	Collider	Experiment	Reaction	arXiv	Name of files
1	fixedTarget	bcdms	inclusiveDis	cern-ep-89-06	
2	hera	h1	beautyProduction	0907.2643	
3	hera	h1	inclusiveDis	1012.4355	
4	hera	h1	jets	0706.3722	
5	hera	h1	jets	0707.4057	
6	hera	h1	jets	0904.3870	
7	hera	h1	jets	0911.5678	
8	hera	h1	jets	1406.4709	
9	hera	h1zeusCombined	charmProduction	1211.1182	
10	hera	h1zeusCombined	inclusiveDis	0911.0884	
11	hera	h1zeusCombined	inclusiveDis	1506.06042	
12	hera	zeus	beautyProduction	1405.6915	
13	hera	zeus	diffractiveDis	0812.2003	
14	hera	zeus	jets	0208037	
15	hera	zeus	jets	0608048	
16	hera	zeus	jets	1010.6167	
17	lhc	atlas	drellYan	1305.4192	
18	lhc	atlas	drellYan	1404.1212	
19	lhc	atlas	jets	1112.6297	
20	lhc	atlas	jets	1304.4739	
21	lhc	atlas	topProduction	1407.0371	
22	lhc	atlas	topProduction	atlas-conf-2012-024	
23	lhc	atlas	wzProduction	1203.4051	
24	lhc	cms	jets	1212.6660	
25	lhc	cms	topProduction	1208.2671	
26	lhc	cms	topProduction	1211.2220	
27	lhc	cms	topProduction	cms-pas-top-11-024	
28	lhc	cms	wzProduction	1110.4973	
29	lhc	cms	wzProduction	1206.2598	
30	lhc	cms	wzProduction	1312.6283	
31	lhc	lhcb	beautyProduction	1306.3663	
32	lhc	lhcb	charmProduction	1302.2864	
33	tevatron	cdf	jets	0807.2204	

xFitter – for pros

xFitter has moved from svn to Git Lab repository
users can navigate freely through the repository (read access)



Release Notes 1.2.2 vs 1.2.1

- Several fixes were applied:

xFitter versions are labeled as **xfitter-i.j.k** where **i** is the stable release number, **j** is beta release number, and **k** is bug fixes.

Release	Date	Description
xfitter-1.2.2	8.07.2016	• Fix in profiling due to multiple sign flips, affects also reweighting. • Fix in the output of PDFs, strange is symetrised to $(s+\bar{s})/2$. • Fix in calculation of theory error bands for parametrisation uncertainties for the **--therr** option. • Fix for **has_photon** LHAPDF variable and protection against LHAPDFQ0 with photon PDFs. • Fixes to dipole steering file in input steering file, updated now to current settings. • Added the H1 beauty data to the list of data files • Fix in the default theoretical parameters for HVQMNR to be used not in Fit mode. • Fix on warning message from Fastnlo. • Added examples in the example directory together with the tutorial slides from CTEQ 2016 school. • Fix in configuratuon for **--disable-root** option. • Fix in α_s interpolation and protection in overriding the output directories. • Fix in photon PDF sum rules.

https://indico.desy.de/contributionDisplay.py?contribId=11&confId=13506

Examples in xFitter

- A list of educational examples are provided in the package - prepared for the CTEQ summer school 2016:

  - **Exercise 1:** PDF fit
    - Learn the basic settings of a QCD analysis, based on HERA data only

  - **Exercise 2:** Simultaneous PDF fit and αs
    - Learn the basic of an αs extraction using H1 jet data

  - **Exercise 3:** LHAPDF analysis
    - How to estimate impact of a new data without fitting:
      - profiling and reweighting techniques

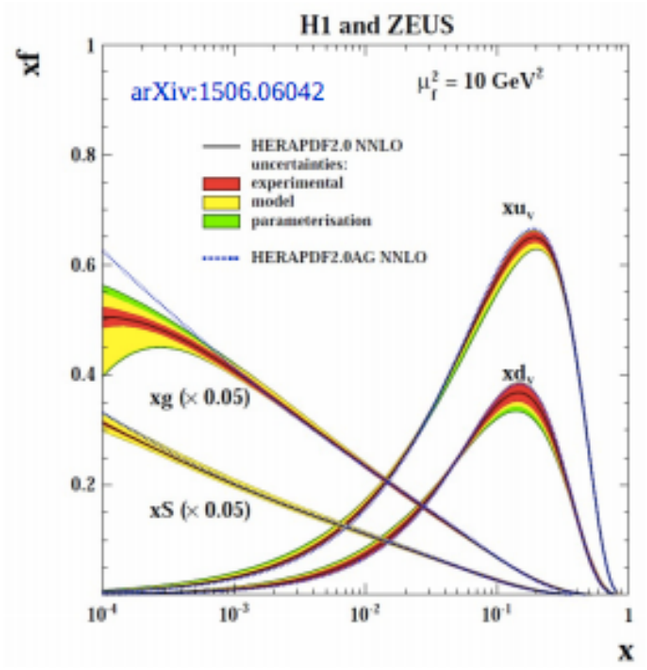
  - **Exercise 4:** Plotting LHAPDF files
    - Direct visualisation of PDFs from LHAPDF6 using simple python scripts

  - **Exercise 5:** Equivalence of $\chi 2$ representations
    - understand different $\chi 2$ representations

Highlights: Results using xFitter

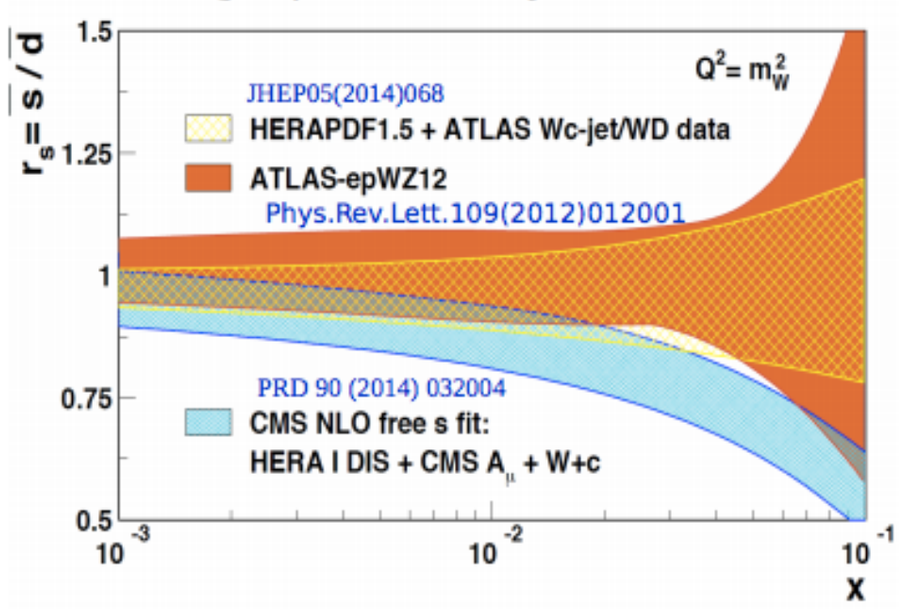
Historically starting with HERA QCD analyses, now extended to most of the LHC QCD analyses + phenomenological studies:

DIS inclusive processes in *ep* (fixed target)



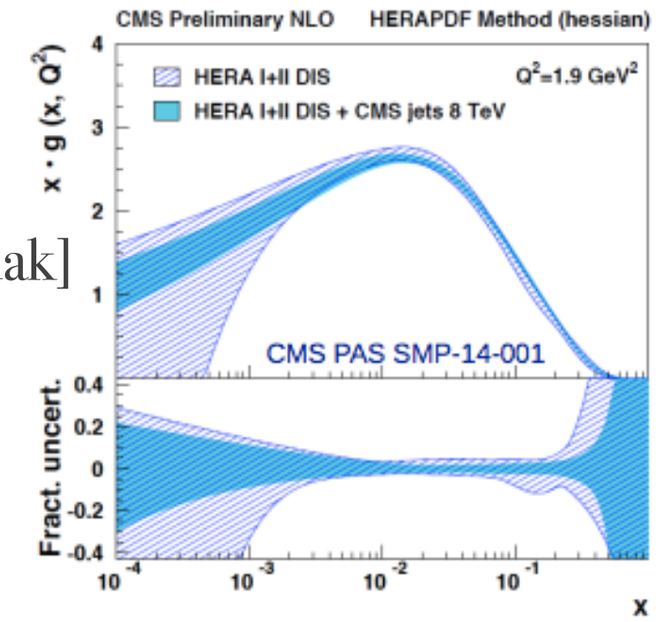
Drell-Yan processes (*pp*, *ppbar*)

→ strange quark density determination



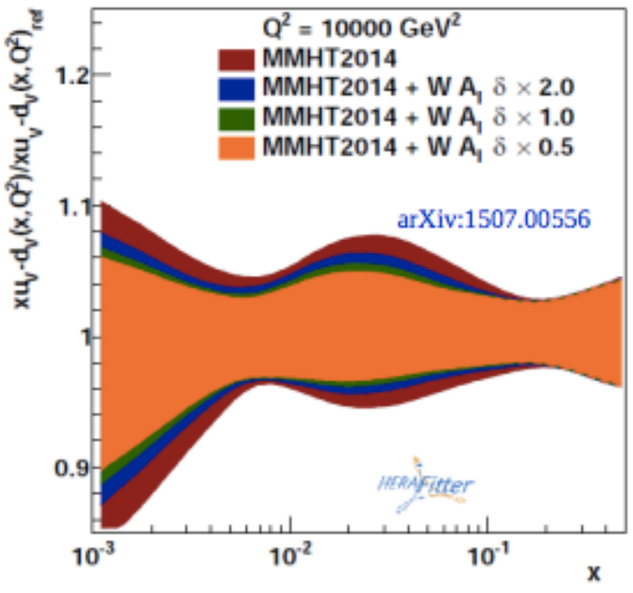
Jet production (*ep*, *pp*, *ppbar*)

[see B. Isildak]



PDF4LHC report (benchmarking)

→ impact of 13 TeV data

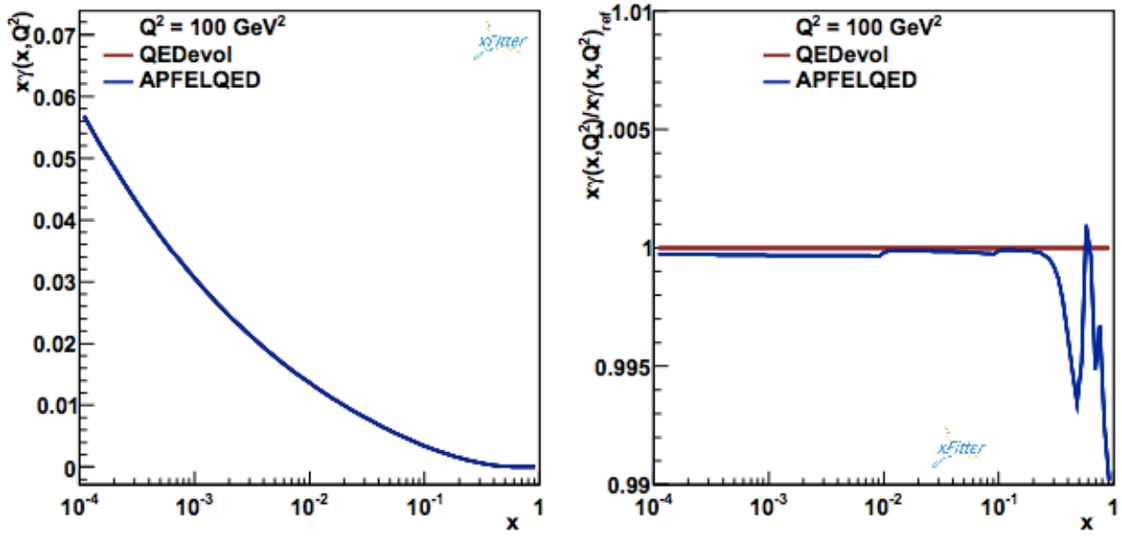


New Physics Cases in xfitter (I)

- **QED PDFs up to NNLO QCD + LO QED in FFNS and VFNS are now available via evolutions in:**
  - QCDNUM adjusted for DGLAP+QED [R. Sadykov]
    http://www.nikhef.nl/~h24/qcdnum
  - APFEL DGLAP+QED as used by NNPDF3.0 [V. Bertone et al]
    https://apfel.hepforge.org

—> plan to add NLO QED, interface APPLGRID to SANC

http://arxiv.org/pdf/1606.07130.pdf



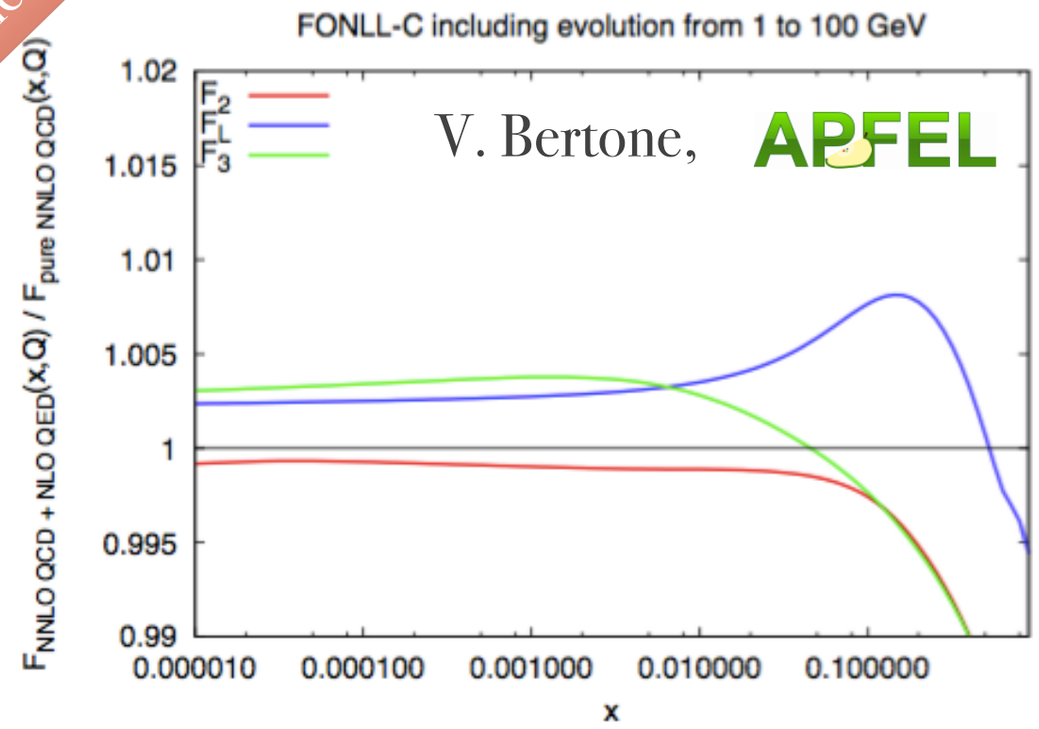
V. Bertone, R. Sadykov

- **New: NLO QCD+QED via APFEL in xFitter:**
  - At LO QED, no corrections to the SFs are needed
  - At NLO QED, access to new diagrams:

new diagrams: $\gamma^*\gamma \to qq$ and $\gamma^* q \to q\gamma$,

  - Implementing the O(αsα) and the O(α^2) corrections to the DGLAP splitting functions on top of the O(α) ones
  - Implementing O($\alpha_s^2\alpha$) and the O(α^2), O($\alpha^2\alpha_s$) corrections to β functions
  - when including NLO QED corrections, not only the evolution is affected but also the DIS structure functions get corrected.

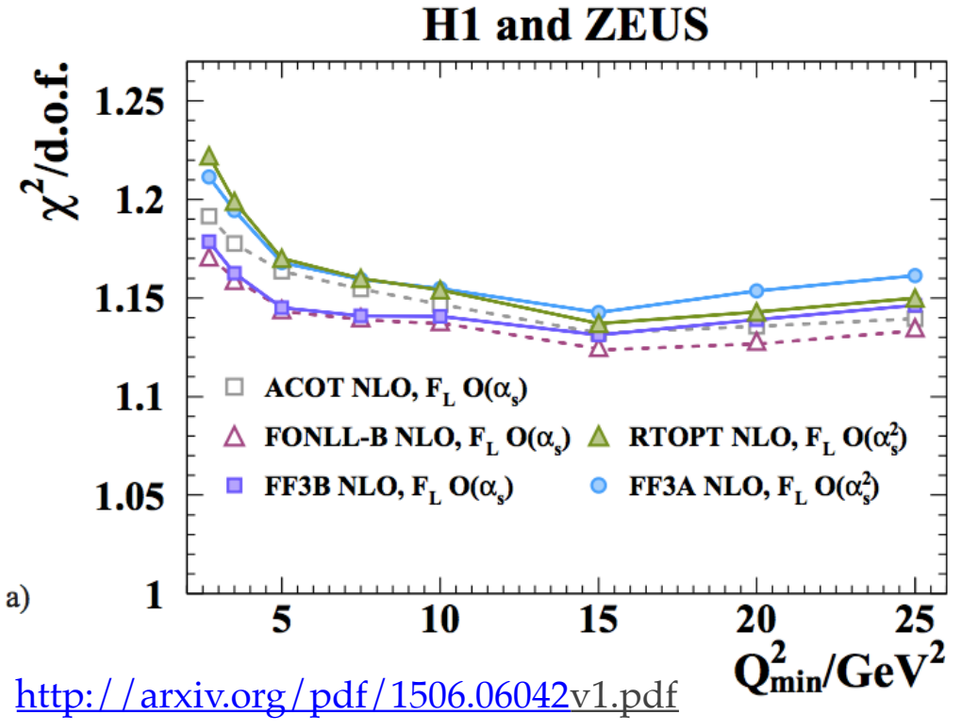
ONLY ON GIT
very new!



New Physics Cases in xfitter (II)

- **Addition of new Heavy Flavour Scheme: FONLL** APFEL
  - it is available thanks to collaboration with APFEL
  - various FONLL options available via interface to APFEL [https://apfel.hepforge.org]
- ABM scheme was up-to-dated to OPENQCDRAD v 2.0b4

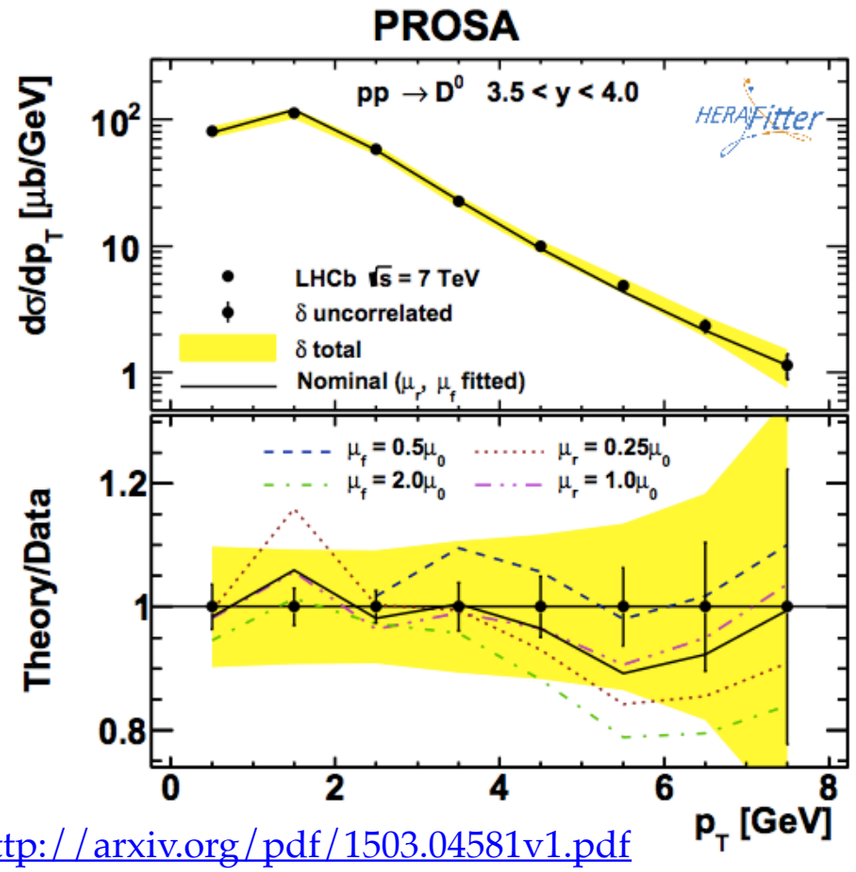
. http://www-zeuthen.desy.de/~alekhin/OPENQCDRAD.



http://arxiv.org/pdf/1506.06042v1.pdf

Nucl. Phys. B373 (1992) 295

- **Interface to Mangano-Nason-Ridolfi (MNR) theory code added** in xfitter and it was used for analysing the heavy-flavour production at LHCb and at HERA (via OPENQCDRAD)
  - use of FFNS for accounting of heavy quark masses at NLO
  - added also corresponding LHCb data
- Added extra reweighing options using Giele-Keller weights



http://arxiv.org/pdf/1503.04581v1.pdf

Recent Analysis by xFitter developers' team:

arXiv.org > hep-ph > arXiv:1605.01946

Search or Arti

High Energy Physics - Phenomenology

A determination of mc(mc) from HERA data using a matched heavy-flavor scheme

xFitter Developers' team: Valerio Bertone, Stefano Camarda, Amanda Cooper-Sarkar, Alexandre Glazov, Agnieszka Luszczak, Hayk Pirumov, Ringaile Placakyte, Klaus Rabbertz, Voica Radescu, Juan Rojo, Andrey Sapranov, Oleksandr Zenaiev, Achim Geiser

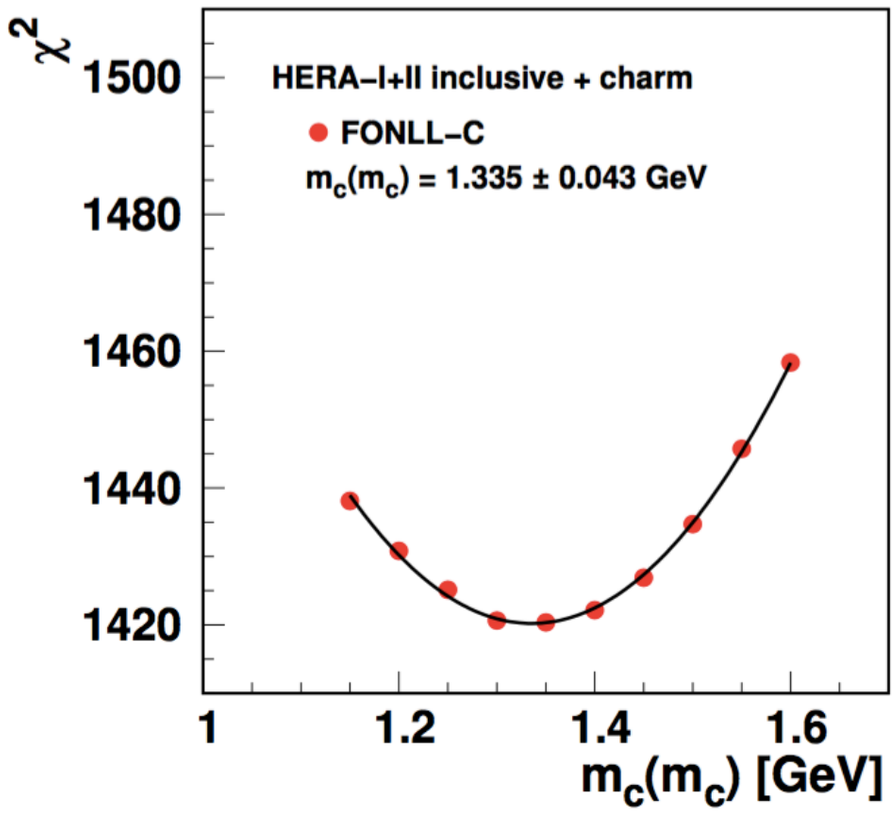
(Submitted on 6 May 2016)

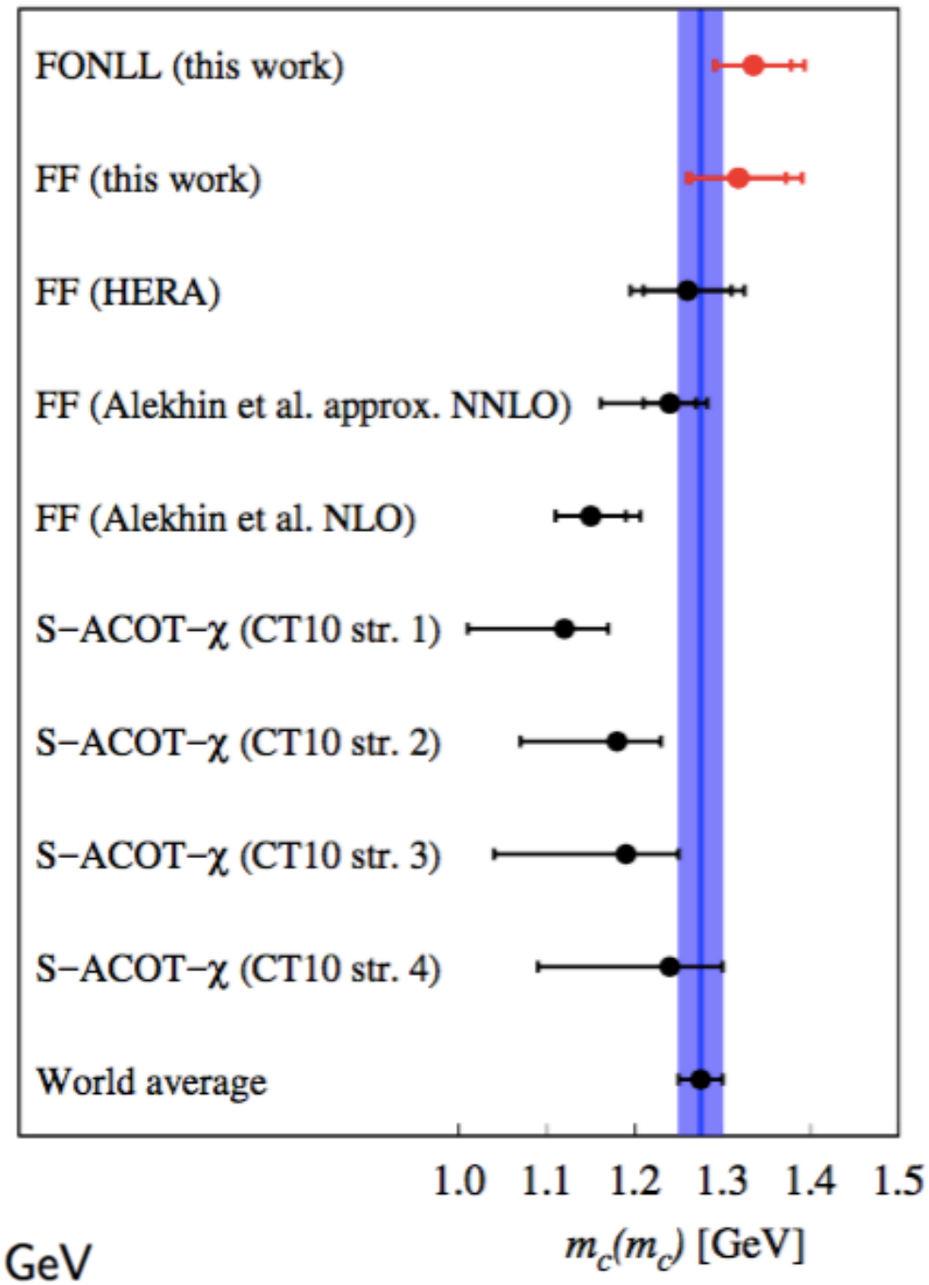
The charm quark mass is one of the fundamental parameters of the Standard Model Lagrangian. In this work we present a determination of the MSbar charm mass from a fit to the inclusive and charm HERA deep-inelastic structure function data. The analysis is performed within the xFitter framework, with structure functions computed in the FONLL general-mass scheme as implemented in APFEL. In the case of the FONLL-C scheme, we obtain mc(mc) = 1.335 +- 0.043(exp) +0.019 -0.000(param) +0.011 -0.008(mod) +0.033 -0.008(th) GeV. We also perform an analogous determination in the fixed-flavor-number scheme at next-to-leading order, finding mc(mc) = 1.318 +- 0.054(exp) +0.011 -0.010(param) +0.015 -0.019(mod) +0.045 -0.004(th) GeV, compatible with the FONLL-C value. Our results are consistent with previous determinations from DIS data as well as with the PDG world average.

- The extraction of mc(mc) was performed using FONLL scheme in terms of the MS masses —> improves perturbative convergence
  - combined HERA I + II charm production and DIS cross sections
  - FONLL-C scheme used – NLO accuracy in the massive sector
  - Also tested in FFNS (fixed flavor number scheme) at NLO

Results of the xFitter charm mass analysis:

- The $m_c(m_c)$ value is determined from a parabolic minimum of the global $\chi 2$scan vs $m_c(m_c)$ with 1σ unc. determined from $\Delta\chi 2$ variation.
- The $m_c(m_c)$ measurement is comparable to previous determinations from DIS as well as PDG world average:





FONLL-C:

$$m_c(m_c) = 1.335 \pm 0.043(\text{exp})^{+0.019}_{-0.000}(\text{param})^{+0.011}_{-0.008}(\text{mod})^{+0.033}_{-0.008}(\text{th})\ \text{GeV}$$

Summary

- xFitter (former HERAFitter) project is based on a multi-functional open source QCD software package that provides a framework for scrupulous interpretations of the QCD analyses with its main application at the LHC program
  - www.xfitter.org
  - xfitter-1.2.2 latest release, however the master is open for pros on GitLab

- New release provides access to new phenomenological studies to follow thanks also to intensive collaboration with theory groups such as APFEL, NNPDF, SANC, ABM, CT, NCTEQ, MMHT, TMD, etc…

Outlook:

- Improve user interface for various parametrisation
- Simplification of the steering card for easier access to profiling module [no fit]
- Add resummation options thanks to interface to APFEL -> MELA, HELL
- More on low x phenomenology: higher twists
- Nuclear PDFs
- Interface to other kind of grids [APFELgrids, TMDgrids]

xFitter Contacts

Organisation

Steering Group is composed of:

- **Conveners:** Voica Radescu, Ringaile Placakyte, Amanda Cooper-Sarkar
- **Release coordinator** (revision of the release candidates): Sasha Glazov
- **Librarian** (continuous revision/development of the main code and doxygen): Hayk Pirumov, Andrey Sapronov
- **Contact Persons:** Cristi Diaconu (H1),Klaus Rabbertz (CMS), Bogdan Malaescu (ATLAS), Olaf Behnke (ZEUS), Ronan McNulty (LHCb), Gavin Salam (theory)
- **DESY IT Contact:** Yves Kemp

Getting help

Send email to xfitter-help@desy.de

New technicalities in xfitter-1.2.0

- **Change of name of executables:**
  - FitPDF —> xfitter
  - DrawPdfs —> xfitter-draw
  - DrawResults —> xfitter-draw
  - Postproc —> xfitter-process
- Note that in the previous releases there was a theoryfiles directory
  - —> now theoryfiles are stored with datafiles to be in sync
- **Installation:**
  - xfitter-1.2.0 is compatible with new QCDNUM version > 17.01.10
    - QCDNUM is available now also with autotools installations
    - QCDNUM provides now access to more than standard 13 PDFs, e.g. photon PDF can be added
  - Installation of the xfitter-1.2.0 can also be configured via prefix
  - Added the possibility to disable root
- Theory formats in xfitter (usage/parsing) have been unified between FASTNLO and APPLGRID
  - old format for FASTNLO is still operational
- Profiling and Reweighing codes now use same general infrastructure
- Possibility to access directly PDFs as stored in LHAPDF (surpassing QCDNUM)
  - LHAPDFNATIVE option added

New Physics Cases in xfitter (III)

- **Mellin Transformation in xfitter via MELA**
  - Mellin transformations convey convolutions in simple products
  - Mellin moments predictions work well:
    - with fixed order calculations
      - main stream in extracting PDFs
    - with all-order resummed predictions
      - needed for other fundamental parameters

The Mellin moments implementation could allow a broader spectrum of phenomenological applications of xFitter:

https://apfel.hepforge.org/mela.html

Release Notes