xFitter (former HERAFitter) Project

Open Source QCD Fit framework

DIS2017 April 3 - 7, 2018

Fredrick Olness

SMU

on behalf of the xFitter team

xFitter Project

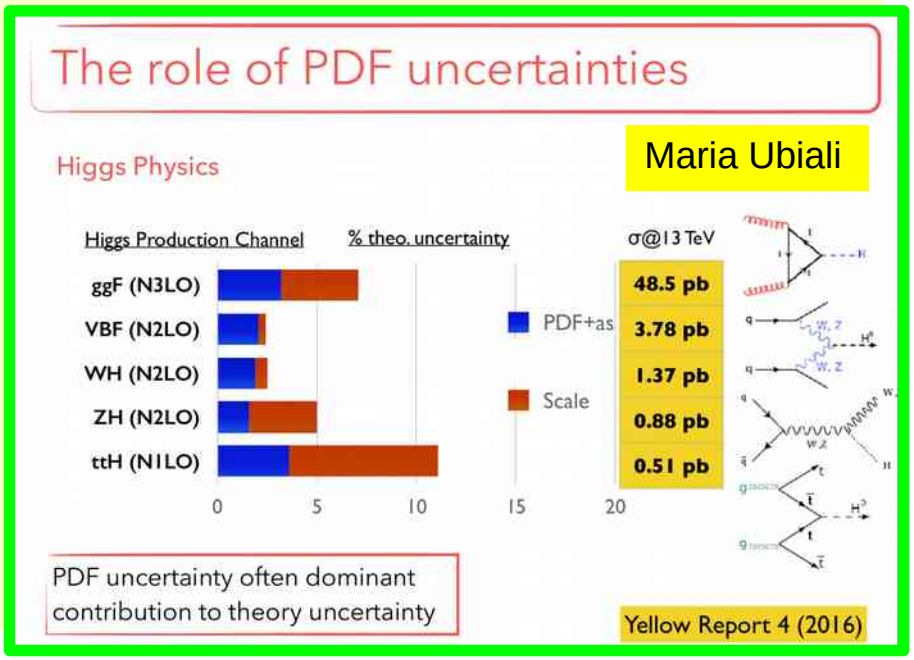
www.xfitter.org

The xFitter project is an open source QCD fit framework ready to extract PDFs and assess the impact of new data.

The framework includes modules allowing for a various theoretical and methodological options, capable to fit a large number of relevant data sets from HERA, Tevatron and LHC.

This framework is already used in many analyses at the LHC.

Proton parton distribution functions (PDFs) are essential for precision physics at the LHC and other hadron colliders. The determination of the PDFs is a complex endeavor involving several physics process. … In particular, the precise measurements obtained or to come from LHC will continue to improve the knowledge of the PDF.



Introduction

Precise knowledge of the PDFs are essential for predictions at hadron colliders

QCD factorisation:

$$\sigma \approx \hat{\sigma} \otimes PDF$$

Experimental Data:

→ a large variety of data from fixed-target and collider experiments

Theory:

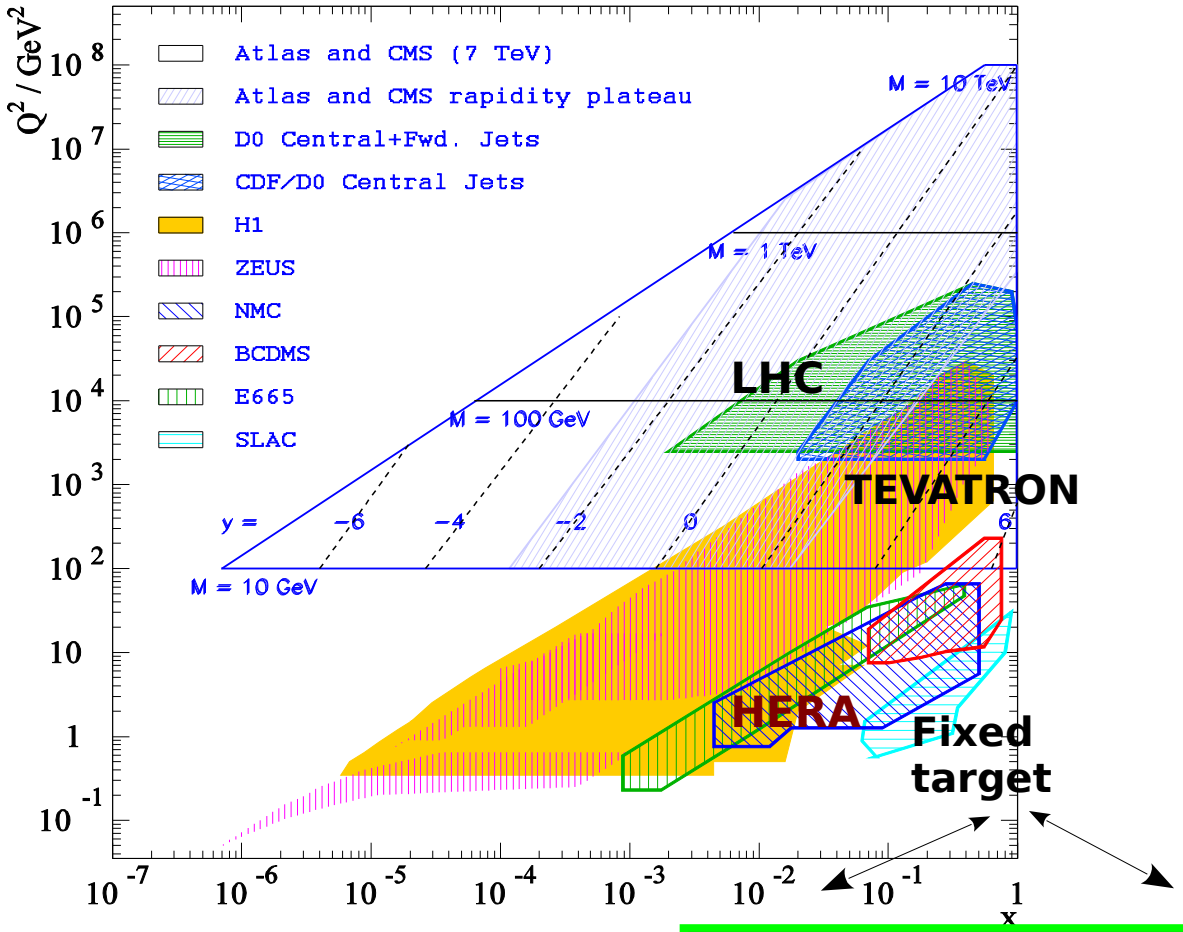
→ intense theoretical developments

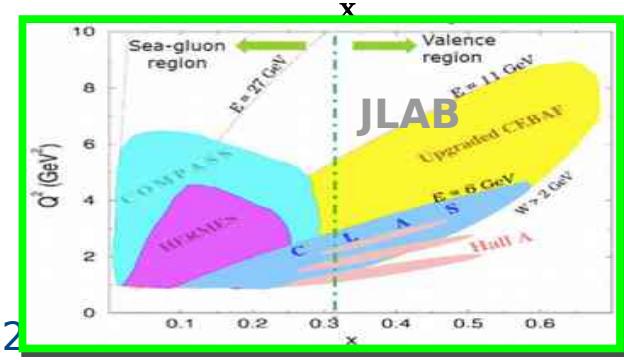
QCD Analysis:

→ available PDFs: CT/CJ, MMHT, NNPDF, ABM, HERAPDF, JR

… and **Tools**

kinematic plane of the experimental data (in x,Q^2)





Data Available at HEPforge

http://xfitter.hepforge.org/data.html

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	Readme
1	fixedTarget	bcdms	inclusiveDis	cern-ep-89-06	README
2	hera	h1	beautyProduction	0907.2643	
3	hera	h1	inclusiveDis	1012.4355	
4	hera	h1	jets	0706.3722	README
5	hera	h1	jets	0707.4057	README
6	hera	h1	jets	0904.3870	README
7	hera	h1	jets	0911.5678	README
8	hera	h1	jets	1406.4709	README
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	1406.5375	
22	lhc	atlas	topProduction	1407.0371	
23	lhc	atlas	wzProduction	1203.4051	
24	lhc	atlas	wzProduction	1612.03016	README
25	lhc	cms	jets	1212.6660	
26	lhc	cms	topProduction	1208.2671	
27	lhc	cms	topProduction	1211.2220	
28	lhc	cms	topProduction	cms-pas-top-11-024	
29	lhc	cms	wzProduction	1110.4973	
30	lhc	cms	wzProduction	1206.2598	
31	lhc	cms	wzProduction	1312.6283	
32	lhc	cms	wzProduction	1603.01803	
33	lhc	lhcb	beautyProduction	1306.3663	
34	lhc	lhcb	charmProduction	1302.2864	
35	lhc	lhec	inclusiveDis	1206.2913	README
36	lhc	lhec	inclusiveDis	1605.08579	README
37	tevatron	cdf	jets	0807.2204	
38	tevatron	cdf	wzProduction	0901.2169	
39	tevatron	cdf	wzProduction	0908.3914	
40	tevatron	d0cdfCombined	topProduction	1309.7570	
41	tevatron	d0	jets	0802.2400	
42	tevatron	d0	wzProduction	0702025	
43	tevatron	d0	wzProduction	1309.2591	
44	tevatron	d0	wzProduction	1312.2895	
45	tevatron	d0	wzProduction	1412.2862	

Tools for PDF determination

Available (open-source) tools for the PDF determination:

xFitter (former HERAFitter): an open-source package that provides a framework for the determination of the PDFs of the proton and for many different kinds of analyses in QCD

EPJC (2015), 75: 304, *xfitter.org*

OPENQCDRAD (ABM collaboration: numerical computation of all hard scattering cross sections (DIS structure function calculation including heavy quark contributions, W and Z production)

PRD86 (2012) 054009, *www-zeuthen.desy.de/˜alekhin/OPENQCDRAD*

APFEL (used by NNPDF): a PDF evolution library, is a computer library specialized in the solution of DGLAP evolution equations up to NNLO in QCD and to LO in QED

arXiv.1310.1394, *apfel.hepforge.org*

QCDNUM: Fast QCD Evolution and Convolution (numerically solves the evolution equations for parton densities and fragmentation functions in pQCD)

Comp.Phys.Com.182:490,2011

ALPOS: an object-oriented data to theory comparison and fitting tool (profit from and exchange with xFitter experience)

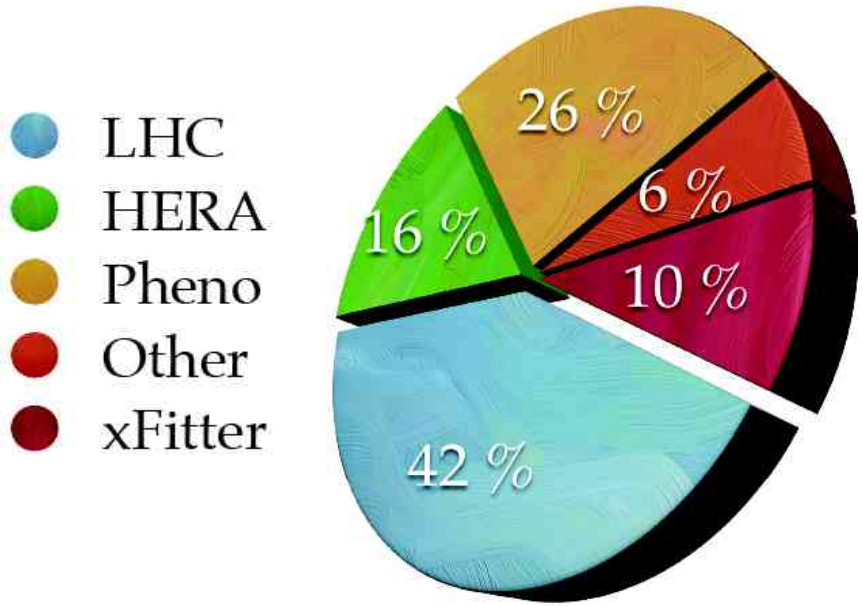
http://desy.de/~britzger/alpos/

→ access from a public svn repository (via request)

Results Obtained with xFitter

More than **30 public results** obtained using xFitter from the beginning of the project

https://www.xfitter.org/xFitter/xFitter/results



LHC experiments provide the main developments and usage of the xFitter platform

xFitter publications:

List of analyses using xFitter

Number	Date	Group	Reference	Title
2016				
42	03.2017	CMS	arXiv:1703.01630, submitted to EPJC (TOP-14-013)	Measurement of double differential cro
41	02.2017	A. Aleedaneshvara, M. Goharipour, S. Rostami	Chin Phys C 41, 2 (2017) 023101	Uncertainty of parton distribution funct
40	01.2017	Y.G. Gbedo, M. Mangin-Brinet	arXiv:1701.07678	Markov Chain Monte Carlo technics ap
39	01.2017	ABMP	arXiv:1701.05838	Parton Distribution Functions, αs and H
38	12.2016	ATLAS	arXiv:1612.03636	Measurements of top-quark pair to Z-b
37	12.2016	ATLAS	arXiv:1612.03016	Precision measurement and interpreta

NEW xFitter release xfitter-2.0.0

www.xFitter.org

xFitter

DESY xFitter

xFitter/xFitterTalks » xFitter/../xFitterDevel.. » xFitter/../Meeting2017-.. » xFitter » xFitter/DownloadPage

Wiki
- WikiPolicy
- RecentChanges
- FindPage
- HelpContents
- xFitter/DownloadPage

Page
- Immutable Page
- Info
- Subscribe
- Add Link
- Attachments
- More Actions:

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 xfitter-getdata.sh.
- Data and theory files are also stored in hepforge and can be accessed from there ("List of Data Files").

Date	Version	Files	Remarks
03/2017	**2.0.0 FrozenFrog**	xfitter-2.0.0.tgz	stable release with decoupled data and theory files
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

Sample data files:
LHC: ATLAS, CMS, LHCb
Tevatron: CDF, D0
HERA: H1, ZEUS, Combined
Fixed Target: …
User Supplied: ...

xFitter 2.0.0 FrozenFrog

By default only final combined HERA I+II data are distributed
→ getter-xfitter.sh script to download data with corresponding theory files
→ in directory 'datasets' located all available files

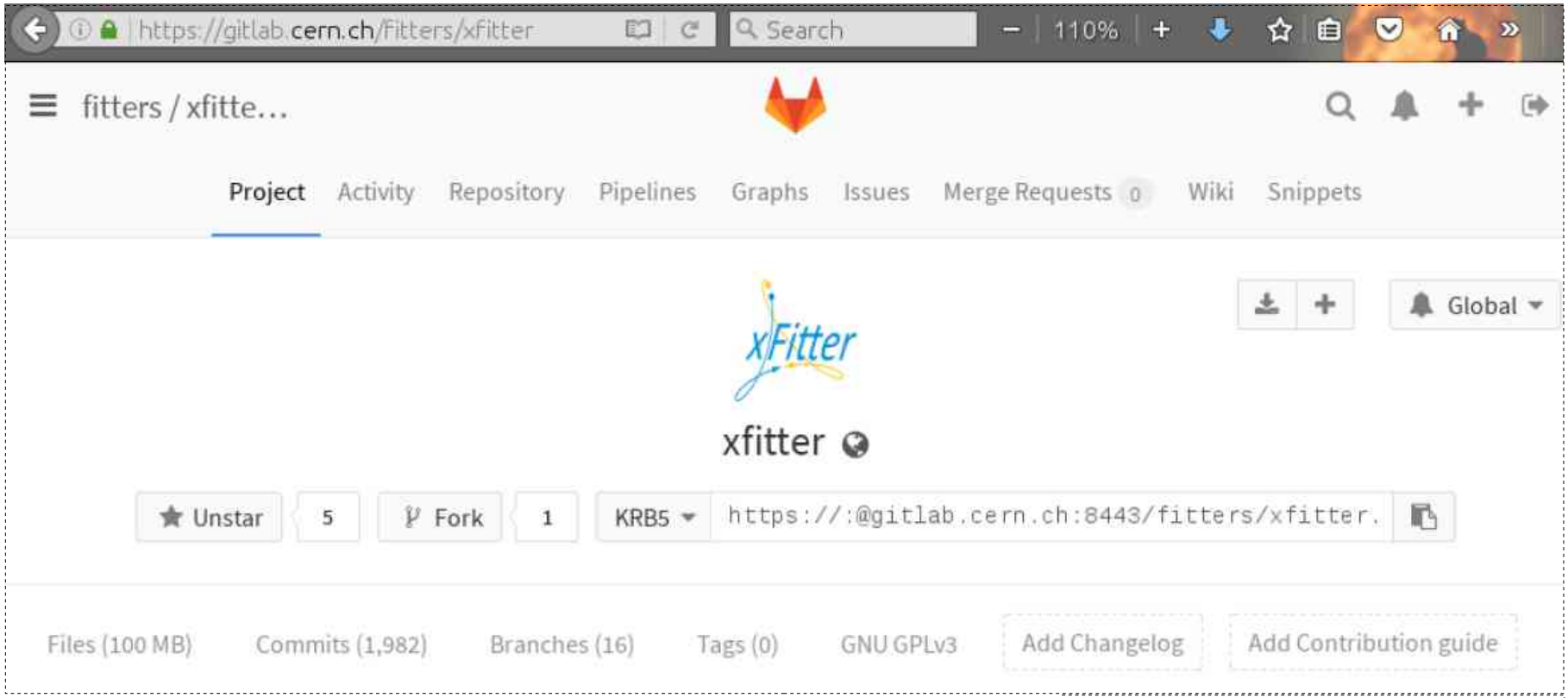
xFitter on GitLab

https://gitlab.cern.ch/fitters/xfitter

GitLab (CERN) is now the main repository of the project

→ open access to download for everyone (read only)

https://gitlab.cern.ch/fitters/xfitter



- **1951** commits during **1917** days
- Average **1.0** commits per day

Commits from developers which have no CERN account handled via mirror-GIT public page

NEW xfitter-2.0.0 vs xfitter-1.2.2 *part 1*

xFitter: Releases and Updates

March, 2017

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-2.0.0 (FrozenFrog)	20.03.2017	**Physics related additions:** • Implementation of switching scales for heavy quarks (APFEL) • Fast convolution using APFELGRID ("fk" tables) • Write out top LHAPDF if top mass is below kinematic limit (5 and 6 flavour PDFs) • Extra PDF parameters of the photon parametrisation • Improvements to QED evolution interface (QEDevol) • (optionally) Produce symmetric hessian PDF sets using minuit HESSE covariance matrix computation instead of default ITERATE method. • Updates to dipole steering files, saturation flag added • Extra option to separate statistical uncertainty from total covariance matrix, when it is uncorrelated **Technical improvements:** • Move to QCDNUM 17-01-13 new PDF interfaces. Make use of fast PDF calls. • Update fastNLO to latest version. Switch from APPLGRID → FastNLO to native FastNLO. • `install-xfitter` script uses cvmfs (recommended way to install xFitter) • `xfitter-getdata.sh` script added to download datasets • Added new datasets from LHC and HERA, and LHeC simulated data. • Synchronisation of the lhapdf6 output grid with initialisation from QCDNUM • Restore optional LHAPDFv5 usage

NEW xfitter-2.0.0 vs xfitter-1.2.2 *continued*

xFitter: Releases and Updates
March, 2017

xF
where **i** is the stabl

Release	Date	Desc
xfitter-2.0.0 (FrozenFrog)	20.03.2017	**Phy**

- Im
- Fa
- W
- Ex
- Im
- (o ma
- Up
- Ex it

Tech

- M
- Up Fa
- in
- xf
- Ac
- Sy
- Re

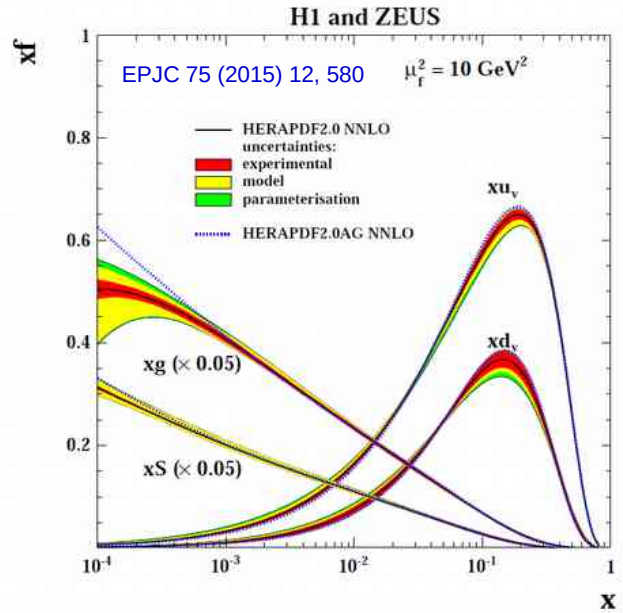
- Possibility to force PDFs to be positive after processing (`xfitter-process` tool)
- Adjustment of internal systematic arrays to to run with all data. Reduction of other internal arrays to keep memory footprint low
- Improvements in configuration and makefiles to work with different compilers and operation systems
- If `OUTPUTDIR` directory exists when running xfitter, it will be moved to `OUTPUTDIR_OLD`
- Increased the possible length of the output directory name
- Clean up (removing/renaming functions, suppressing unneeded outputs)
- Updates to README, INSTALLATION, steering files, manual, doxygen config
- Add error message if combine utility is used with LHAPDFv 5.x
- Cleanup of warning messages, better indication of potential problems
- Restore `make dist` functionality
- Added extra automatic checks
- Add feature to draw individual sets by using set:ID:dir syntax
- Additional option `--loose-mc-replica-selection`
- Add strict check for second option of MC-replica path matching
- Other small fixes in drawing options (logo, coloured error bands, etc)

Bug Fixes:

- Fix in the gluon parametrisation (affecting HERAPDF parameterisation sum-rule)
- Enable compilation with LHAPDF6 and without APPLgrid
- Fixes in non-standard parameterisations (e.g. using Chebyshev polynomials)
- Fix few conflicting fortran symbols.

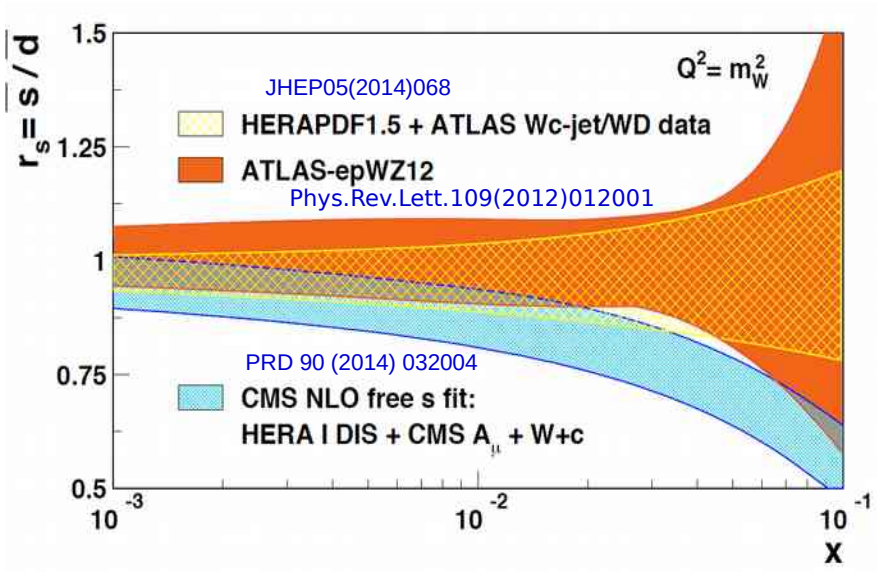
Results Obtained with xFitter: Examples

DIS inclusive processes in *ep*

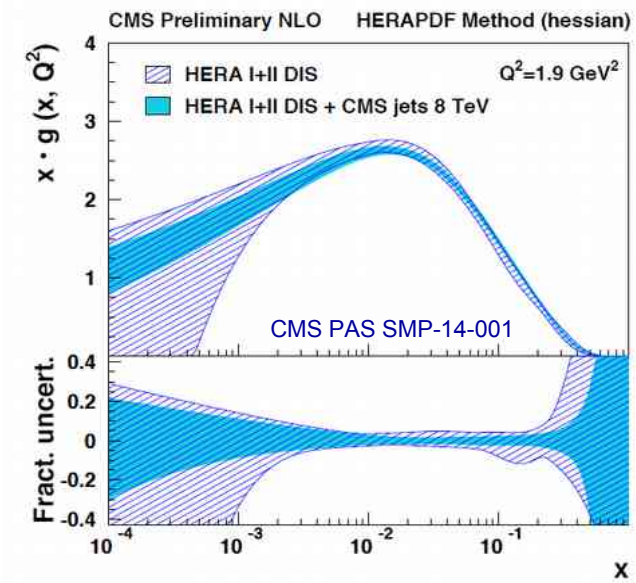


Drell-Yan processes (*pp, ppbar*)

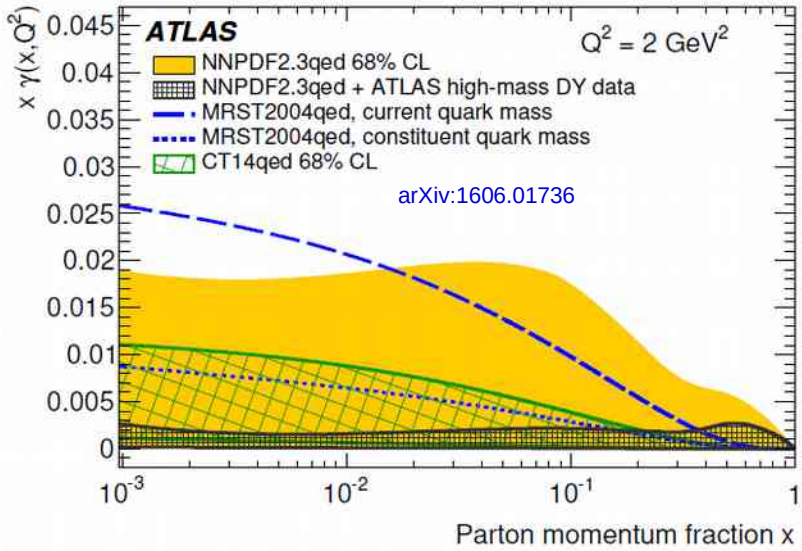
→ strange quark density determination



Jet production (*ep, pp, ppbar*)

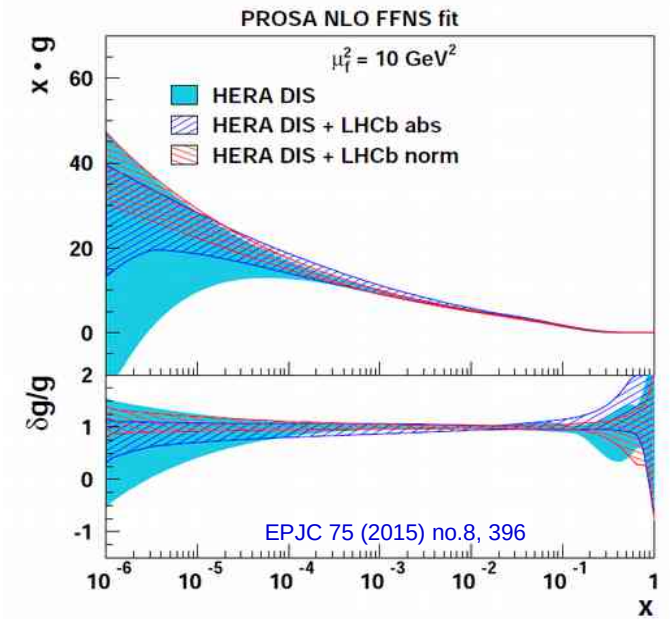


DY data sensitivity to photon PDF

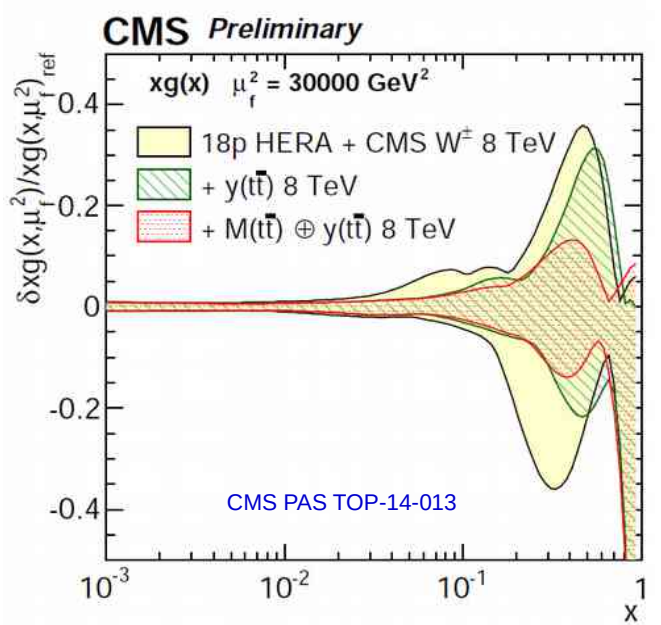


Results Obtained with xFitter: Examples

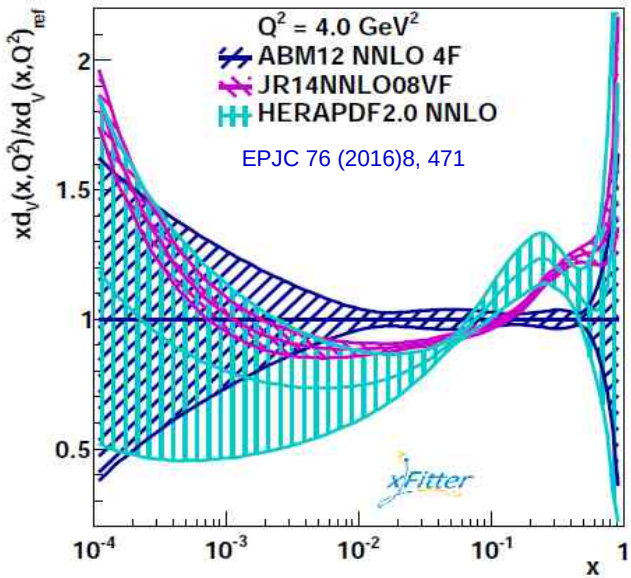
Heavy Quark production (*ep, pp, ppbar*)



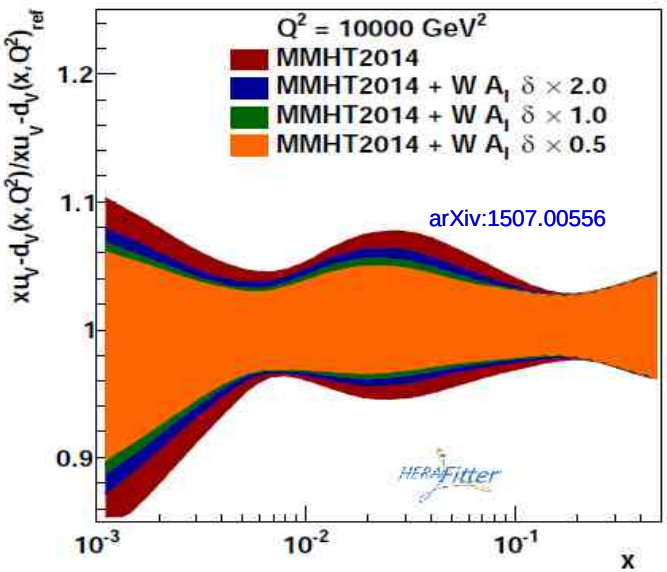
Top-quark production (*pp, ppbar*)



Evaluation of modern PDFs (benchmarking)



PDF4LHC report (benchmarking)



Latest xFitter Developers Team Publication

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.

JHEP 1608 (2016)

The extraction of $m_c(m_c)$ was performed using FONLL scheme in terms of the $\overline{\text{MS}}$ 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 flavour number scheme) at NLO

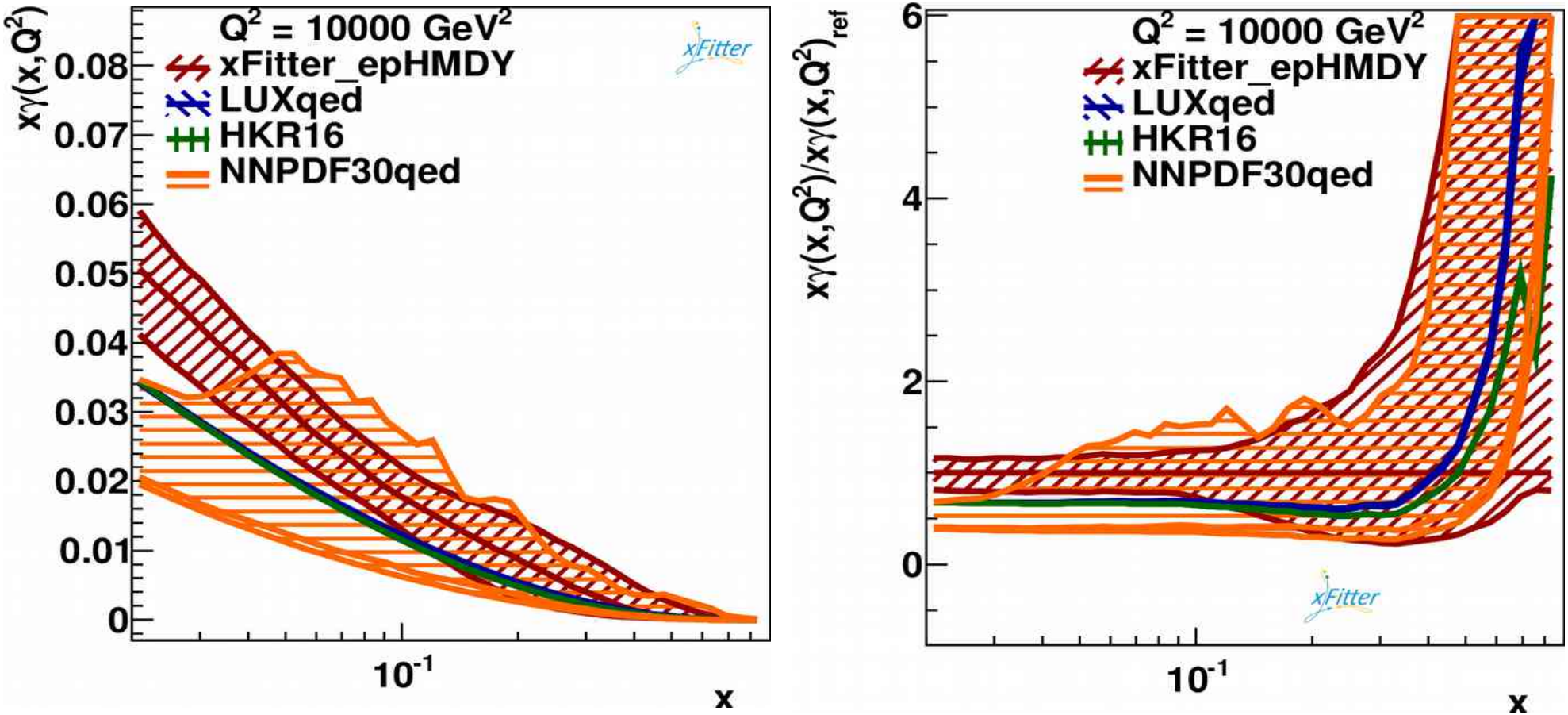
pole mass definition suffers from non-perturbative effects which result in an intrinsic uncertainty of order Λ_{QCD}

xFitter Photon PDF

See talk by Francesco Giuli earlier today

Determination of the photon PDF from fits to recent ATLAS measurements of high-mass Drell-Yan dilepton production at √s=8 TeV

Fit photon PDF at Q_0 $$x\gamma(x) = A_\gamma\, x^{B_\gamma}(1-x)^{C_\gamma}(1 + D_\gamma\, x + E_\gamma\, x^2)$$

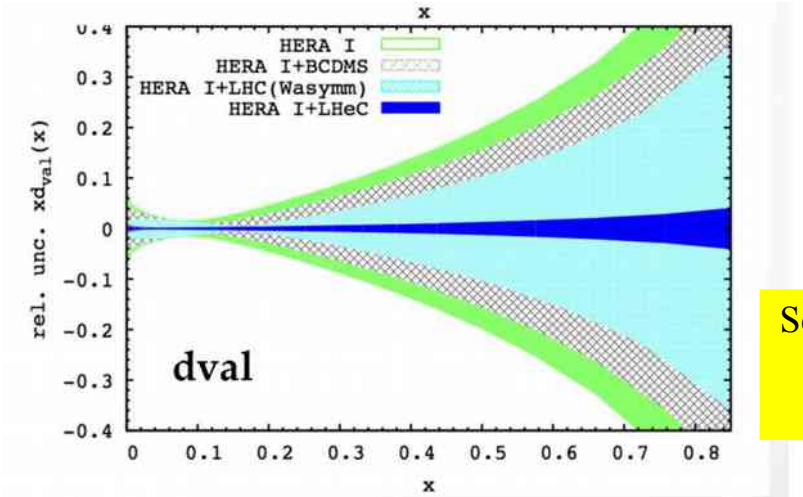


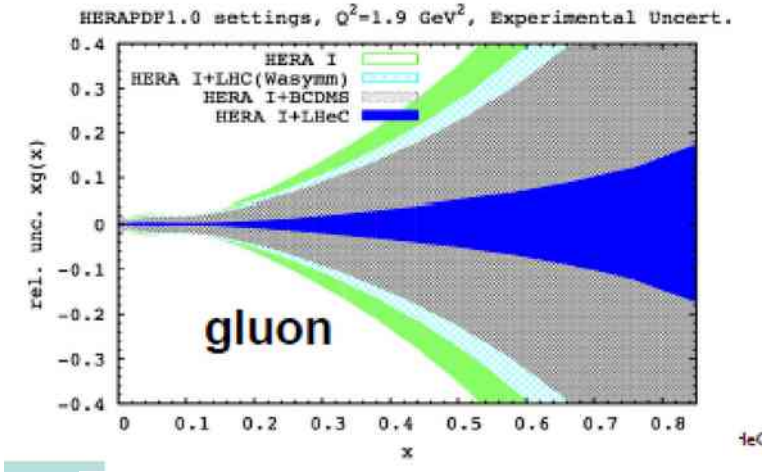
The photon PDF from high-mass Drell Yan data at the LHC
F. Giuli, et al., xFitter Developers' team
arXiv:1701.08553 [hep-ph]

V. Bertone and S. Carrazza, arXiv:1606.07130.
NNPDF Collaboration, JHEP 04 (2015) 040
A. Manohar, P. Nason, G. P. Salam, and G. Zanderighi, arXiv:1607.04266.
L. A. Harland-Lang, V. A. Khoze, and M. G. Ryskin, Eur. Phys. J. C76 (2016)

LHeC & FCCeh Studies

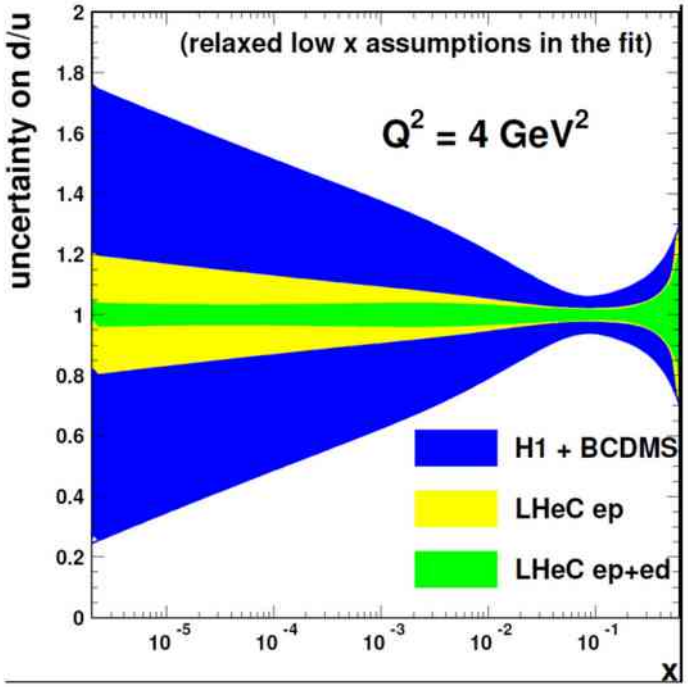
→ Compute PDFs for future facilities
→ Determine discovery reach

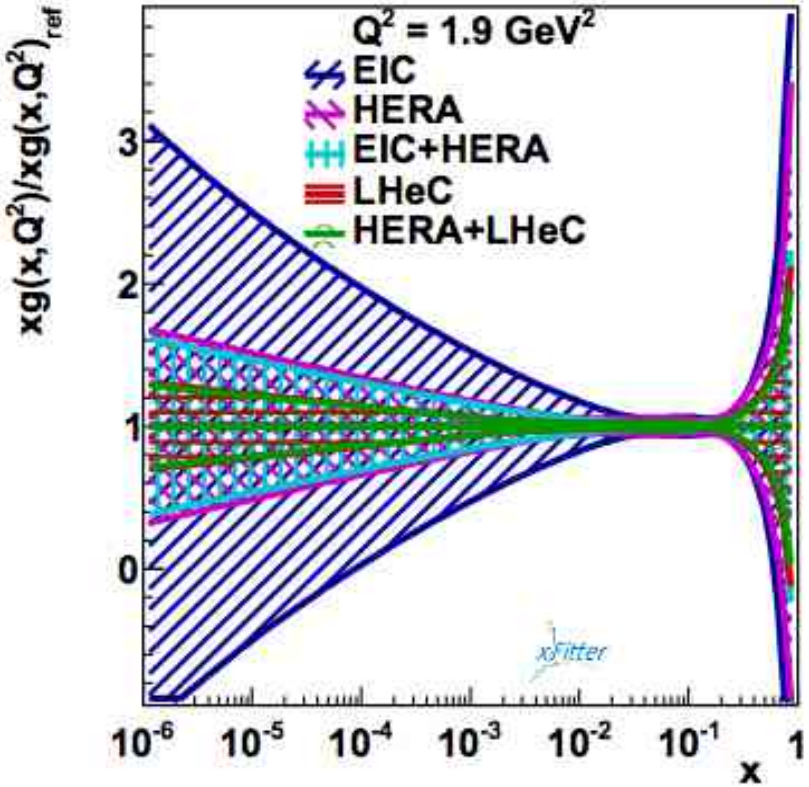




See talks by Claire Gwenlan & Mandy Cooper in WG7 (Tuesday)

pseudo data available



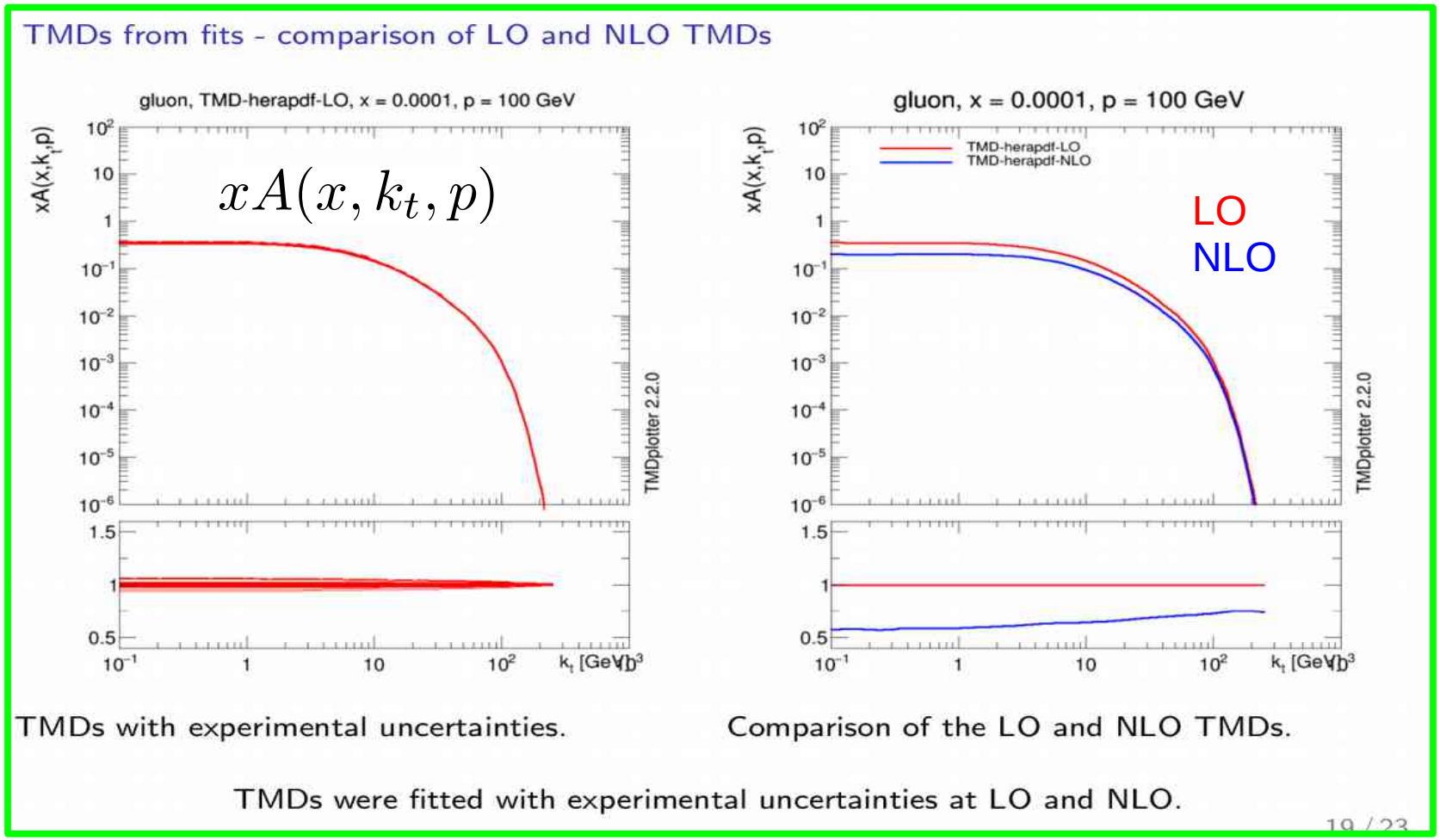


Thanks to Voica Radescu

TMD (uPDFs) in xFitter

→ work in progress
→ sample results shown
→ evolve in Q with DGLAP, BFKL, or CCFM

Talk by Ola Lelek
WG1 (Wednesday)



Quark and Gluon collinear and TMD parton distributions from HERA DIS data
Ola Lelek, Francesco Hautmann, Hannes Jung PoS DIS2016 (2016) 036

Ola Lelek, Francesco Hautmann, Hannes Jung
xFitter Workshop, Oxford March 2017

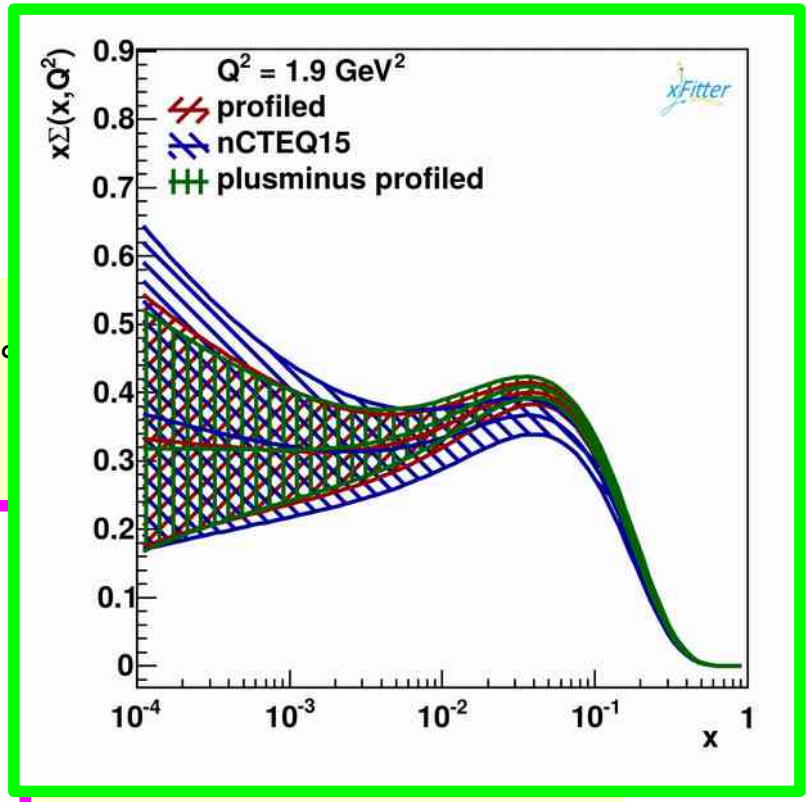
Profiling $W^{\pm}$ in Proton-Lead Collisions

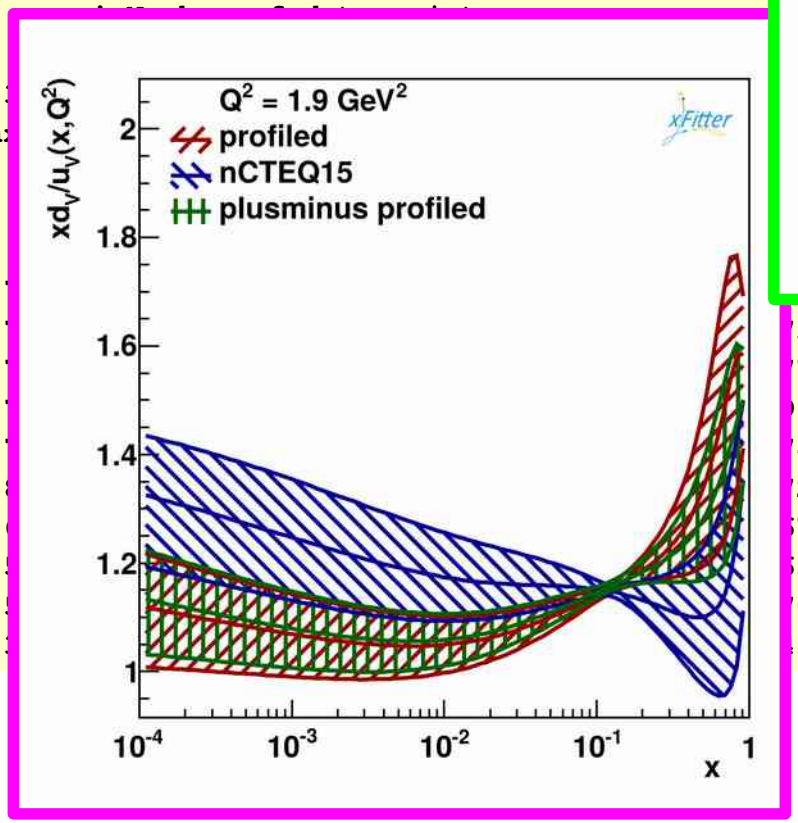
- → Use nCTEQ15 LHAPDF grids
- → Use FEWZ for W cross section calculations
- → Input LHC pPb data
- → Use xFitter Profiling utilities

```
! This theory file a test file
! generated from cms_Wm_pPb/tab1_NLO_nCTEQ15/0-NLO.w.output_FEWZextractor.pic
!
&Data
   Name   = 'cms_wm_fig3b_rew_theory'
   NData =  10
   NColumn =  35
   ColumnType = 2*'Bin','Theory',
   ColumnName = 'bin_min','bin_ma

   Percent = 35*false
&End
-3.210000  -2.210000  68.741530
-2.710000  -1.710000  73.166300
-2.210000  -1.210000  77.117926
-1.710000  -0.710000  76.802215
-1.210000  -0.210000  74.028980
-0.710000   0.290000  71.703561
-0.210000   0.790000  66.724986
 0.290000   1.290000  60.784235
 0.790000   1.790000  55.089179
 1.290000   2.290000  50.663899
```

```
3.155551  73.195358  72.75966
7.284879  96.182211  95.26098
6.491652  76.373931  75.46185
4.670278  73.321801  72.60121
2.562872  70.763443  70.600849
7.724555  65.643148  66.244718
1.834261  7
0.149144  5
1.320199  3
```





Both profiling & reweighting available

Thanks to Eric Godat & Voica Radescu

Variable Matching Scale μ_m

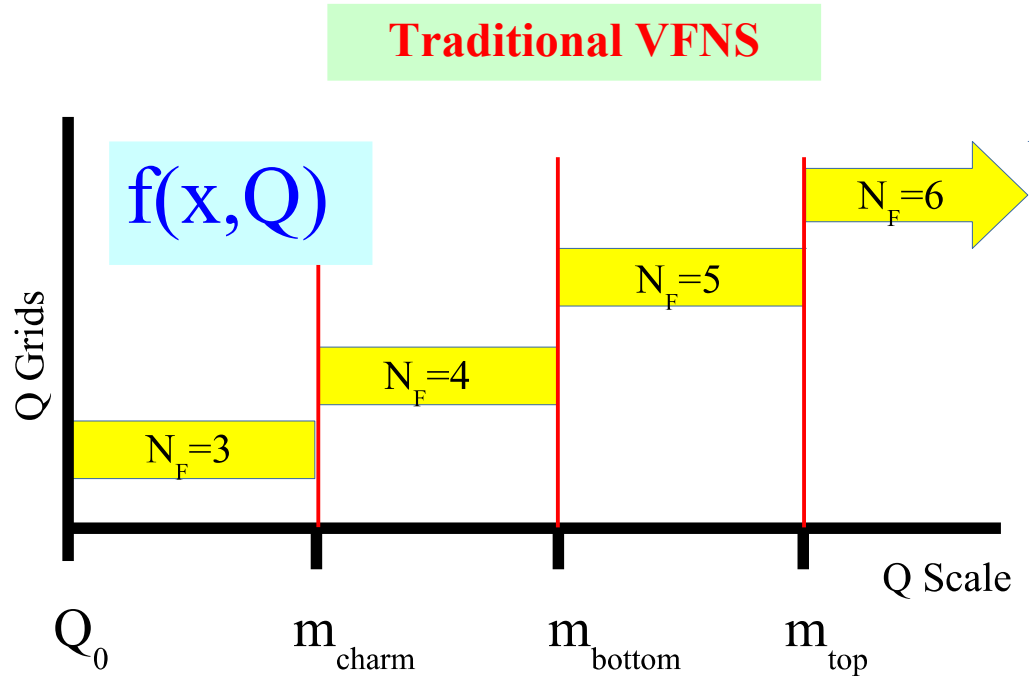
APFEL has a new feature

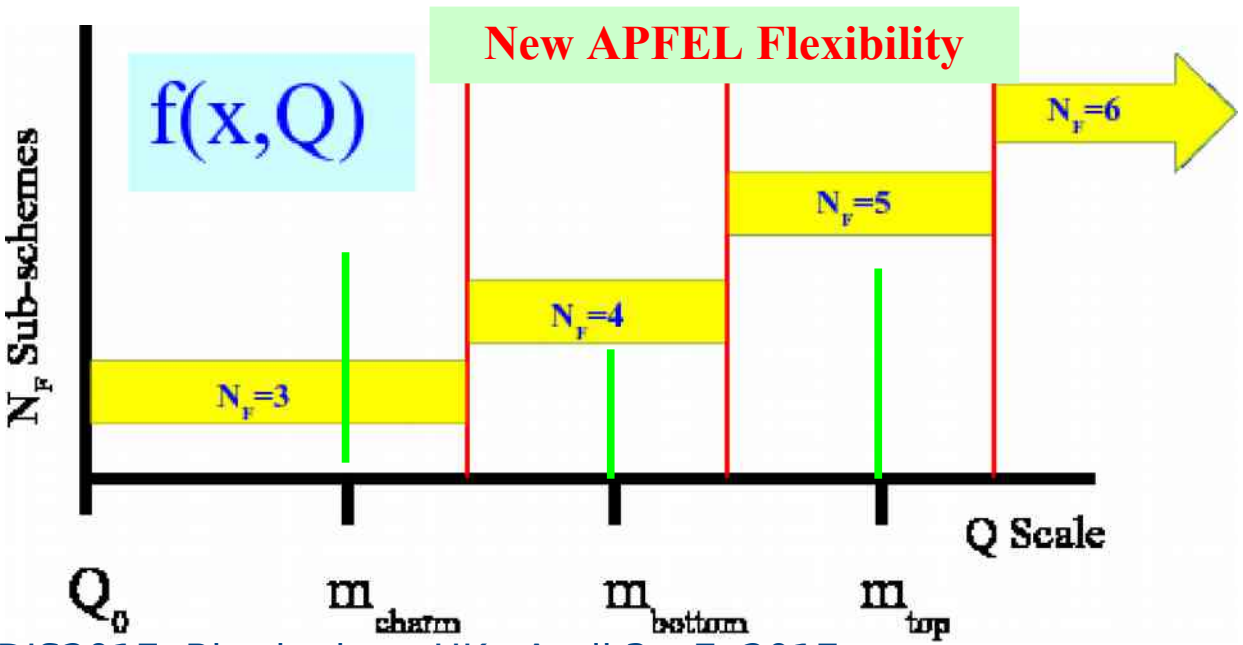
We can adjust the matching scale for the heavy quark PDF transition

What are the benefits?

1) **avoid discontinuities in the middle of data sets**

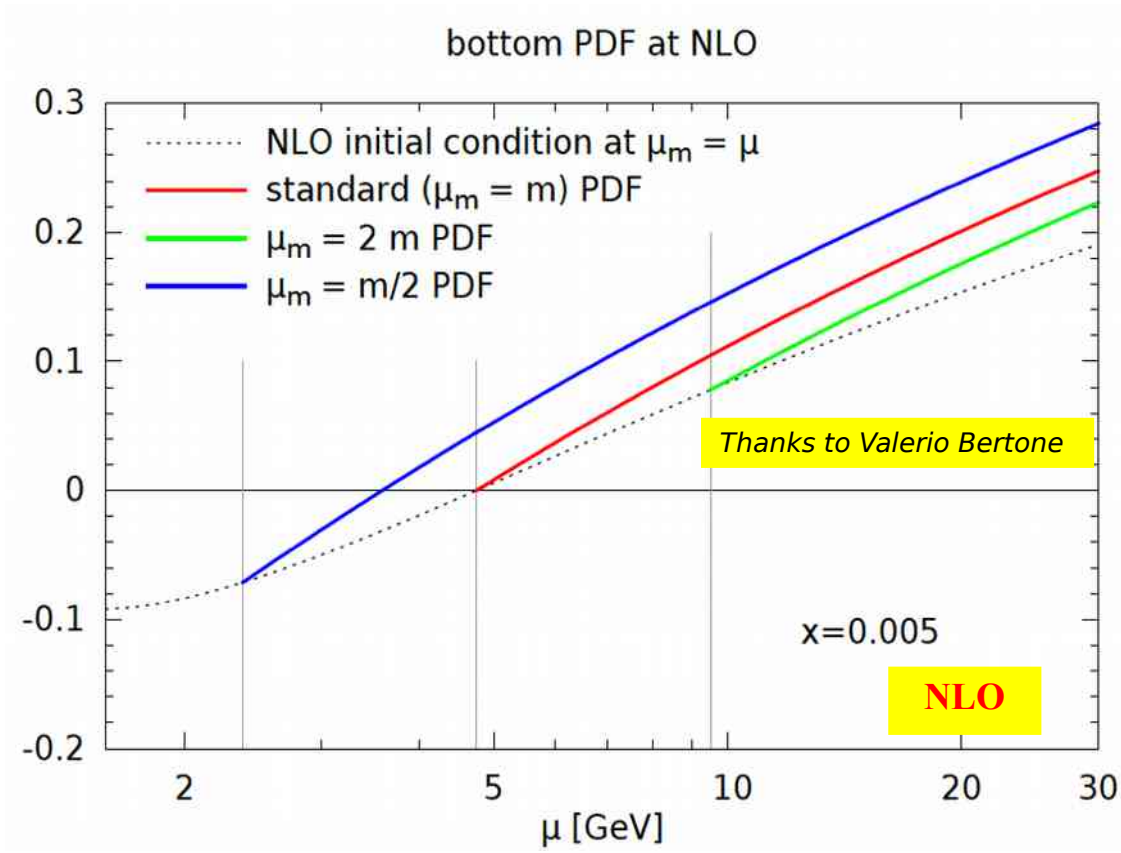
2) **avoid delicate matching in region $\mu \sim m_{c,b}$**

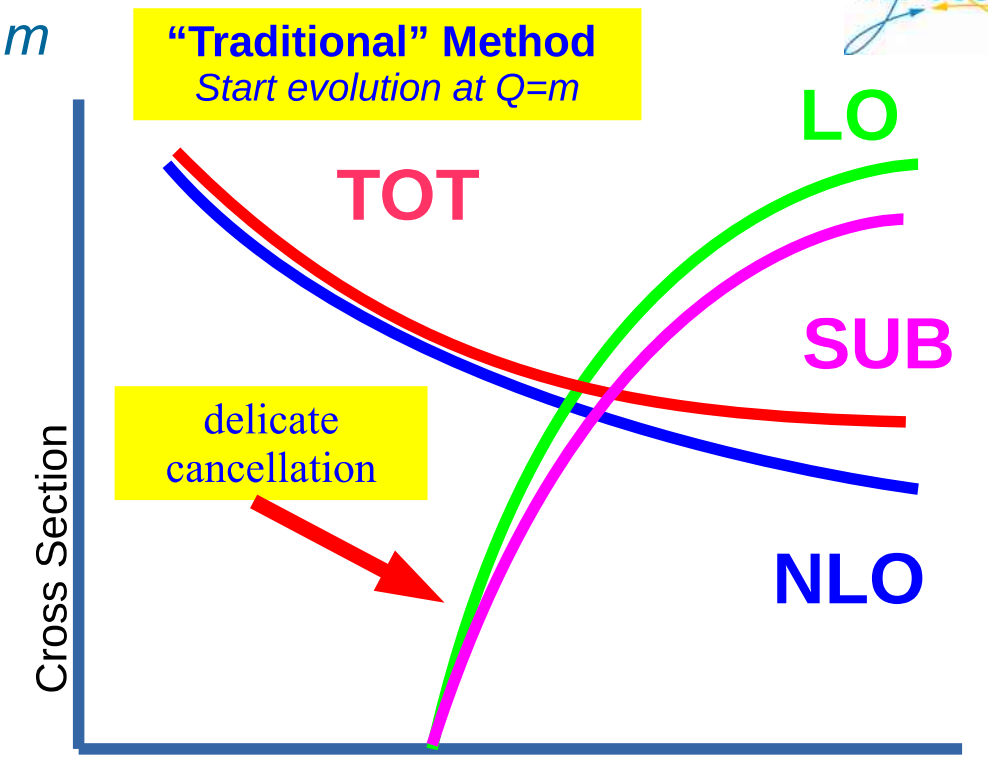


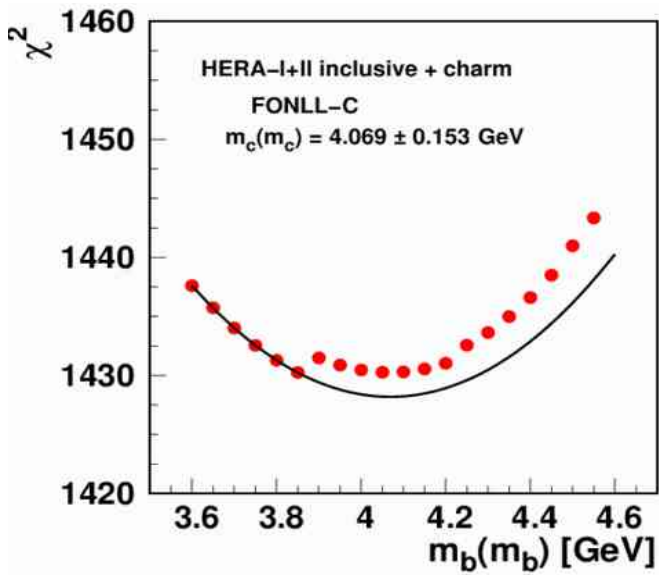


Variable Matching Scale μ_m

→ Freedom to Choose Matching Scale μ_m
→ Avoid delicate cancellations
→ Select scale "away" from data





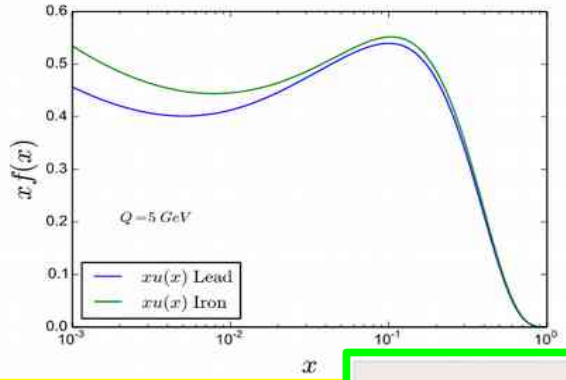


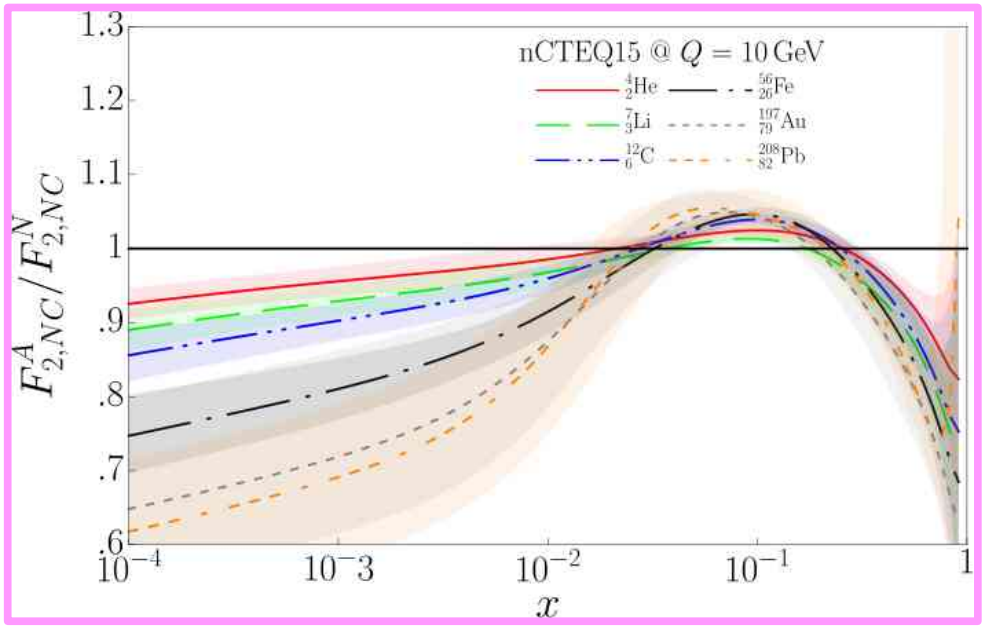
A theoretical laboratory ...
1) flexibly interpolate between VFNS and FFNS
2) answer many outstanding theoretical debates with numerical results!!!

Tools for PDF Analysis

- → LHAPDF Standard
- → Interface to Python
- → ManeParse Mathematica Package

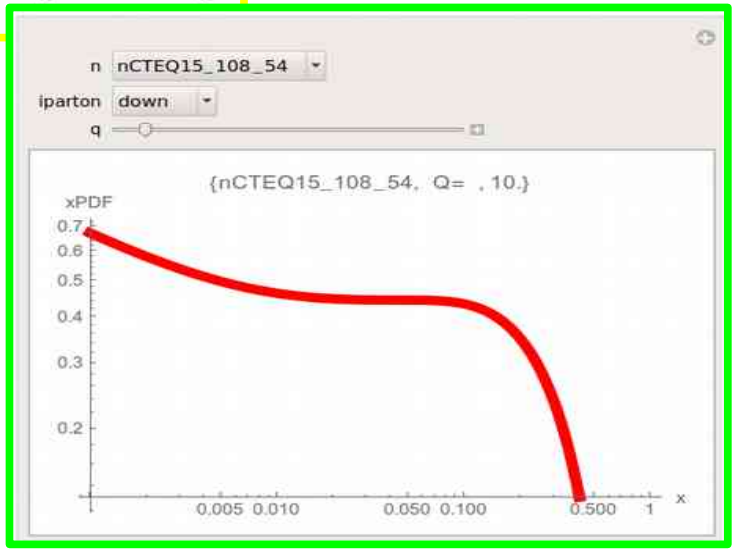
```
# loop over Q values
for iq,qq in enumerate(Qval):
    # divide it into two subplot vertically
    subplot2grid((1,2),(0,iq))
    semilogx(xvalues, fulllead_x_vals[qq], label='$xu(x)\ \
    semilogx(xvalues, fulliron_x_vals[qq], label='$xu(x)\ \
    legend(loc=3)
    text(2e-3,0.2, "$Q={}\ GeV$".format(qq))
    xlabel('$x$',fontsize=18)
    ylabel('$xf(x)$',fontsize=18)
```

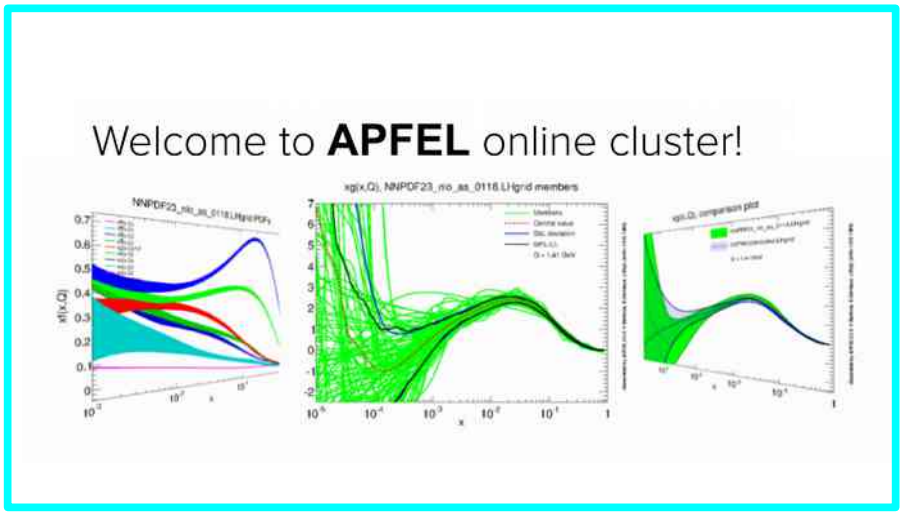




Thanks to Florian Lyonnet & Eric Godat

PDF Set
MSTW2008nnlo68cl [7]
CT14nnlo [8]
NNPDF30_nnlo_as_0118_nf_6 [9]
HERAPDF20_NLO_VAR [10]
abm12lhc_5_nnlo [11]
CJ15nlo [12]
nCTEQ15_1_1 [13]
nCTEQ15_208_82 [13]
ct10.pds [14]
ctq66m.pds [2]





Summary

xFitter project - a multi-functional QCD framework well integrated into the high energy community (both, experimental and theory) EPJC (2015) 75: 304

→ many active developments thanks to the close collaboration with experiments and theory groups

→ technical updates include usage of GitLab and HEPFORGE

→ **xfitter-2.0.0** is latest (recommended) release **Frozen Frog**

→ over 30 public results obtained using xFitter (main applications are from LHC)

→ several published dedicated physics studies (developers team publications), more studies are ongoing

→ foreseen future physic (low-x phenomenology, nuclear PDF, etc...) and technical developments (improved user interface for PDF parametrisation form, data cards, python interface, etc...)

→ useful for future projects, and room for suggestions and contributions

we welcome new ideas and developers :)

www.xfitter.org

Organisation

Steering Group is composed of:

- **Conveners:** Voica Radescu, Ringaile Placakyte, Amanda Cooper-Sarkar
- **Release coordinator/Librarian** (revision of the release candidates): Sasha Glazov, Oleksandr Zenaiev
- **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

Organisation

Steering Group is composed of:

- **Conveners:** Voica Radescu, Ringaile Placakyte, Amanda Cooper-Sarkar
- **Release coordinator/Librarian** (revision of the release candidates): Sasha Glazov, Oleksandr Zenaiev
- **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

xFitter convener: 1.10.2012-31.03.2017

- Almost 5 years of convenership
- A few HERAFitter / xFitter releases
- A number of published papers
- A lot of fun to work together

Best wishes and fun with the new work !

Summary

xFitter project - a multi-functional QCD framework well integrated into the high energy community (both, experimental and theory) EPJC (2015) 75: 304

→ many active developments thanks to the close collaboration with experiments and theory groups

→ technical updates include usage of GitLab and HEPFORGE

→ **xfitter-2.0.0** is latest (recommended) release **Frozen Frog**

→ over 30 public results obtained using xFitter (main applications are from LHC)

→ several published dedicated physics studies (developers team publications), more studies are ongoing

→ foreseen future physic (low-x phenomenology, nuclear PDF, etc...) and technical developments (improved user interface for PDF parametrisation form, data cards, python interface, etc...)

→ useful for future projects, and room for suggestions and contributions

we welcome new ideas and developers :)

www.xfitter.org

Back-up Slides

xFitter Developers Meeting

https://indico.cern.ch/event/578304/

External xFitter's meeting in Oxford:

→ 33 participants

→ 2.5 days workshop with number of talks and many discussions

Downloads of xFitter software package

xFitter-2.0.0 release is publicly available.
All the xFitter releases can be accessed HERE.
All the former (HERAFitter) releases can be acce
Description: http://arxiv.org/abs/1410.4412

xFitter Meetings

xFitter Meeting in Oxford 20-22 March 2017

- User's Meetings: meetings to enhance communi
- Developer's Meeting: technical weekly meetings access)
- Steering Group's Meeting (restricted access)

xFitter representation

- List of results
- List of collected talks

Developers Info (restricted to developers

- Internal Developments

Organisation

Steering Group is composed of:

- **Conveners:** Voica Radescu, Ringaile Placakyte
- **Release coordinator/Librarian** (revision of the
- **Contact Persons:** Cristi Diaconu (H1),Klaus Ra
- **DESY IT Contact:** Yves Kemp

Getting help

xFitter Workshops

www.xfitter.org

NEW xfitter examples (CTEQ school)

http://qcd2016.desy.de

Stefano Camarda
Ringailė Plačakytė

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 χ^2 representations
→ understand different χ^2 representations
nuisance parameters and covariance matrix χ2 formulas

Technical Changes (since 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

16

QCD@LHC 2016

xFitter on Hepforge: data access

http://xfitter.hepforge.org/

Complementary information about the project (to xfitter.org)

→ possibility to download **data** files (including theory)

→ updated automatically with new data added to svn

will include script to download all data at once

Your feedback is welcome

(via email xfitter-help@desy.de)

xFitter

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

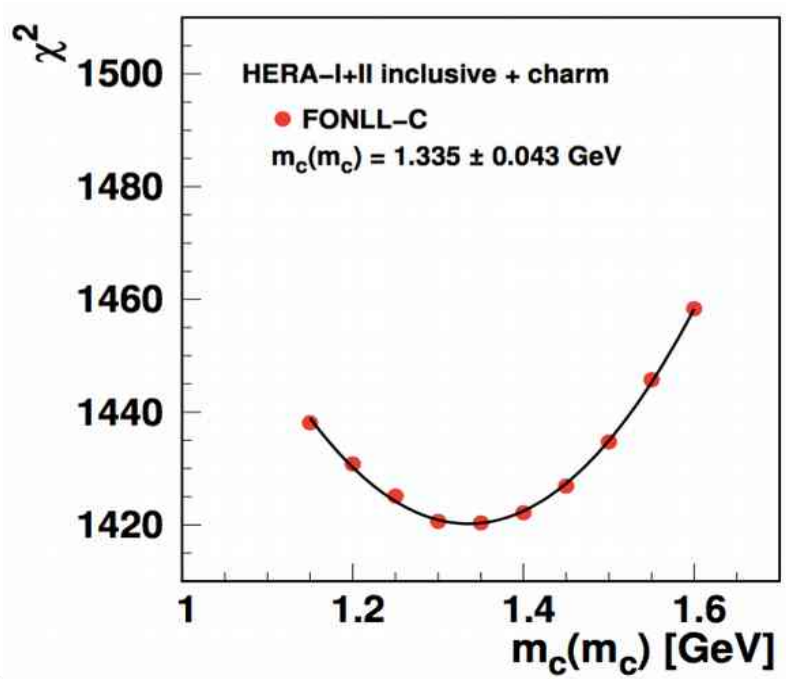
To download data set please click on the arXiv link (and open/save tar.gz file).

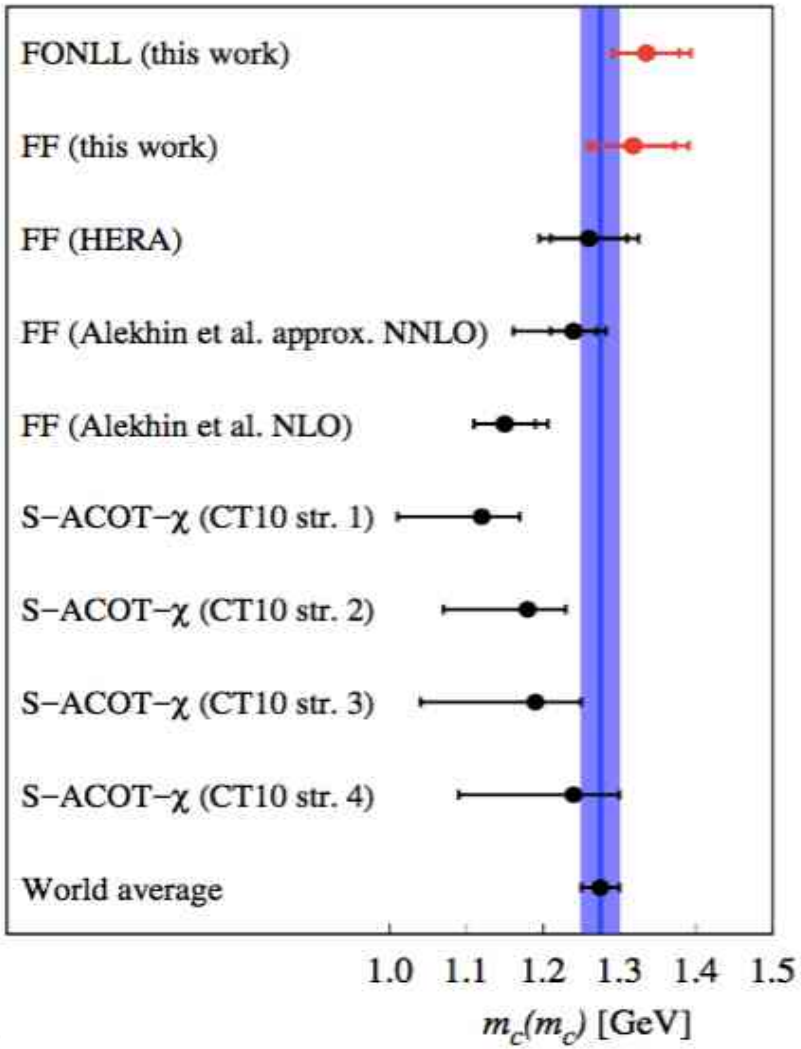
No	Collider	Experiment	Reaction	arXiv	Readme
1	fixedTarget	bcdms	inclusiveDis	cern-ep-89-06	README
2	hera	h1	beautyProduction	0907.2643	
3	hera	h1	inclusiveDis	1012.4355	
4	hera	h1	jets	0706.3722	README
5	hera	h1	jets	0707.4057	README
6	hera	h1	jets	0904.3870	README
7	hera	h1	jets	0911.5678	README
8	hera	h1	jets	1406.4709	README
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	

xFitter Developers Team Publication: Results

→ $m_c(m_c)$ value is determined from a parabolic minimum of the global χ^2 scan vs $m_c(m_c)$ with 1σ uncertainty determined from $\Delta\chi^2$ variation

→ $m_c(m_c)$ measurement is comparable to previous determinations from DIS as well as PDG world average:





FONLL-C:

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

Physics Cases in xFitter

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

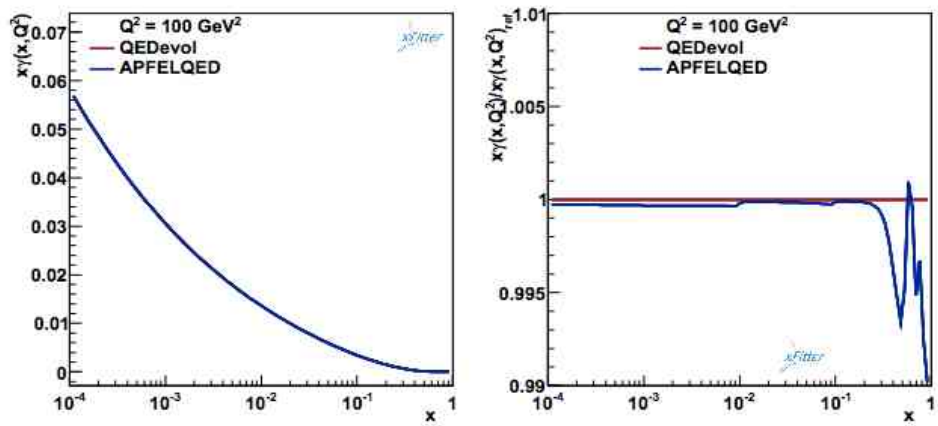
→ APFEL DGLAP+QED as used by NNPDF2.3 [V. Bertone et al]

https://apfel.hepforge.org

→ plan to add NLO QED, interface APPLGRID to SANC

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

Project SANC (former CalcPHEP): Support of Analytic and Numeric calculations for experiments at Colliders



V. Bertone, R. Sadykov

New: NLO QCD + QED via APFEL in xFitter:

→ at LO QED, no corrections to the SFs are needed

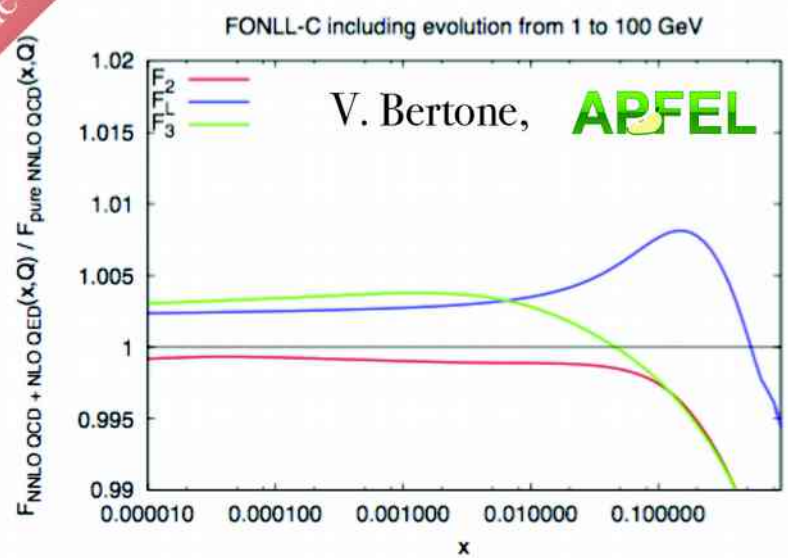
→ at NLO QED, access to new diagrams: $\gamma^*\gamma \to qq$ and $\gamma^* q \to q\gamma$

→ implementing the $O(\alpha_S\alpha)$ and the $O(\alpha^2)$ corrections to the DGLAP splitting functions on top of the $O(\alpha)$ ones

→ implementing $O(\alpha_S{}^2\alpha)$ and the $O(\alpha^2)$, $O(\alpha^2\alpha_S)$ 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!



Physics Cases in xFitter

Addition of new Heavy Flavour Scheme: **FONLL VFNS**

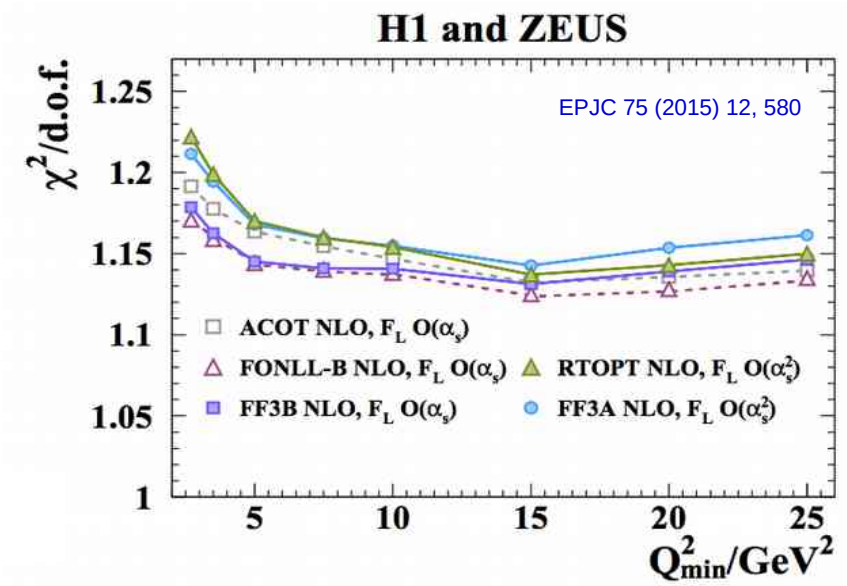
→ it is available thanks to collaboration with APFEL

→ 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



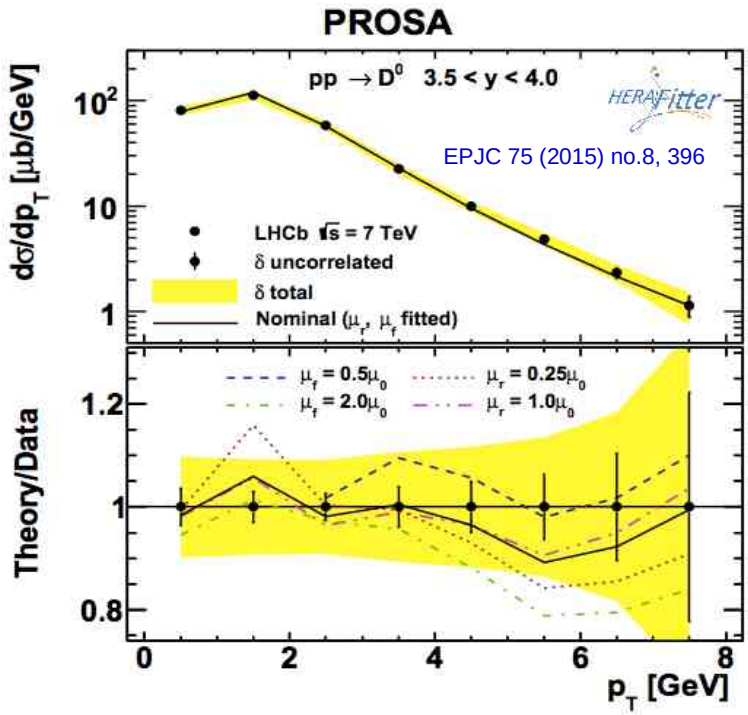
Interface to Mangano-Nason-Ridolfi (MNR, NPB 373 (1992) 295) theory code added in xFitter

→ 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 corresponding LHCb data

Added extra reweighing option using Giele-Keller weights



Schematic View of the xFitter Program

Main steps in QCD analysis:

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

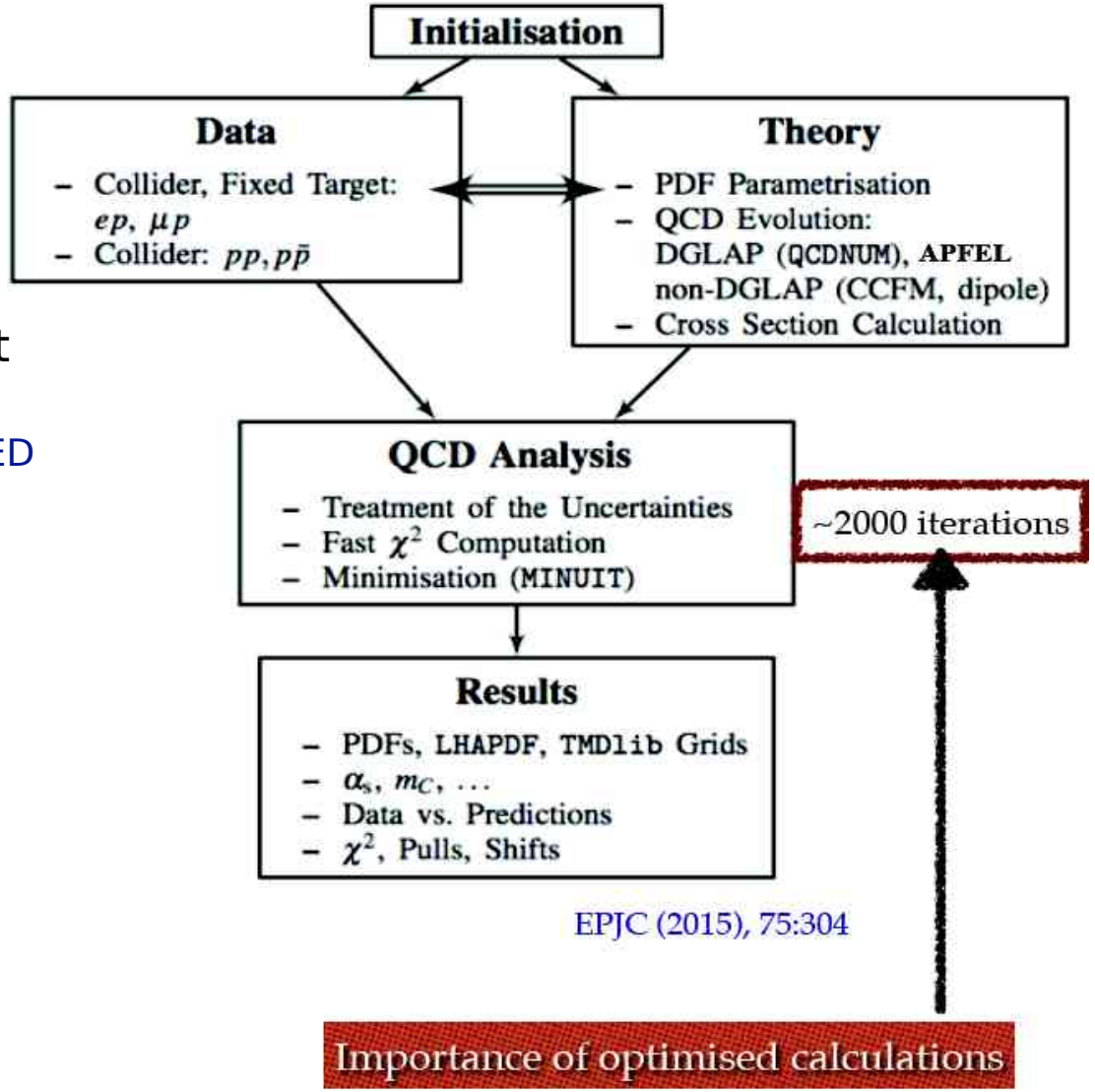
→ various heavy flavour schemes:
  → RT, ACOT, FONLL, FFNS(ABM)
→ fast grid techniques interfaced to DY:
  → APPLGRID, FASTNLO

Compare with data via χ^2:

→ multiple forms to account for correlations

Minimize χ^2 with respect to PDF parameters

→ profiling, reweighting
→ fit: MINUIT, data driven regularisation



xFitter Project

www.xfitter.org

2011 Open Source Revolution:

first open source QCD Fit Platform which started the wave of sharing QCD fit codes

EPJC (2015), 75: 304

- A team of ~30 developers:
  - LHC/HERA/theory/independent
  - several releases since 2011
  - 33 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

address consistency of Tevatron measurement and evaluate their collective impact on valence

determination of the running mass in $\overline{\text{MS}}$ scheme