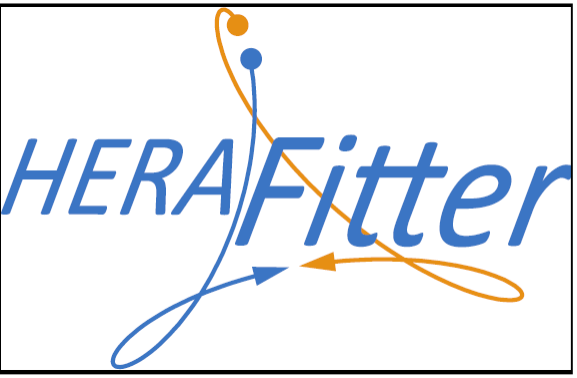


A M Cooper-Sarkar
University of Oxford
on behalf of the xFitter team

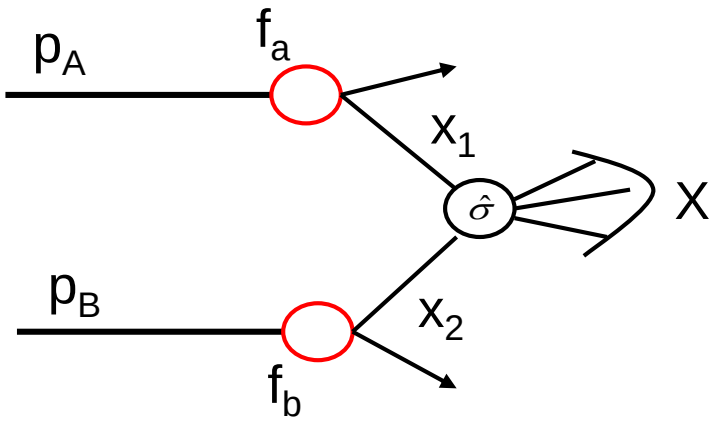
- xFitter is an open source QCD framework for PDF fitting that has proved to be a successful platform well integrated in the high energy physics community
- xFitter infrastructure has increased the scientific output of both HERA and LHC data, providing a flexible environment for theory benchmarking
- Stable release: xFitter-1.2.2 is available at www.xfitter.org
- It was developed in a close collaboration of experimentalists from HERA and the LHC with theoreticians
- There are ~30 developers

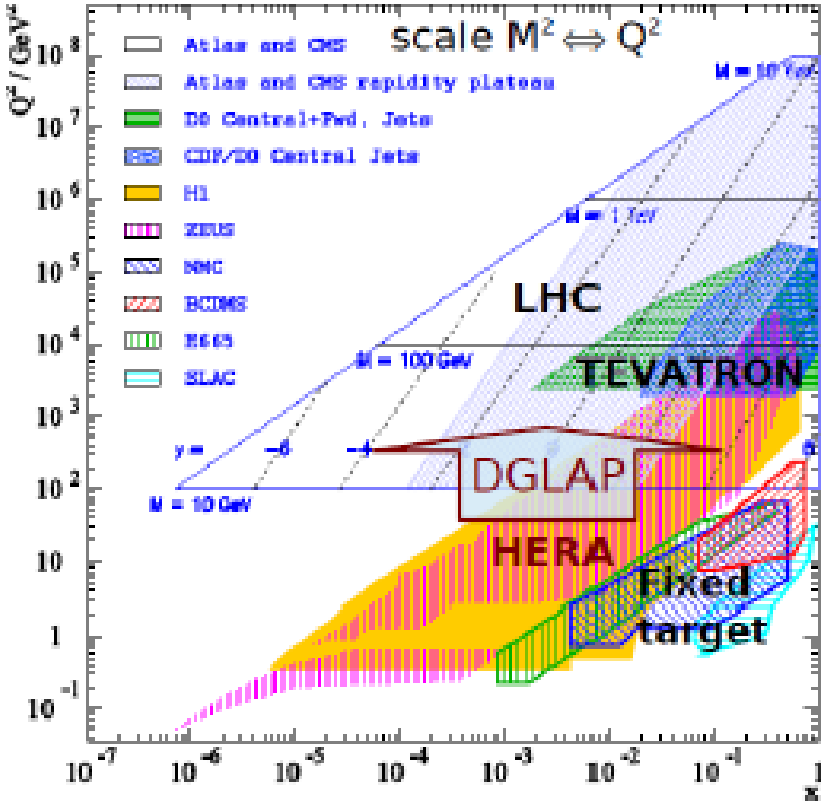
Uncertainties on Parton Distribution Functions (PDFs) limit our knowledge of cross sections whether SM or BSM.

$$\sigma_X = \sum_{a,b} \int_0^1 dx_1 dx_2 \, f_a(x_1, \mu_F^2) \, f_b(x_2, \mu_F^2)$$

$$\times \hat{\sigma}_{ab \to X}\left(x_1, x_2, \{p_i^\mu\}; \alpha_S(\mu_R^2), \alpha(\mu_R^2), \frac{Q^2}{\mu_R^2}, \frac{Q^2}{\mu_F^2}\right)$$

where X=W, Z, D-Y, H, high-E_T jets, prompt-γ and σ is known to some fixed order in pQCD and EW or in some leading logarithm approximation (LL, NLL, …) to all orders via re-summation





Current knowledge of PDFs is dominated by the HERA data

PDFs are evolved up in scale using the DGLAP equations to make predictions for LHC cross -sections

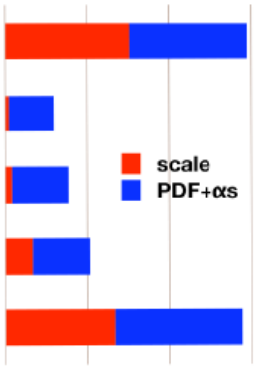
Accurate knowledge of Parton Distribution Functions is essential for precision physics at the LHC

- Uncertainty on PDFs is one of the main uncertainties on the SM Higgs cross section
- And on M_W
- And on predictions for high scale BSM production

Different PDF groups use different methodologies as well as different data

PDFs and the Higgs

		σ (8 TeV)	uncertainty
NNLL QCD +NLO EW	gg→H	19.5 pb	14.7%
	VBF	1.56 pb	2.9%
NNLO QCD +NLO EW	WH	0.70 pb	3.9%
	ZH	0.39 pb	5.1%
NLO QCD	ttH	0.13 pb	14.4%



HERAFitter is an open source QCD fitting code which allows the comparison of the use of different data sets and different methodology, e.g. choice of heavy flavour scheme, using a common platform

It can be used to extract PDFs ------- it is used for the HERAPDF---------- and to assess the impact of new data and hence to improve the sensitivity of new measurements to PDF- this is already being done within ATLAS and CMS before finalisation of measurements and publication

How do we determine Parton Distribution Functions ?

Parametrise the parton distribution functions (PDFs) at Q^2_0 (~1-2 GeV^2)- Use (NN)LO QCD DGLAP equations to evolve these PDFs to $Q^2 > Q^2_0$

Construct the measurable cross-sections by convoluting PDFs with (NN)LO matrix elements: make predictions for ~2000 data points across the x,Q^2 plane- Perform χ^2 fit to the data

Formalism
(NN)LO DGLAP
MSbar factorisation
Q_0^2
functional form @ Q_0^2
Heavy quark treatment…

$$f_i(x,Q^2) \pm \delta f_i(x,Q^2)$$

$$\alpha_S(M_Z)$$

Who?
ABM, CT, MMHT,
HERA,JR,NNPDF

Data
DIS (Fixed target and HERA)
Drell-Yan (E605, E772, E866, …)
High E_T jets (Tevatron)
W,Z rapidity and asymmetry (Tevatron)
etc. and NOW LHC data…

http://durpdg.dur.ac.uk/hepdata/
http://projects.hepforge.org/lhapdf/

LHAPDFv5/6

HERAFitter allows the choice of input parametrisation

- HERAPDF/MSTW style
- CTEQ style
- Chebyshevs
- Log Normal

- Standard Polynomials:

$$xf(x) = Ax^B(1-x)^C P_i(x),$$

HERAPDF, MSTW, CTEQ
CT add exponentials

- Log-Normal Distributions:

$$xf(x) = x^{p-b\log(x)}(1-x)^{q-\log(1-x)}$$

- Chebyshev Polynomials:

MMHT

$$xg(x) = A_g(1-x)\sum_{i=0}^{N_g-1} A_{g_i} T_i\left(-\frac{2\log x - \log x_{min}}{\log x_{min}}\right),$$

$$xS(x) = (1-x)\sum_{i=0}^{N_S-1} A_{S_i} T_i\left(-\frac{2\log x - \log x_{min}}{\log x_{min}}\right).$$

- Use of External PDFs via LHAPDF interface to construct theoretical predictions.

And the choice to input a wide range of data in addition to the HERA-DIS data e.g. LHC data

Measurement at LHC	PDF sensitivity
Jets	high x quarks and gluons (alphas)
Inclusive W, Z and asymmetries	quark flavour separation (u,d,s)
Low and high mass Drell-Yan	quarks at low and high x (u,d)
W + charm	Direct sensitivity to s-quark
Isolated photons	medium - x gluons
Single top	u,d and b quark
ttbar (total, differential)	Medium-x gluon (alphas)
W,Z production with jets	Medium-x gluon
Z+b production	sensitive to b-quark

HERAFitter allows various ways of treating experimental systematic uncertainties

Data should be provided with information on correlated systematic uncertainties this can be in the form of a correlation matrix, or in terms of correlated shifts for each systematic source. These are used in the χ2 minimisation as:

- Nuisance parameter representation
  - Simple form

$$\chi^2_{exp}(m,b) = \sum_i \frac{\left(m_i - \sum_j \gamma_j^i b_j - \mu_i\right)^2}{(\delta_{i;stat}\mu_i)^2 + (\delta_{i;uncor}\mu_i)^2} + \sum_j b_j^2$$

  - Scaled form

$$\chi^2_{exp}(m,b) = \sum_i \frac{\left(m_i - \sum_j \gamma_j^i b_j - \mu_i\right)^2}{\delta^2_{i;stat}\mu_i\left(m_i - \sum_j \gamma_j^i b_j\right) + (\delta_{i;uncor}\, m_i)^2} + \sum_j b_j^2 + \text{log penalty}$$

- Covariance matrix representation

$$\chi^2_{exp}(m) = \sum_{ij} (m_i - \mu_i)\, C_{ij}^{-1} \left(m_j - \mu_j\right)$$

- Mixed form (covariance matrix and nuisance parameters):

$$\chi^2_{exp}(m,b) = \sum_{i} \left(m_i - \sum_k \Gamma_k^i(m_i) b_k - \mu_i\right) C^{-1}_{i;stat}\left(m_i, m_j\right) \left(m_j - \sum_k \Gamma_k^j(m_j) b_k - \mu_j\right) + \sum_k b_k^2$$

Experimental errors can be propagated to the PDFs by several methods

i) Hessian method – nuisance parameters are fitted, χ2 tolerance T >1 can also be used to account for marginally compatible input data sets

ii) Offset method- nuisance parameters are applied as 1σ shifts

iii) MC-method—data points are shifted randomly within their 1σ limits to form MC replicas. This can also allow for asymmetric uncertainties

Herafitter allows comparison of different theoretical formalisms

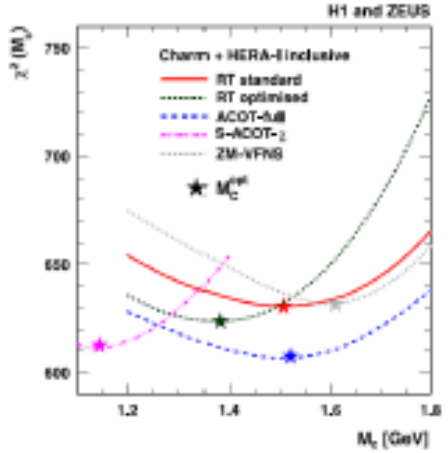
QCDNUM is used for DGLAP evolution, but QCDRAD and APFEL can also be used

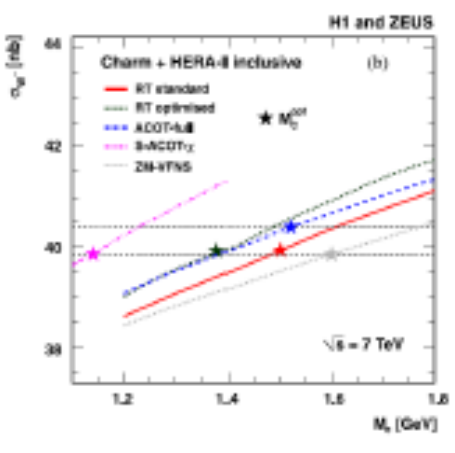
Coefficient functions can be calculated in **various heavy quark schemes**

- Variable Flavour Number schemes a la MMHT(TR), CT(ACOT) or NNPDF (FONLL)
- Fixed Flavour Number schemes as used by ABM

Variety of schemes were tested by H1/ZEUS collaborations in F_2^{charm} *analysis*

[Eur. Phys. J. C73 (2013) 2311]





Spread in predictions for W and Z @LHC is reduced significantly when predictions are evaluated at the optimal m_{charm} determined from F_2^{charm}

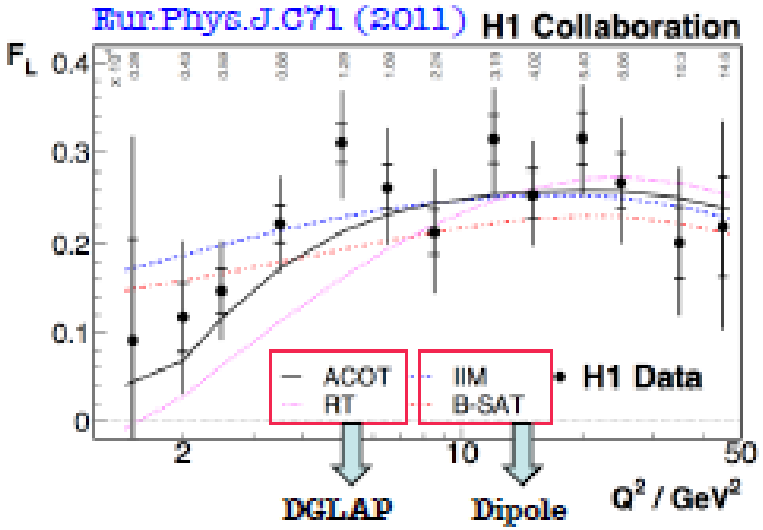
Tools like FastNLO and Applgrid are implemented to make fast calculations for NLO (and NNLO) cross sections which are otherwise too slow for input to a fit

- NLO jet production can be done by FastNLO or Applgrid interfaced NLOJet++
- NLO Drell-Yan and W,Z production can now be done exactly using Applgrid interfaced to MCFM.
- NNLO Drell-Yan using DYNNLO should be available soon
- Top production, from MCFM at NLO, is extended to NNLO by DiffTop
- – and an interface to the calculations from Mitov et al is coming

Going beyond DGLAP

As an alternative to DGLAP, X Fitter includes also Dipole models:

- Studied by the H1 collaboration in comparing different models on FL:
  - Dipole Models implemented in X Fitter:
    - GBW model: first model
    - IIM (based on BK-equation)
    - BGK (based on GBW, but gluon evolved using DLGAP)
  - DGLAP Models:
    - RT as used by MSTW group
    - ACOT as used by CTEQ group



Unintegrated PDFs based on the kT-factorisation (CCFM) evolution.

- applicable only to NC ep scattering:
  https://www.herafitter.org/HERAFitter/HERAFitter/HERAFitterMeetings/Meeting2012-Oct-29?action=AttachFile&do=get&target=updf.pdf

Diffractive DIS PDF fits.

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

Xfitter release 2.0.0 March 2017

Frozen Frog

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").

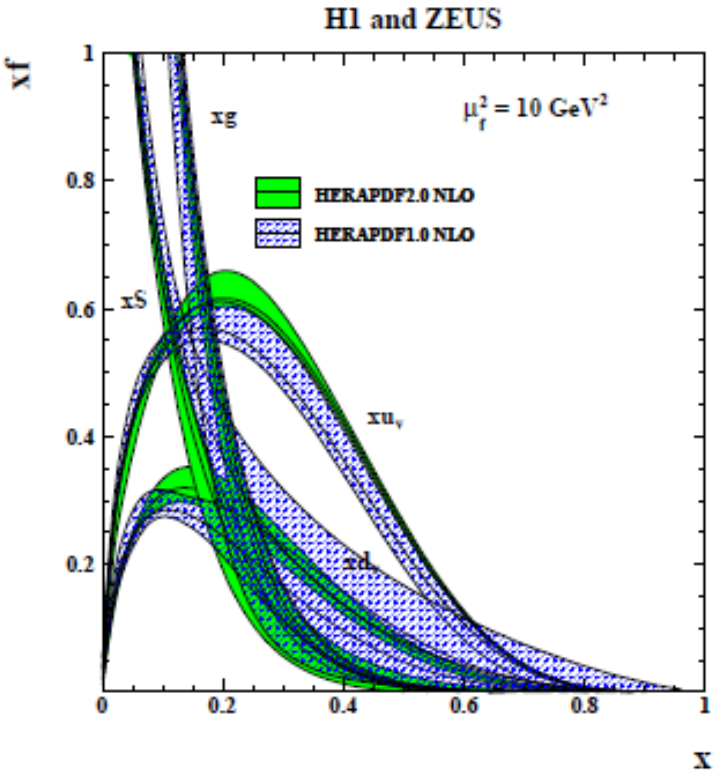
Date	Version	Files	Remarks
03/2017	**2.0.0 FrozenFrog**	xfitter-2.0.0.tgz	stable release with decoupled data and theory files
07/2016	**1.2.2**	xfitter-1.2.2.tgz	release with decoupled data and theory files
05/2016	**1.2.1**	xfitter-1.2.1.tgz	release with decoupled data and theory files
02/2016	**1.2.0**	xfitter-1.2.0.tgz	release with decoupled data and theory files

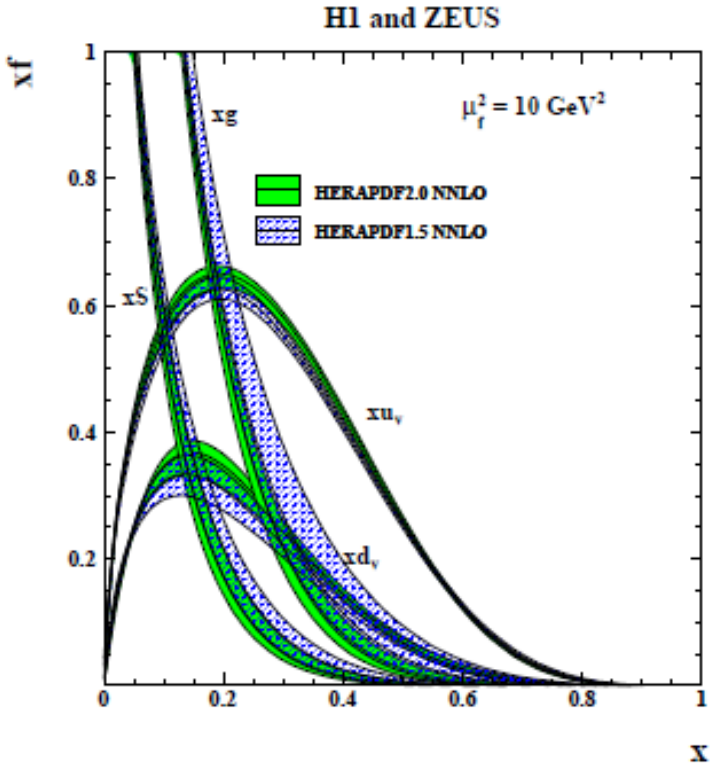
Documentation

- 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

Examples of the use of xFitter





The first was the production of the HERAPDF-- now HERAPDF2.0

xFitter also contains the HAverager tool which is used to combine ZEUS and H1 data, and now to combine electron and muon channel data at the LHC

Quantitative comparison of agreement between new data sets and predictions from various PDFs– not just HERAPDF

- Fitter provides a quantitative assessment of level of agreement between data and theory by taking into account theoretical and experimental uncertainties

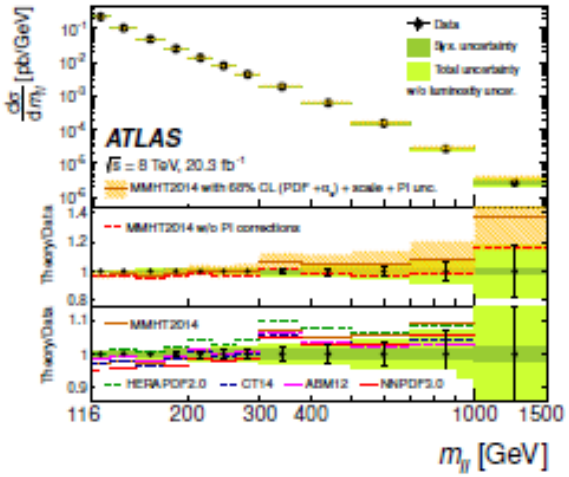
$$\chi^2 = \sum_i \left(\frac{\mu_i - m_i \left[1 + \sum_j b_j^{exp} \gamma_{ji}^{exp} + \sum_j b_j^{theo} \gamma_{ji}^{theo} \right]}{\Delta_i} \right)^2 + \sum_j (b_j^{exp})^2 + \sum_j (b_j^{theo})^2$$

Ex: 30 points from ATLAS
WZ 2010 vs NNLO predictions

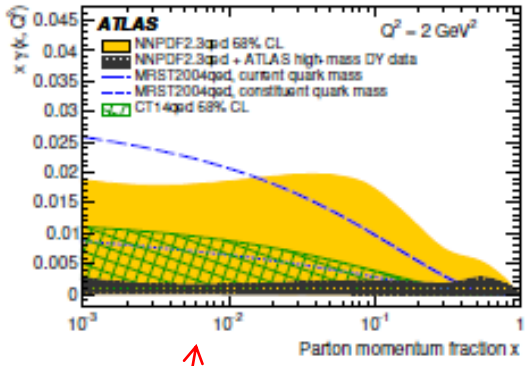
PDF set	Central PDF	With PDF uncertainties
CT10	34.1	32.0
MSTW08	72.0	49.7
HERAPDF1.5eig	43.1	39.2

Used in ATLAS publications:

arXiv: 1606.01736



	m_{ll}	$\lvert y_{ll} \rvert$	$\lvert \Delta\eta_{ll} \rvert$
MMHT2014	18.2/12	59.3/48	62.8/47
CT14	16.0/12	51.0/48	61.3/47
NNPDF3.0	20.0/12	57.6/48	62.1/47
HERAPDF2.0	15.1/12	55.5/48	60.8/47
ABM12	14.1/12	57.9/48	53.5/47

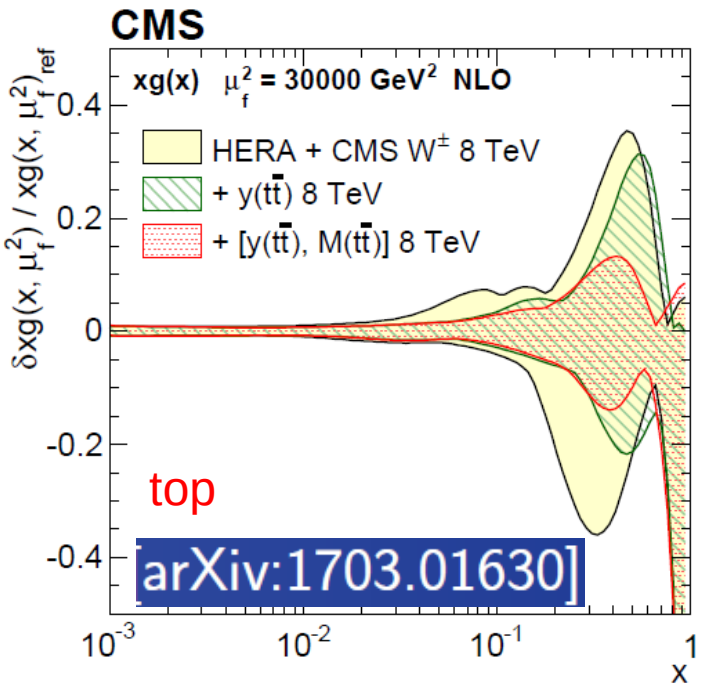


This is also the basis of the **profiling method** for determining the impact of new data sets on current PDFs

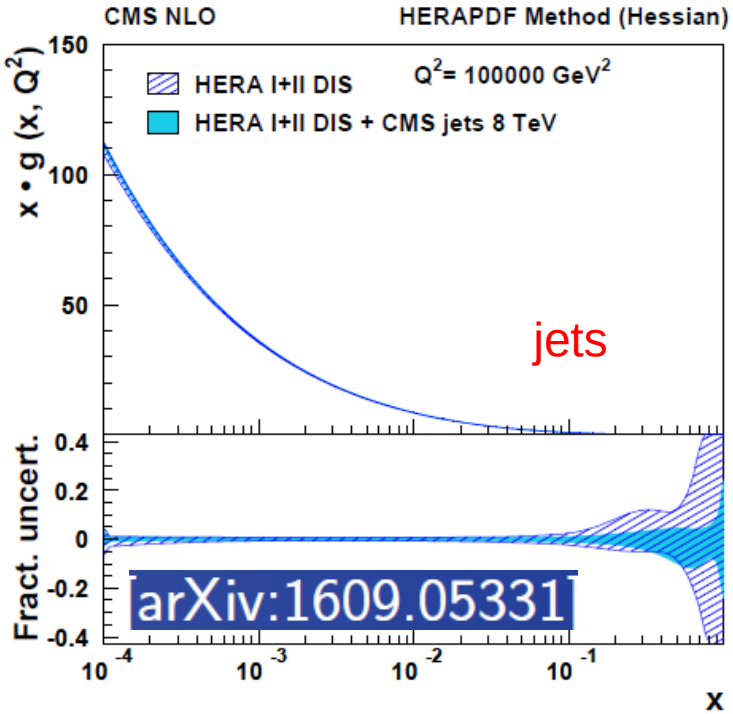
The **NNPDF reweighting method**, which weights replica PDFs according to their Goodness of fit is also implemented in xFitter. Here High Mass Drell-yan data are used to reweight the NNPDFqed photon

Inputting new data sets to a PDF fit to assess –and improve- their impact

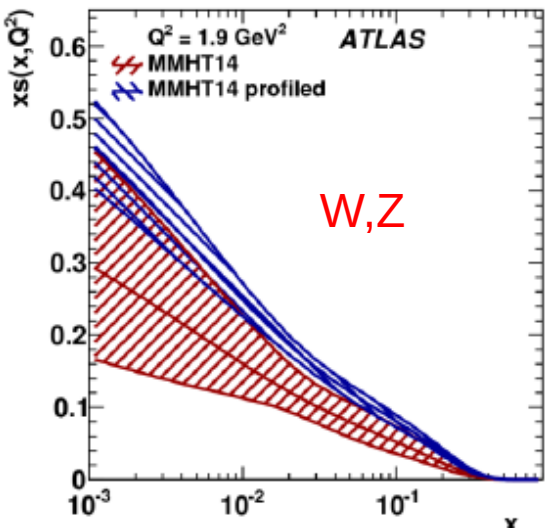
Both CMS and ATLAS have added top data, jet data and W,Z data to the HERA data to asses their impact.

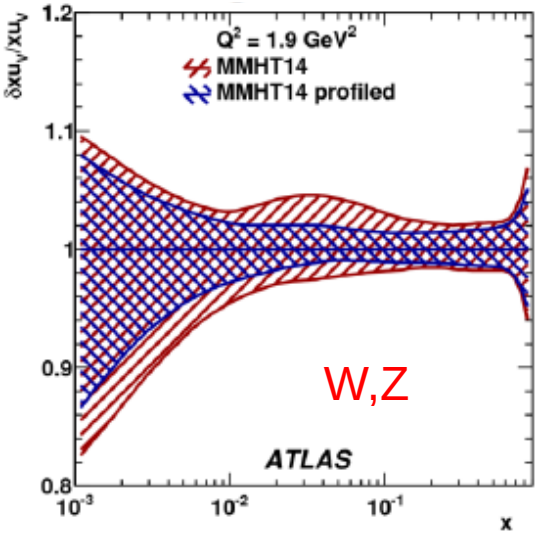


Improving gluon PDF



Improving valence PDFs and
Determining strangeness fraction
arXIV:1612.03016

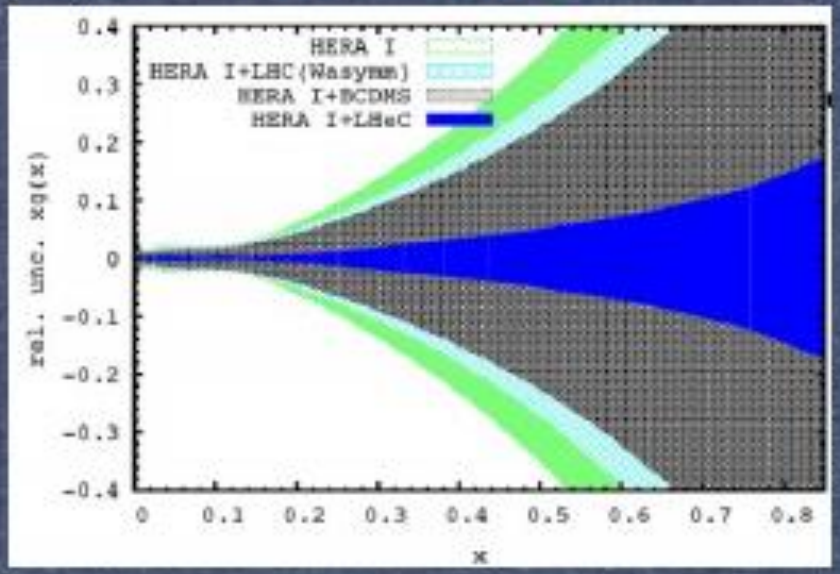




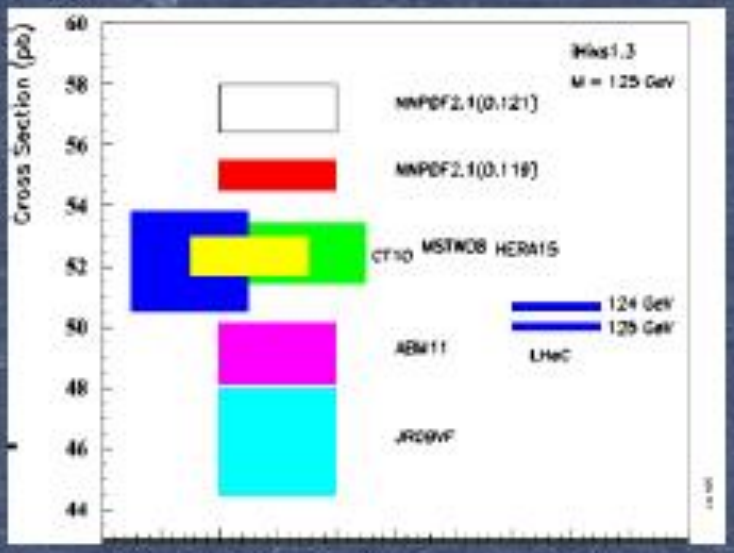
Sensitivity Studies

Platform can be used for sensitivities studies of the potential of future colliders:

- LHeC ep simulated data was used for to study sensitivity to PDFs:



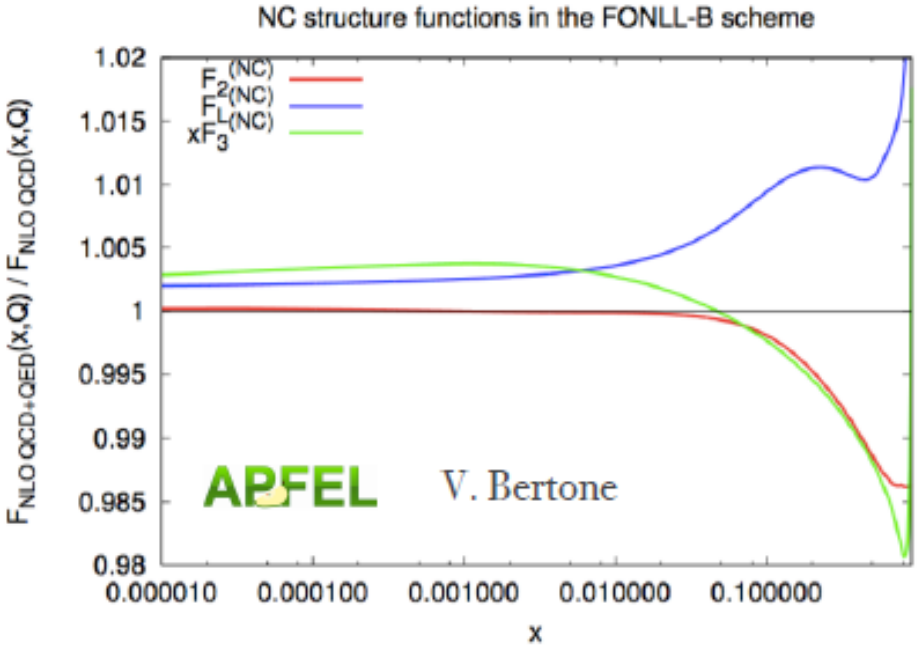
- The output in LHAPDF format can be used for Higgs predictions:



(Journal of Phys. G 39 (2012))

New Physics Cases in xFitter

- NLO QCD+QED via APFEL in xFitter:
  - At NLO QED, access to new diagrams: **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.

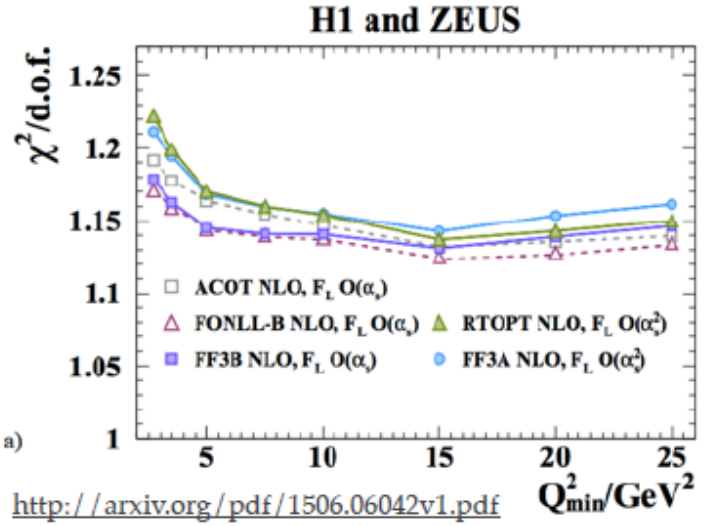


- Possibility to fit for photon PDF:
  - parametrisation form
  - sum rules adjusted

New Physics Cases in xfitter (II)

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

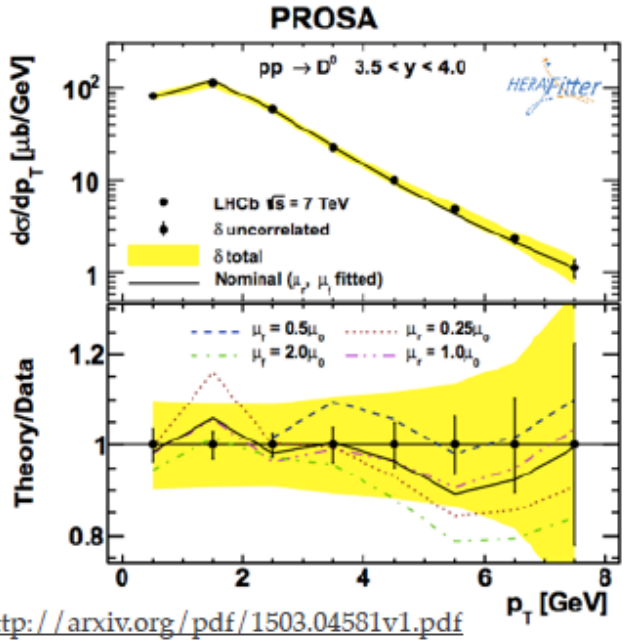
  . http://www-zeuthen.desy.de/~alekhin/OPENQCDRAD.



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



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

- Added extra reweighing options using Giele-Keller weights

New Results by xFitter developers team

APFEL

arXiv.org > hep-ph > arXiv:1701.08553

Search or Art

(Help | Advanced

High Energy Physics – Phenomenology

The photon PDF from high-mass Drell Yan data at the LHC

F. Giuli, xFitter Developers' team: V. Bertone, D. Britzger, S. Carrazza, A. Cooper-Sarkar, A. Glazov, K. Lohwasser, A. Luszczak, F. Olness, R. Placakyte, V. Radescu, J. Rojo, R. Sadykov, P. Shvydkin, O. Zenaiev, M. Lisovyi

(Submitted on 30 Jan 2017)

arXiv.org > hep-ph > arXiv:1605.01946

Search or Art

High Energy Physics – Phenomenology

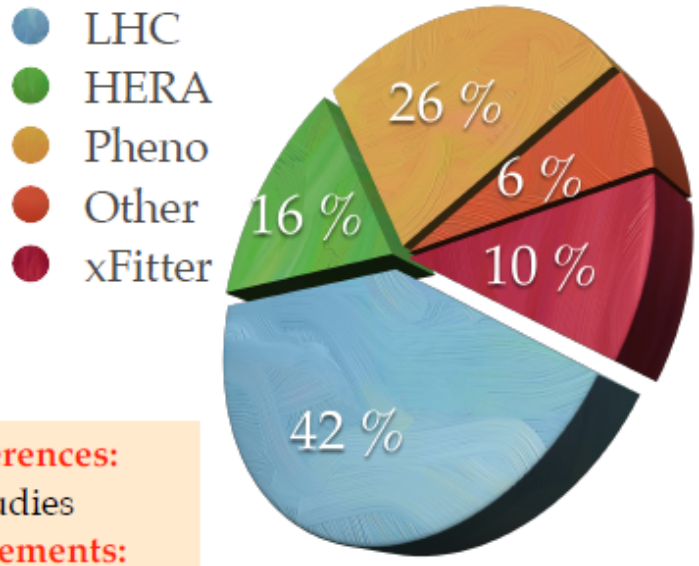
A determination of mc(mc) from HERA data using a matched heavy-flavor scheme

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)

xFitter (former HERAFitter) www.xfitter.org

- **2011 Open Source Revolution:**
  - 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 submitted to JHEP

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-2.0.0 latest release

What did we talk about at Oxford?

- We reviewed PDFs NNPDF/CT/MMHT/ABMP
- We reviewed new relevant data

We discussed tools

QCDNUM, Top++, Hathor, APFEL codes, APFELgrids, links of LHAPDF/HEPDATA/xFitter

- Sharing Grids for predictions
- Sharing k-factors for NNLO/NLO corrections

Developments beyond fixed order predictions, such as:

- pt-resummation/parton showers and TMD PDFs
- Intrinsic charm
- Resummation at low-x and high-x
- EW corrections
- Nuclear PDFs

extras

But where is the information coming from?

Fixed target e/μ p/D data from **NMC, BCDMS, E665, SLAC**

$$F_2(e/\mu_p) \sim \frac{4}{9}x(u+\bar{u}) + \frac{1}{9}x(d+\bar{d}) + \frac{4}{9}x(c+\bar{c}) + \frac{1}{9}x(s+\bar{s})$$

$$F_2(e/\mu_D) \sim \frac{5}{18}x(u+\bar{u}+d+\bar{d}) + \frac{4}{9}x(c+\bar{c}) + \frac{1}{9}x(s+\bar{s})$$

Assuming u in proton = d in neutron – strong-isospin

Also use ν, $\bar{\nu}$ fixed target data from **CCFR, NUTEV, CHORUS** (Beware Fe target needs corrections)

$$F_2(\nu, \bar{\nu}N) = x(u+\bar{u}+d+\bar{d}+s+\bar{s}+c+\bar{c})$$

$$xF_3(\nu, \bar{\nu}N) = x(u_v + d_v) \quad (\text{provided } s = \bar{s})$$

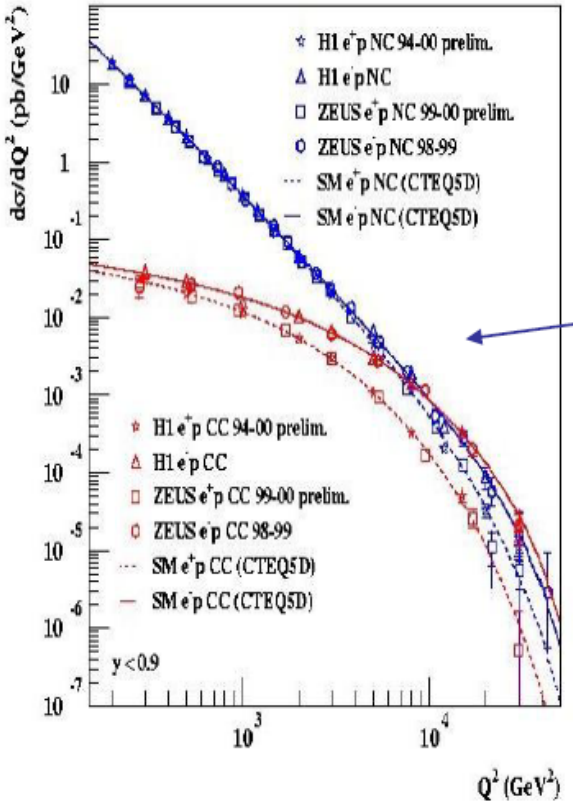
We have 4 equations so we can get ~4 distributions from this:

e.g. u, d, $\bar{u}$, $\bar{d}$ – but need assumptions like $q = \bar{q}$ for all flavours, $\bar{s} = \frac{1}{2}(\bar{u}+\bar{d})$ or even $s = \bar{s} = 0$!, and need heavy quark treatment

(actually heavy quarks can be considered as generated by $g \to q, \bar{q}$ splitting and their distributions are perturbatively calculable- we don't have to guess).

Note gluon enters only indirectly via DGLAP equations for Q^2 evolution

High Q^2 HERA data



HERA data have also provided information at high $Q^2 \rightarrow Z^0$ and $W^{+/-}$ become as important as γ exchange → NC and CC cross-sections comparable

For NC processes

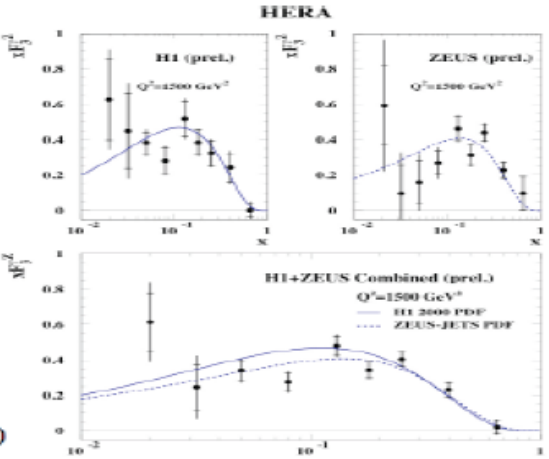
$$F_2 = \Sigma_i \, A_i(Q^2) \, [xq_i(x,Q^2) + x\bar{q}_i(x,Q^2)] -$$

$$xF_3 = \Sigma_i \, B_i(Q^2) \, [xq_i(x,Q^2) - x\bar{q}_i(x,Q^2)]$$

$$A_i(Q^2) = e_i^2 - 2\, e_i\, v_i\, v_e\, P_Z + (v_e^2+a_e^2)(v_i^2+a_i^2)\, P_Z^2$$

$$B_i(Q^2) = -2\, e_i\, a_i\, a_e\, P_Z + 4 a_i\, a_e\, v_i\, v_e\, P_Z^2$$

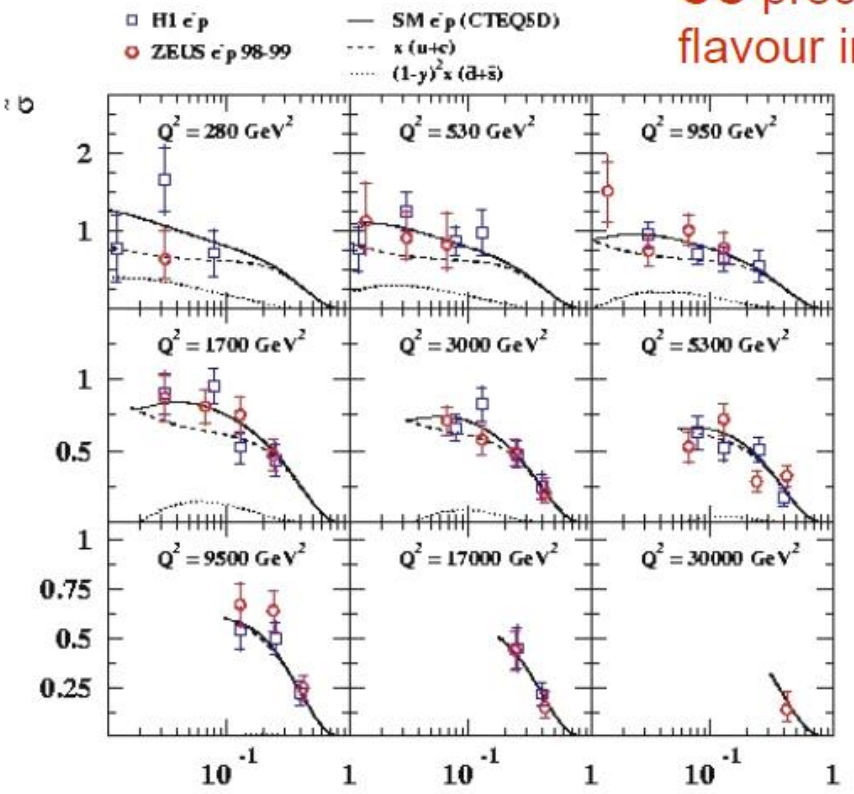
$$P_Z^2 = Q^2/(Q^2 + M^2_Z)\; 1/\sin^2\theta_W$$

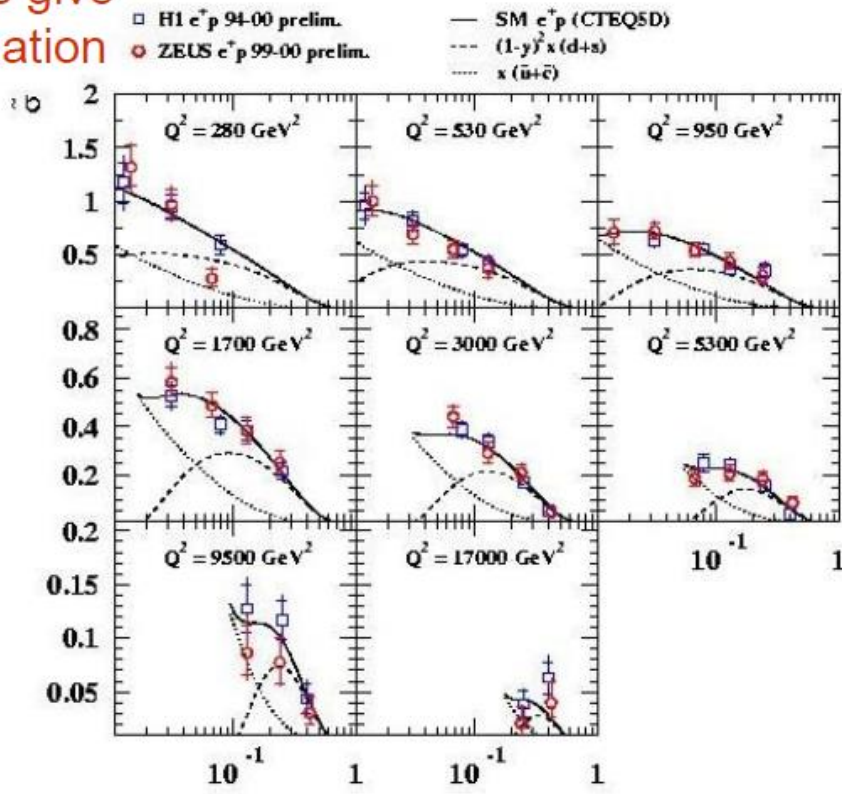


→F2 gives the usual information on the Seas but we also have a new valence structure function xF_3 due to Z exchange

This is measurable from low to high x- on a pure proton target → no heavy target corrections- no assumptions about strong isospin

CC processes give flavour information





$$\frac{d^2\sigma(e^-p)}{dxdy} = \frac{G_F^2 M^4_W [x(u+c) + (1-y)^2 x(\bar{d}+\bar{s})]}{2\pi x(Q^2+M^2_W)^2}$$

u_v at high x

M_W information

$$\frac{d^2\sigma(e^+p)}{dxdy} = \frac{G_F^2 M^4_W [x(\bar{u}+\bar{c}) + (1-y)^2 x(d+s)]}{2\pi x(Q^2+M^2_W)^2}$$

d_v at high x

Measurement of high-x d_v on a pure proton target

d is not well known because u couples more strongly to the photon. Historically information has come from deuterium targets –but even Deuterium needs binding corrections. And you have to assume d in proton = u in neutron

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

Release Notes

xFitter: Releases and Updates

February, 2016

er 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.

se	Date	Description
ter-1.2.0	15.02.2016	• Project renamed from herafitter to xfitter. • Added stand-alone scripts for downloading data/theory files: `getter` . No need of theory directory anylonger, the theory files are now stored under same location with data files. • Change in the executable names: – FitPDF → xfitter – DrawPdfs → xfitter-draw – postproc → xfitter-process • Updated configure.ac to work with latest QCDNUM which is now available with autotools installation (> 17.01.10). – new QCDNUM allows possibility to have more than standard PDFs. • Added QED PDFs via generalised `nxn` convolution engines of QCDNUM. • Added interface to APFEL which provides access to: – evolution code: added DGLAP_APFEL option for standard evolution, or DGLAP_APFEL_QED for QED adjusted evolution. – FONLL heavy flavour schemes with multiple options. • Added interface to n-space code MELA for Mellin Transformation and it is available via configuration flag. • Added direct access to LHAPDFs avoiding QCDNUM: LHAPDFNATIVE option • Added more data formatted for xfitter: updated Tevatron data, LHCb, HERA) • Added `--disable-root` option (root is enabled by default). • Default steering updated to HERAI+II data. • Removed DrawResults package, which was redundant, and added and updated drawing options for data files. • Added fixes to DIS electroweak part of the code. • Fixed several fortran warning messages. • Unifying theory interface for expression between FastNLO and APPLGRID usage. • Updated FastNLO to the latest version • Installation possible with `--prefix` option, added xfitter-config script. • Added MNR calculation code as used for the LHCb and HERA data analysis [Eur.Phys.J. C75 (2015) 8, 396] • Added new options for the reweighting using Giele-Keller weights. Merged common codes between profiling and reweighting. • Fixing lapack and blas tests to give configure errors and stop • Updated the ABM calculations in sync with OPENQCDRAD 2.0b4 • Added possibility to get integrated cross sections for DIS. • Tools/RunJobs and steerings for diffraction adjusted to xFitter.