HERAFitter - an open source QCD fit framework and related studies

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on behalf of the HERAFitter team

DIS 2015, Dallas, Texas, April 27 – May 1

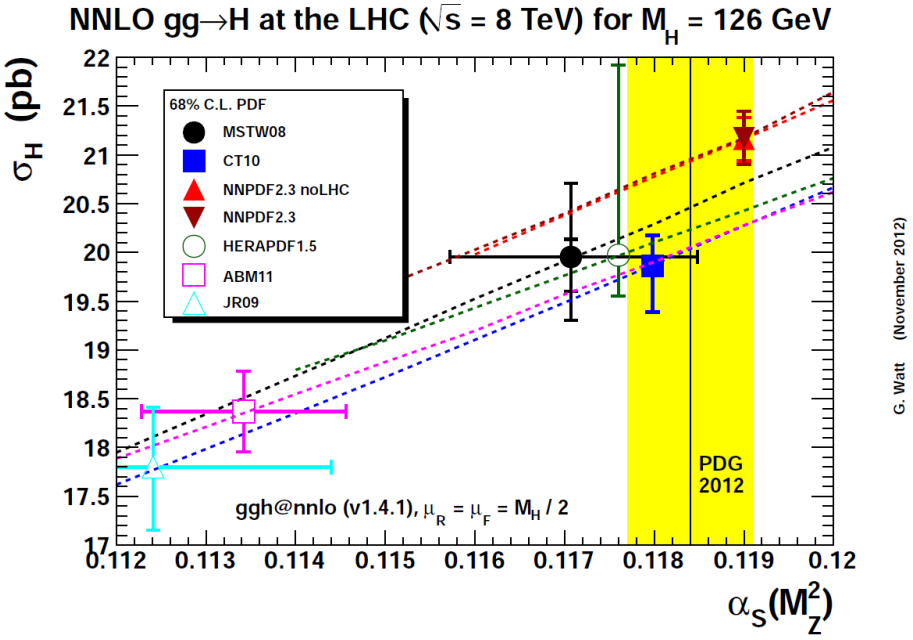
Motivation

PDFs are essential for precision physics at LHC

PDFs are one of main theory uncertainties in Higgs production, M_W, BSM searches, ...

Different PDF fitting groups (CT, MMHT, NNPDF, HERAPDF, ABM, JR) use different data and methodology to extract PDFs

→ lead to differences in the predicted cross sections

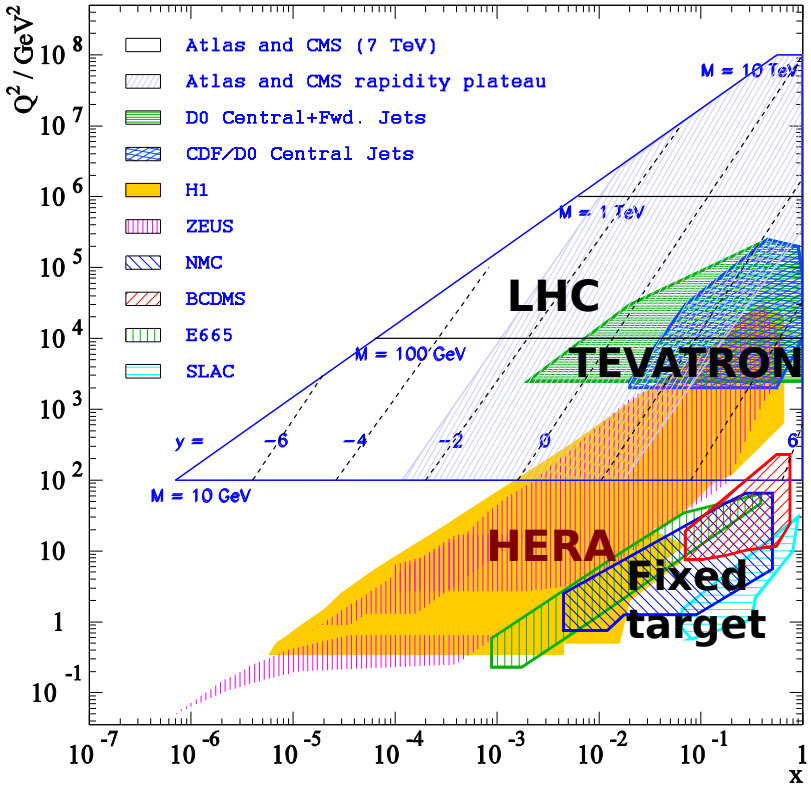


HERAFitter is an open source QCD platform which can be used for benchmarking and understanding such differences

www.herafitter.org

HERAFitter Project

Different experimental data can be used for QCD studies in HERAFitter:



- **LHC**
  - → Drell-Yan
  - → jet production
  - → top quark pair production
- **TEVATRON**
  - → Drell-Yan
  - → jet production
  - → top quark pair production
- **HERA**
  - → inclusive DIS
  - → jet production
  - → diffraction
  - → low-x data
- **Fixed target**

Understanding of the correlations in the measurement is important for the proper inclusion of data into PDF fits

HERAFitter provides tools to test correlations and assess impact of new data on PDFs

HERAFitter: New Release

New release herafitter-1.1.1 is publicly available www.herafitter.org

HERAFitter / DownloadPage

Releases of the HERAFitter 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: HERAFitter_release_notes.pdf .
- Description paper in preparation.

Date	Version	Files	Remarks
02/2015	**1.1.1**	herafitter-1.1.1.tgz	fix release with decoupled theoryfiles-new.tgz
09/2014	1.1.0	herafitter-1.1.0.tgz	release with decoupled theoryfiles-new.tgz
12/2013	1.0.0	herafitter-1.0.0.tgz	stable released with decoupled theoryfiles.tgz
06/2013	0.3.1	herafitter-0.3.1.tgz	fix release includes manual-0.3.1.pdf and decoupled theoryfiles.tgz
03/2013	0.3.0	herafitter-0.3.0.tgz	release includes manual-0.3.1.pdf and decoupled theoryfiles.tgz
07/2012	0.2.1	herafitter-0.2.1.tgz	fix release for 0.2.0
05/2012	0.2.0	herafitter-0.2.0.tgz	added functionality for LHC users
09/2011	0.1.0	herafitter-0.1.0.tgz	first release

Documentation

- Data set Index used in HERAFitter to identify each data set is stored for logging purposes in here.
- From 0.3.0 on a manual is provided together with an example directory.
- The **README** file (accessible via the package) gives an explanation for a quick start.

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Description

- Removed dependence on CERNLIB and related libraries.
- Added interface to `LHAPDFv6.`
- Added more and improved drawing options for visualisation of results.
- Added possibility to deal with multi-dimensional data (virtual grids).
- Additional options in parametrisation styles: added mixed forms between HERA style for gluon and sea and CTEQ style for valence.
- Added new data from Tevatron, ATLAS and CMS.
- Added improvements and more flexibility in the χ^2 and covariance matrix code: possibility to transform into nuisance representation for data with uncertainties given in the covariance form.
- Included a new fastNLO version, which was generalised in order to accommodate DiffTop grids.
- Added DiffTop grids via fastNLO.

Results Obtained with HERAFitter

https://www.herafitter.org/HERAFitter/HERAFitter/results

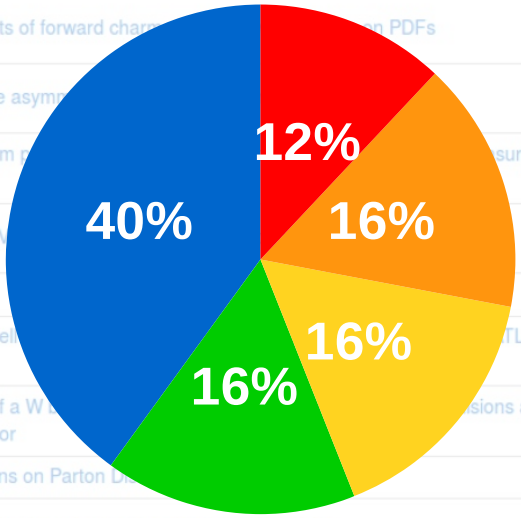
List of analyses by HERAFitter

NEW 03.2015	**HERAFitter team**	to be submitted to EPJC, arXiv:1503.05221	QCD analysis of W- and Z-boson production at Tevatron	Material
10.2014	**HERAFitter team**	submitted to EPJC, arXiv:1410.4412	HERAFitter Open Source QCD Fit Project	
04.2014	**HERAFitter team**	EPJC (2014) 74: 3039, arXiv:1404.4234	Parton distribution functions at LO, NLO and NNLO with correlated uncertainties between orders	Material

List of analyses using HERAFitter

	Date	Group	Reference	Title
	NEW 10.2014	LHC/ATLAS	ATL-PHYS-PUB-2014-015	Studies of theoretical uncertainties on the measurement of the mass of the W boson at the LHC
	NEW 10.2014	LHC/CMS	arXiv:1410.6765 (CMS-SMP-12-028)	Constraints on parton distribution functions and extraction of the strong coupling constant from the inclusive jet cross section in pp collisions at sqrt(s) = 7 TeV
	NEW 09.2014	LHC/ATLAS	arxiv:1406.7844	Comprehensive measurements of t-channel single top-quark production cross sections at s√=7 TeV with the ATLAS
Theory	NEW 09.2014	M.Guzzi, K.Lipka, S-O.Moch	arxiv:1406.0386	production at hadron colliders: differential cross section and phenomenological
	NEW 08.2014	PROSA	preliminary	of the LHCb measurements of forward charm on PDFs
	NEW 08.2014	LHC/CMS	PRD 90 (2014) 032004 / arXiv:1312.6283	Measurement of the muon charge asymm
	05.2014	HERA/ZEUS	arxiv:1405.6915	Measurement of beauty and charm p surement of the beauty quark mass
	05.2014	ggH benchmark HERAPDF, CT, NNPDF, MSTW	arxiv:1405.[illegible]	Les Houches 2013: Physics at TeV
	04.2014	HERA	preliminary	HERAPDF2.0
	04.2014	LHC/ATLAS	EPJC (2014) 112, arXiv:1404.1212	Measurement of the low-mass Drell detection
	02.2014	LHC/ATLAS	JHEP05(2014)068, arXiv:1402.6263	Measurement of the production of a W sqrt(s)=7 TeV with the ATLAS detector
Theory	01.2014	R. Sadykov	arXiv:1401.1133	Impact of QED radiative corrections on Parton D
Theory	01.2014	F. Hautmann and H. Jung	Nucl. Phys. B 883, 1, PLBv736:293, 2014, arXiv:1312.7875	Transverse momentum dependent gluon density from DIS precision data

25 public results obtained with HERAFitter since the beginning of the project (end of 2011)



HERAFitter General Paper

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04.2014	**HERAFitter team**	EPJC (2014) 74: 3039, arXiv:1404.4234	Parton distribution functions at LO, NLO and NNLO with correlated uncertainties between orders	Material

HERAFitter

Open Source QCD Fit Project

S. Alekhin[1,2] · O. Behnke[3] · P. Belov[3,4] · S. Borroni[3] · M. Botje[5] · D. Britzger[3] · S. Camarda[3] · A.M. Cooper-Sarkar[6] · K. Daum[7,8] · C. Diaconu[9] · J. Feltesse[10] · A. Gizhko[3] · A. Glazov[3] · A. Guffanti[11] · M. Guzzi[3] · F. Hautmann[12,13,14] · A. Jung[15] · H. Jung[3,16] · V. Kolesnikov[17] · H. Kowalski[3] · O. Kuprash[3] · A. Kusina[18] · S. Levonian[3] · K. Lipka[3] · B. Lobodzinski[19] · K. Lohwasser[1,3] · A. Luszczak[20] · B. Malaescu[21] · R. McNulty[22] · V. Myronenko[3] · S. Naumann-Emme[3] · K. Nowak[3,6] · F. Olness[18] · E. Perez[23] · H. Pirumov[3] · R. Plačakytė[3] · K. Rabbertz[24] · V. Radescu[3] · R. Sadykov[17] · G.P. Salam[25,26] · A. Sapronov[17] · A. Schöning[27] · T. Schörner-Sadenius[3] · S. Shushkevich[3] · W. Slominski[28] · H. Spiesberger[29] · P. Starovoitov[3] · M. Sutton[30] · J. Tomaszewska[31] · O. Turkot[3] A. Vargas[3] · G. Watt[32] · K. Wichmann[3]

arXiv:1410.4412

Abstract `HERAFitter` is an open-source package that provides a framework for the determination of the parton distribution functions (PDFs) of the proton and for many different kinds of analyses in Quantum Chromodynamics (QCD). It encodes results from a wide range of experimental measurements in lepton-proton deep inelastic scattering and proton-proton (proton-antiproton) collisions at hadron colliders. These are complemented with a variety of theoretical options for calculating PDF-dependent cross section predictions corresponding to the measurements. The framework covers a large number of the existing methods and schemes used for PDF determination. The data and theoretical predictions are brought together through numerous methodological options for carrying out PDF fits and plotting tools to help visualise the results. While primarily based on the approach of collinear factorisation, `HERAFitter` also provides facilities for fits of dipole models and transverse-momentum dependent PDFs. The package can be used to study the impact of new precise measurements from hadron colliders. This paper describes the general structure of `HERAFitter` and its wide choice of options.

HERAFitter Developers Papers

https://www.herafitter.org/HERAFitter/HERAFitter/results

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QCD analysis of W- and Z-boson production at Tevatron

HERAFitter developers' team: S. Camarda[1] · P. Belov[1,2] · A.M. Cooper-Sarkar[3] · C. Diaconu[4] · A. Glazov[1] · A. Guffanti[5] · A. Jung[6] · V. Kolesnikov[7] · K. Lohwasser[8] · V. Myronenko[1] · F. Olness[9] · H. Pirumov[1] · R. Plačakytė[1] · V. Radescu[10] · A. Sapronov[6] · W. Slominski[11] · P. Starovoitov[1] ·

NEW

arXiv:1503.0522

Abstract Recent measurements of the W-boson charge asymmetry and of the Z-boson production cross sections, performed at the Tevatron collider in Run II by the D0 and CDF collaborations, are studied to assess their impact on the proton parton distribution functions (PDFs), using the HERAFitter framework. The Tevatron measurements, together with deep-inelastic scattering data from HERA, are included in a QCD analysis performed at next-to-leading order, and compared to the predictions obtained using other PDF sets from different groups. Good agreement between measurements and theoretical predictions is observed. The Tevatron data provide significant constraints on the d-valence quark distribution.

1 Introduction

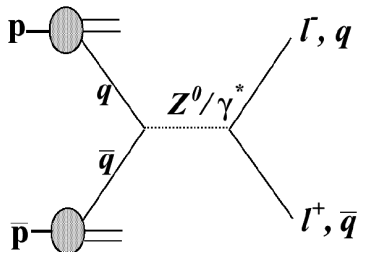
Accurate knowledge of the parton distribution functions (PDFs) is essential for predictions at hadron colliders. The primary source of information on the proton PDFs comes from deep-inelastic scattering (DIS). Measurements at fixed target experiments and at the HERA $e^{\pm}p$ collider provide constraints on the quark and gluon densities, and discrimination of the quark flavours. The DIS proton data mostly constrain the u-type quark density, due to the greater couplings to the photon at low absolute four momentum transfers, Q^2, whereas the d-type quark densities are only constrained at high Q^2 with limited precision. Even more chal-

Motivation

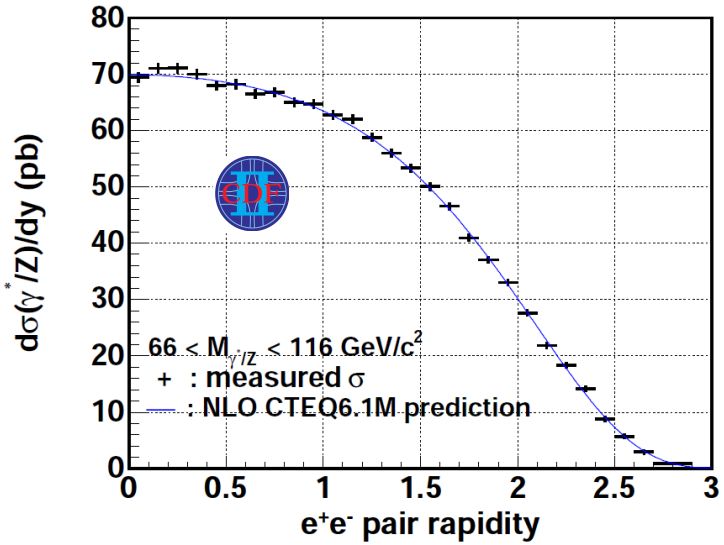
W and Z boson production at Tevatron is valence quark dominated

→ W and Z measurements at Tevatron can be used to improve valence quark PDFs, especially the d-quark type (less constrained by DIS data)

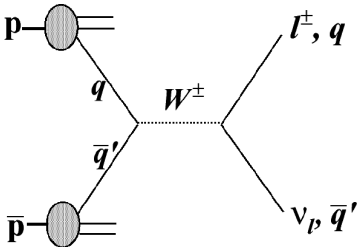
Z rapidity

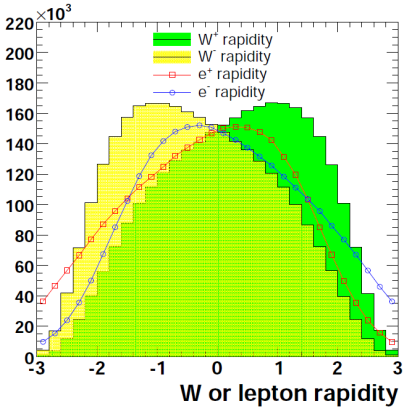


Phys Lett B 692 (2010) 232

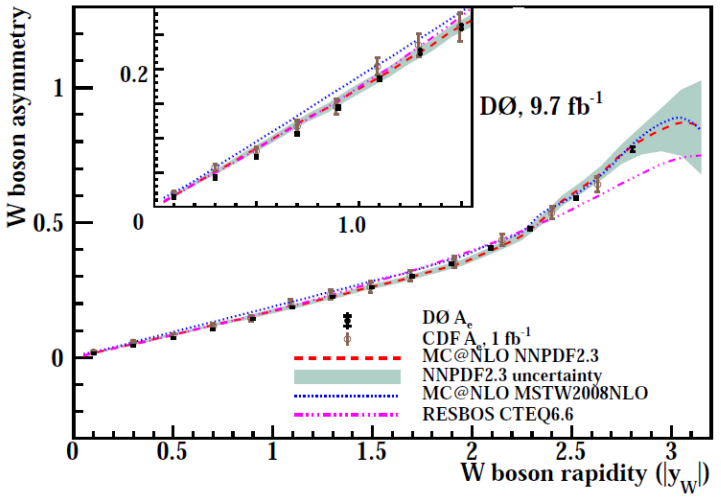


W and lepton charge asymmetry





Phys Rev Lett 112 no15 (2014)151803



W and Z Measurements at Tevatron

Tevatron W and Z production data sets (used in the QCD analysis)

Observable	Experiment	Integrated luminosity	Kinematic requirements	Used in the nominal fit	Ref.
$d\sigma(Z)/dy$	D0	0.4 fb^{-1}	$71 < m_{ee} < 111$ GeV	yes	Phys Rev D 76 (2007) 012003
$d\sigma(Z)/dy$	CDF	2.1 fb^{-1}	$66 < m_{ee} < 116$ GeV	yes	Phys Lett B 692 (2010) 232
A_μ $W \to \mu\nu$	D0	7.3 fb^{-1}	$p_T^\mu > 25$ GeV, $p_T^\nu > 25$ GeV	yes	Phys Rev D 88 (2013) 091102
A_e $W \to e\nu$	D0	9.7 fb^{-1}	$E_T^e > 25$ GeV, $p_T^\nu > 25$ GeV	no	Phys Rev D 91 no3 (2015) 032007
A_W $W \to e\nu$	CDF	1.0 fb^{-1}	none	yes	Phys Rev Lett 102 (2009) 181801
A_W $W \to e\nu$	D0	9.7 fb^{-1}	$E_T^e > 25$ GeV, $p_T^\nu > 25$ GeV	yes	Phys Rev Lett 112 no15 (2014)151803

Revised correlation model:

→ uncertainties of data-driven corrections are treated as bin-to-bin uncorrelated (lepton ID, trigger and charge efficiencies)

(Fast) theoretical predictions: MCFM+APPLGRID

QCD Analysis Settings

In the QCD analysis HERA I data sets (JHEP 1001 (2010) 109) used in a simultaneous fit with Tevatron W and Z production data

Parametrisation functional form:

→ optimisation via paramterisation scan

→ 15 parameter central parametrisation which includes linear and exponential terms

$$
\begin{aligned}
xg(x) &= A_g x^{B_g}(1-x)^{C_g}(1+D_g x)\,; \\
xu_v(x) &= A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}} e^{F_{u_v} x}\,; \\
xd_v(x) &= A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}} e^{F_{d_v} x}\,; \\
x\bar{u}(x) &= A_{\bar{u}} x^{B_{\bar{u}}}(1-x)^{C_{\bar{u}}}(1+D_{\bar{u}} x)\,; \\
x\bar{d}(x) &= A_{\bar{d}} x^{B_{\bar{d}}}(1-x)^{C_{\bar{d}}}(1+D_{\bar{d}} x)\,.
\end{aligned}
$$

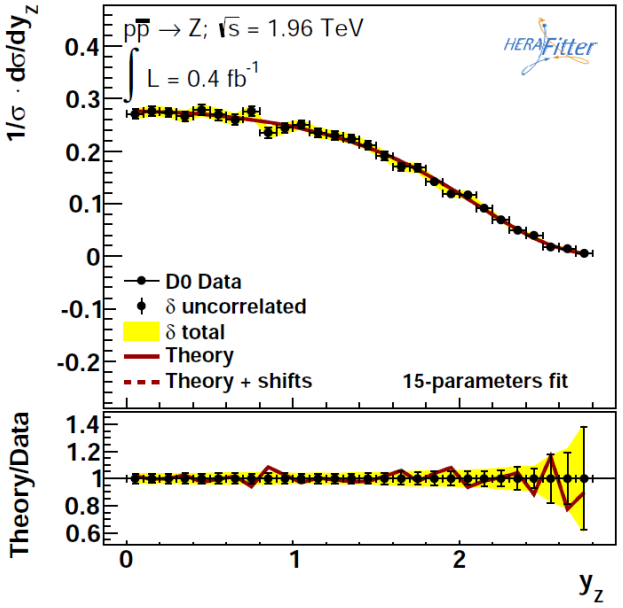
$x\bar{U}=x\bar{u}$ and $x\bar{D}=x\bar{d}+x\bar{s}$ at the starting scale $Q^2 = 1.7\ \mathrm{GeV}^2$ ($x\bar{s}=r_s x\bar{D}$ with $r_s=1.0$)

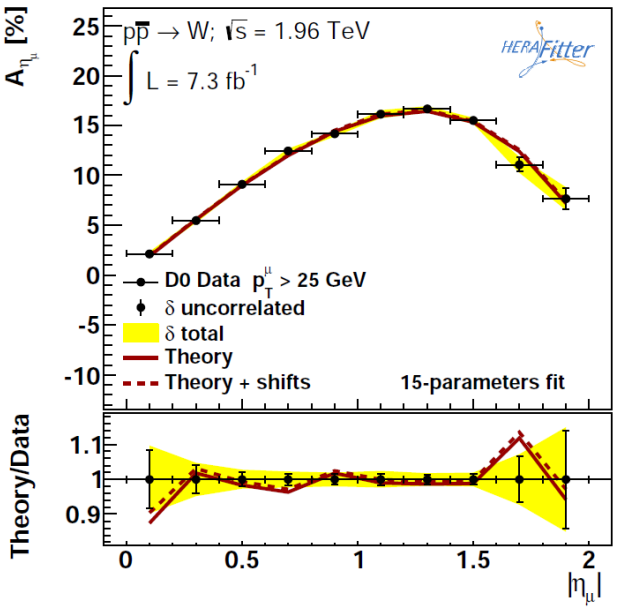
A_g, A_{uv}, A_{dv} are fixed by the sum rules, $B_{\bar{u}}=B_{\bar{d}}$ and $A_{\bar{u}}=A_{\bar{d}}$

QCD Analysis Results

Good total and partial (per data set) χ^2 of the fit:

Data set	HERA I χ^2 / number of points	HERA I + Tevatron W, Z χ^2 / number of points
NC DIS cross sections H1-ZEUS combined e^-p.	112 / 145	109 / 145
NC DIS cross sections H1-ZEUS combined e^+p.	326 / 337	333 / 337
CC DIS cross sections H1-ZEUS combined e^-p.	20 / 34	20 / 34
CC DIS cross sections H1-ZEUS combined e^+p.	27 / 34	31 / 34
HERA I correlated χ^2	21	23
D0 $d\sigma(Z)/dy$	-	23 / 28
CDF $d\sigma(Z)/dy$	-	32 / 28
D0 muon charge asymmetry in $W \to \mu\nu$	-	12 / 10
CDF W charge asymmetry in $W \to e\nu$	-	14 / 13
D0 W charge asymmetry in $W \to e\nu$	-	8 / 14
Total χ^2_{min} / dof	505 / 535	606 / 628



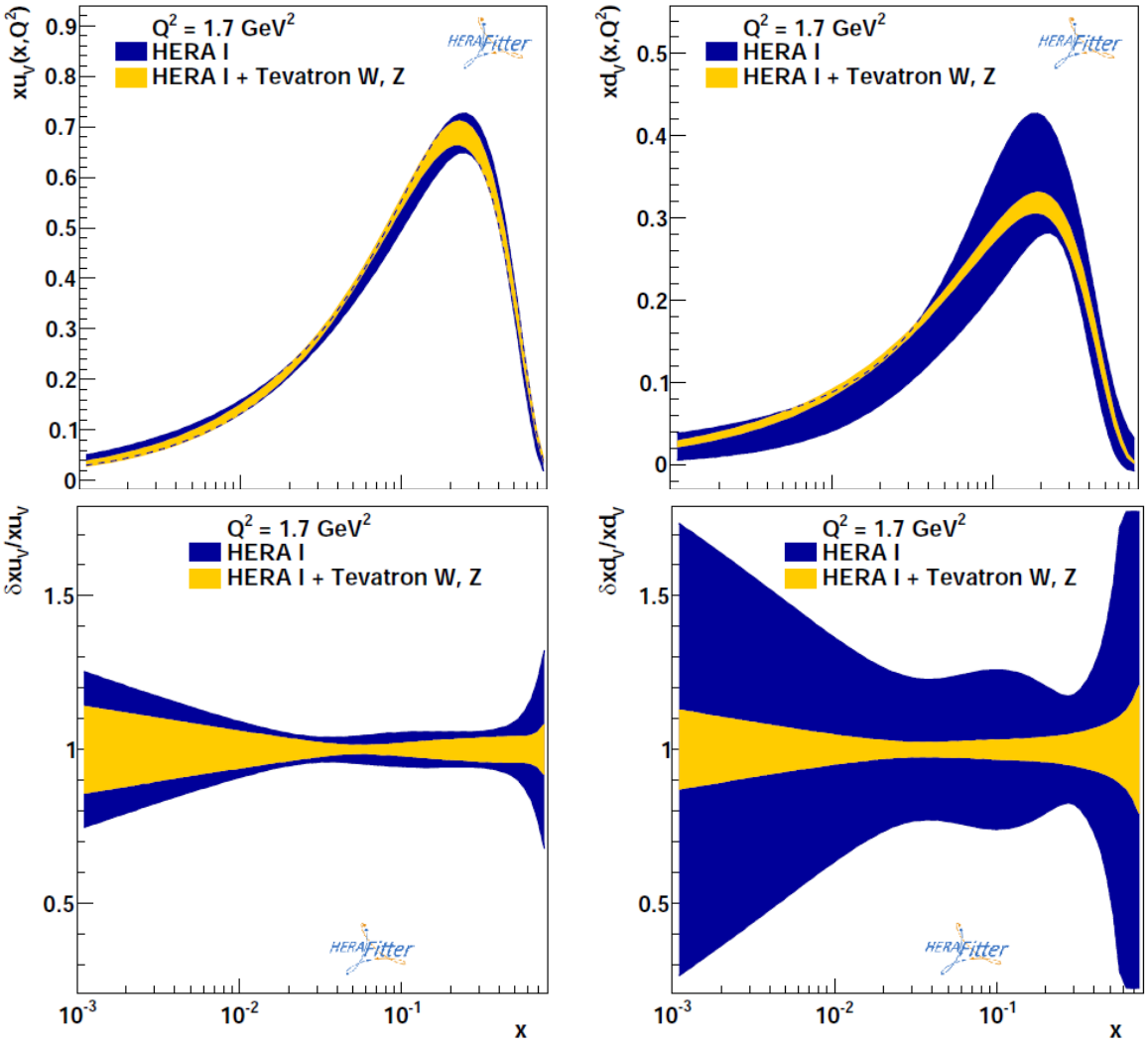


Impact on Valence Quarks

Significant impact of the W and Z boson measurements on the valence quarks and particularly on the d-type quarks

→ comparison of PDFs from a fit to the HERA data alone to a fit to the HERA and Tevatron data

→ after the inclusion of Tevatron data, the uncertainties of u_v and d_v become comparable in size



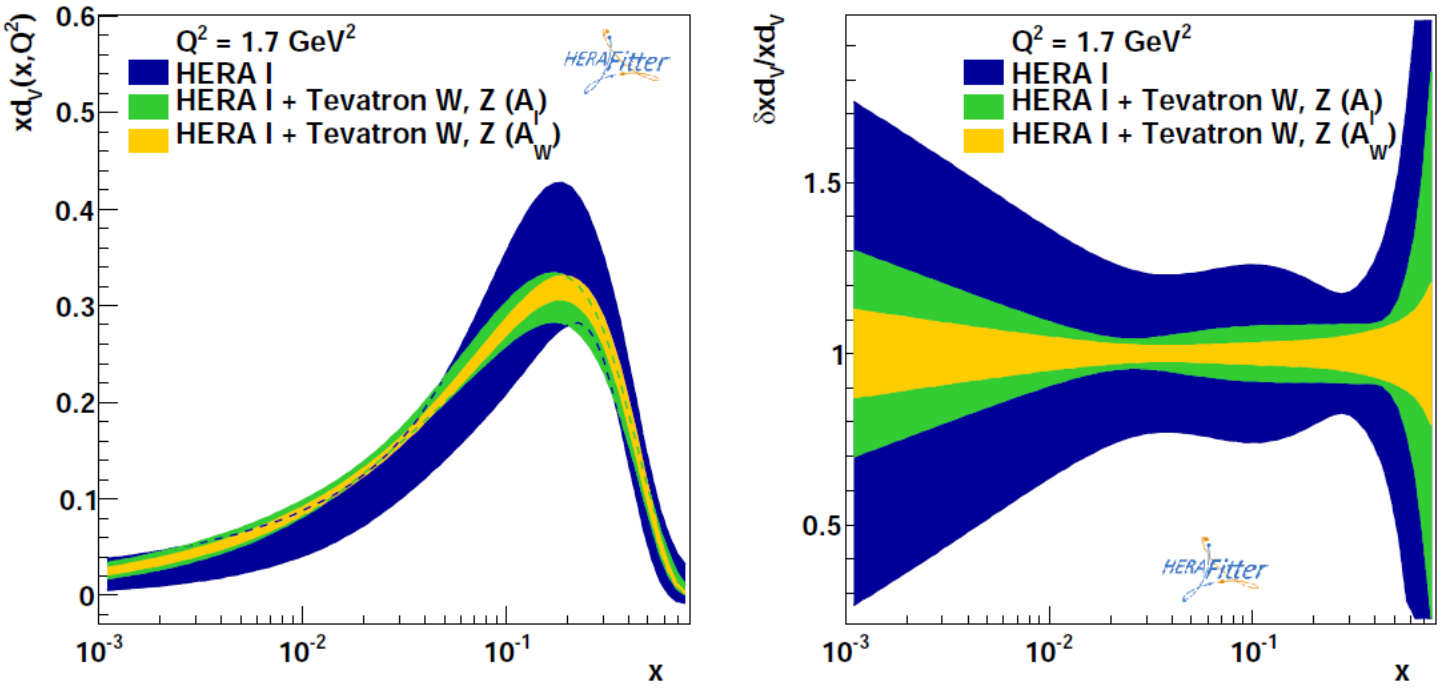
W vs Lepton Charge Asymmetry

W boson charge asymmetries rely on the reconstruction of the W boson rapidity

→ requires assumptions on the longitudinal momentum of the neutrino

→ model dependence is introduced

→ study of possible bias via alternative fit, excluding W and including lepton asymmetries



→ compatible results but larger uncertainties in a fit with lepton asymmetries

Comparison of Tevatron Data with Modern PDFs

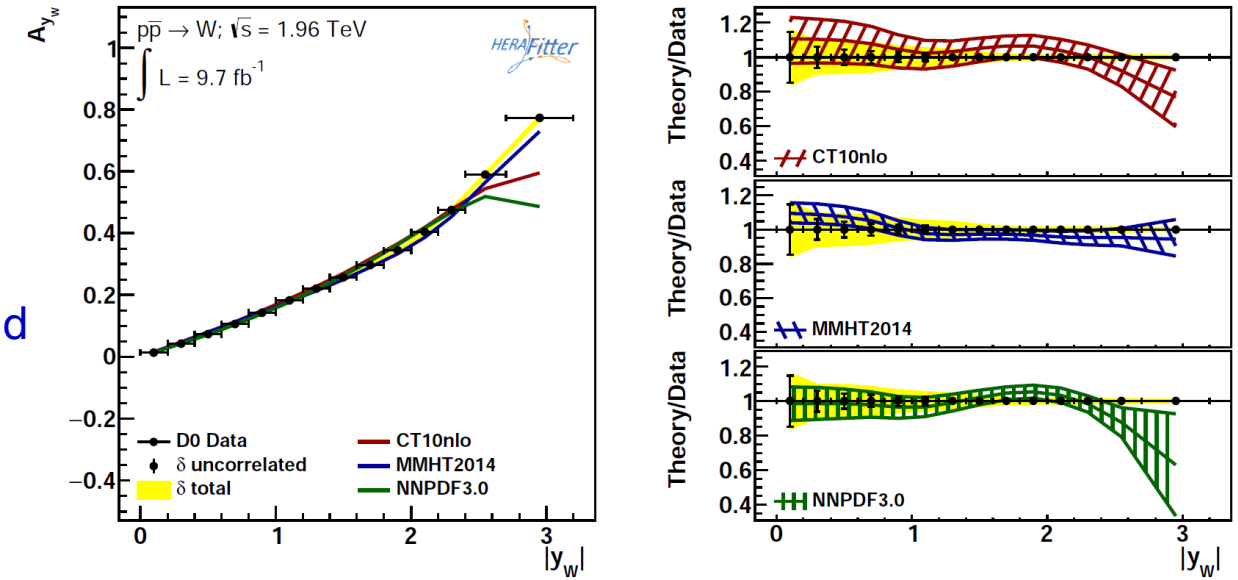
→ consider only the data sets which are not yet included in the PDF fits

w/wo taking into account theory uncertainties: $\chi^2 = \sum_i \left(\frac{\mu_i - m_i \left[1 + \sum_j b_j^{exp} \gamma_{ji}^{exp} + \sum_j b_j^{theo} \gamma_{ji}^{theo} \right]}{\Delta_i} \right)^2 + \sum_j (b_j^{exp})^2 + \sum_j (b_j^{theo})^2$

PDF set	CT10nlo χ^2 / number of points	MMHT2014 χ^2 / number of points	NNPDF3.0 χ^2 / number of points
D0 muon charge asymmetry in $W \to \mu\nu$	13 / 10	-	12 / 10
CDF W charge asymmetry in $W \to e\nu$	14 / 13	-	15 / 13
D0 W charge asymmetry in $W \to e\nu$	8 / 14	5/14	2 / 14
PDF correlated χ^2	3	2	7
Total χ^2 / dof	39 / 37	7 / 14	36 / 37
Total χ^2 / dof without PDFs uncertainties	369/37	25/14	906 / 37

Good description

→ no tension between Tevatron data observed

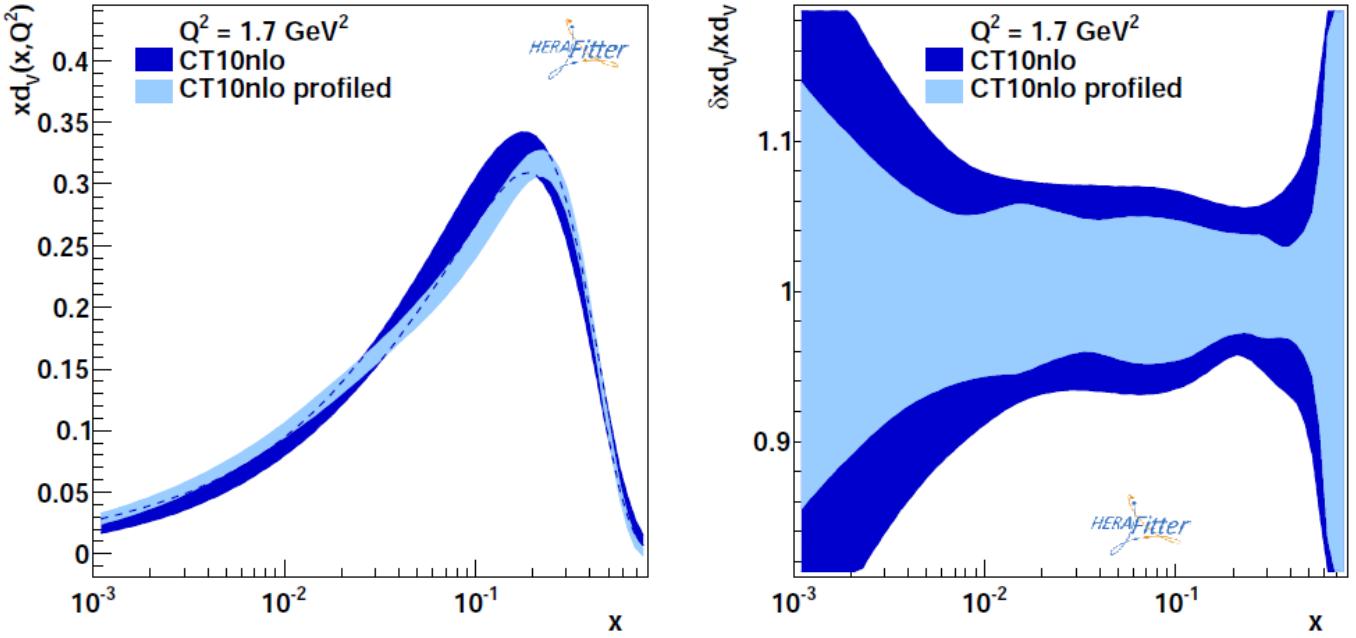


Impact on PDFs Using Profiling Technique

Impact of Tevatron data on PDFs can be studied by minimizing data to theory χ^2 vs nuisance parameters corresponding to PDF eigenvectors ("profiling")

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

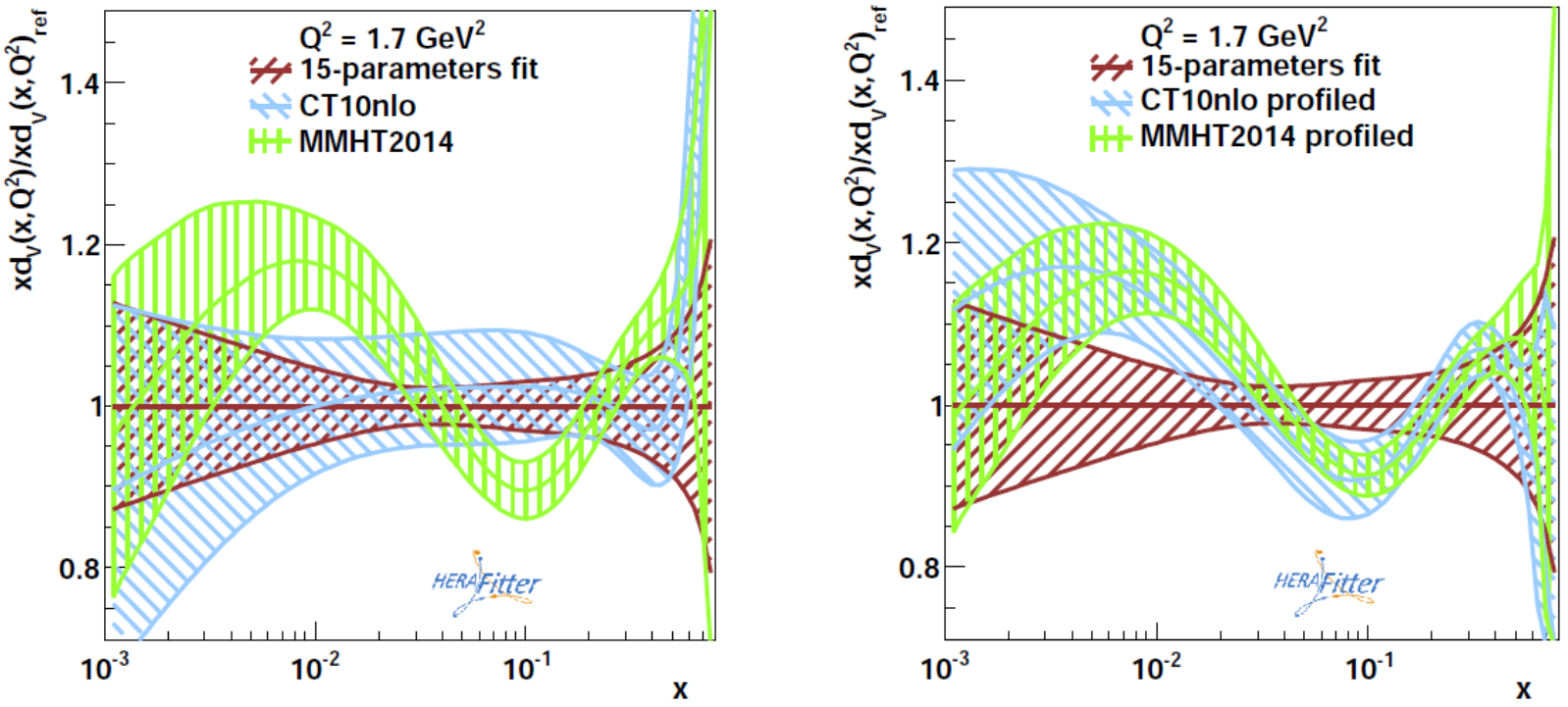
μ_i - data, m_i – theory, β_j^{theo} – nuisance parameters of theory uncertainties (PDF)
(asymmetric uncertainties are taken into account)



→ similar as in PDF fit case, a significant reduction on the d_v quark is observed

Impact on PDFs Using Profiling Technique

Original CT and MMHT PDFs → Profiled CT and MMHT PDFs



only the measurements that are not included in the each of PDF sets are considered for the profiling

→ improved agreement of the d-valence distribution between the MMHT2014 and CT10nlo PDF sets

Summary

HERAFitter project - a multi-functional QCD framework well integrated into the high energy community (both, experimental and theory)

arXiv:1410.4412

→ various physics cases
→ various options for data uncertainty treatment
→ different parametrisation styles

Project is open to everyone and everyone can contribute

Successful inclusion of the latest Tevatron W and Z data in a PDF fit

arXiv:1503.05221

→ highlighting the importance Tevatron data for constraining valence quark PDFs

→ data tables and APPLGRID theory predictions to fit the Tevatron data are available in http://herafitter.org

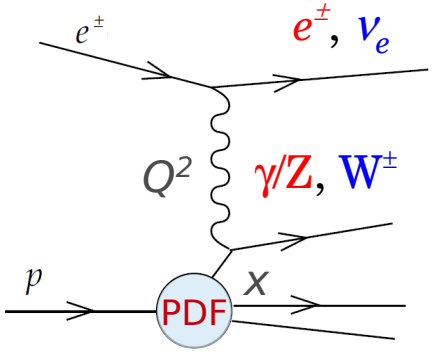
Back-up slides

Motivation

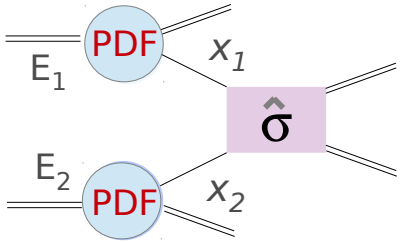
QCD factorisation: hadronic cross section is a convolution of the PDFs and perturbatively calculable hard-scattering coefficients:

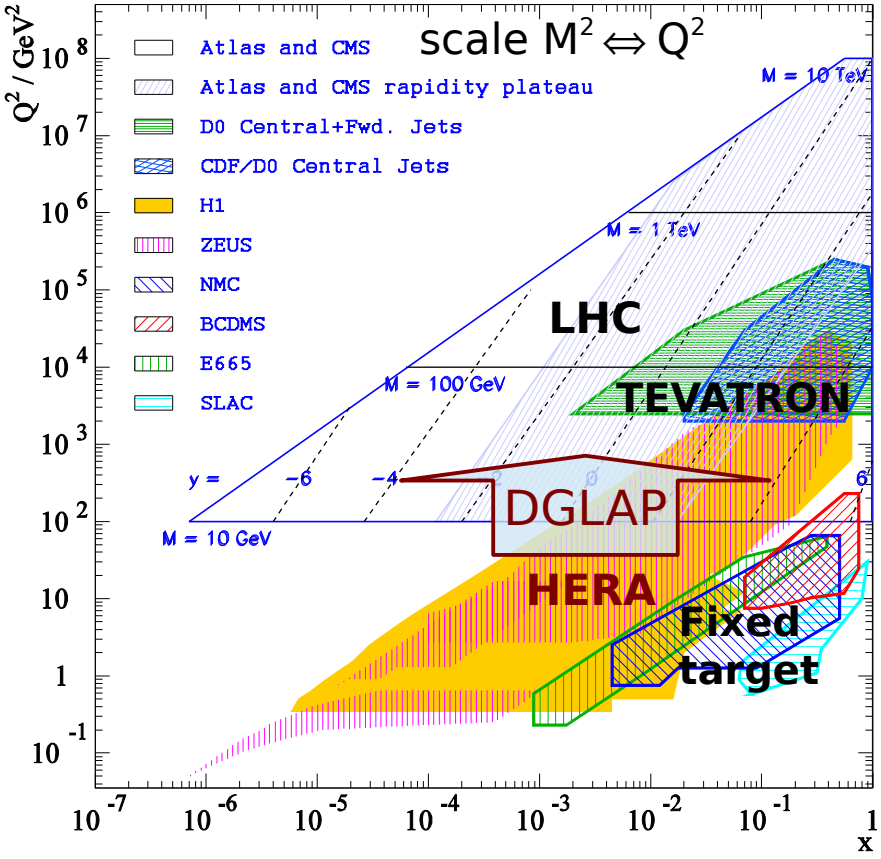
$$\sigma \approx \hat{\sigma} \otimes \text{PDF}$$

Deep Inelastic Scattering (DIS): unique opportunity to study PDFs



same PDFs can be used to predict *pp* collisions

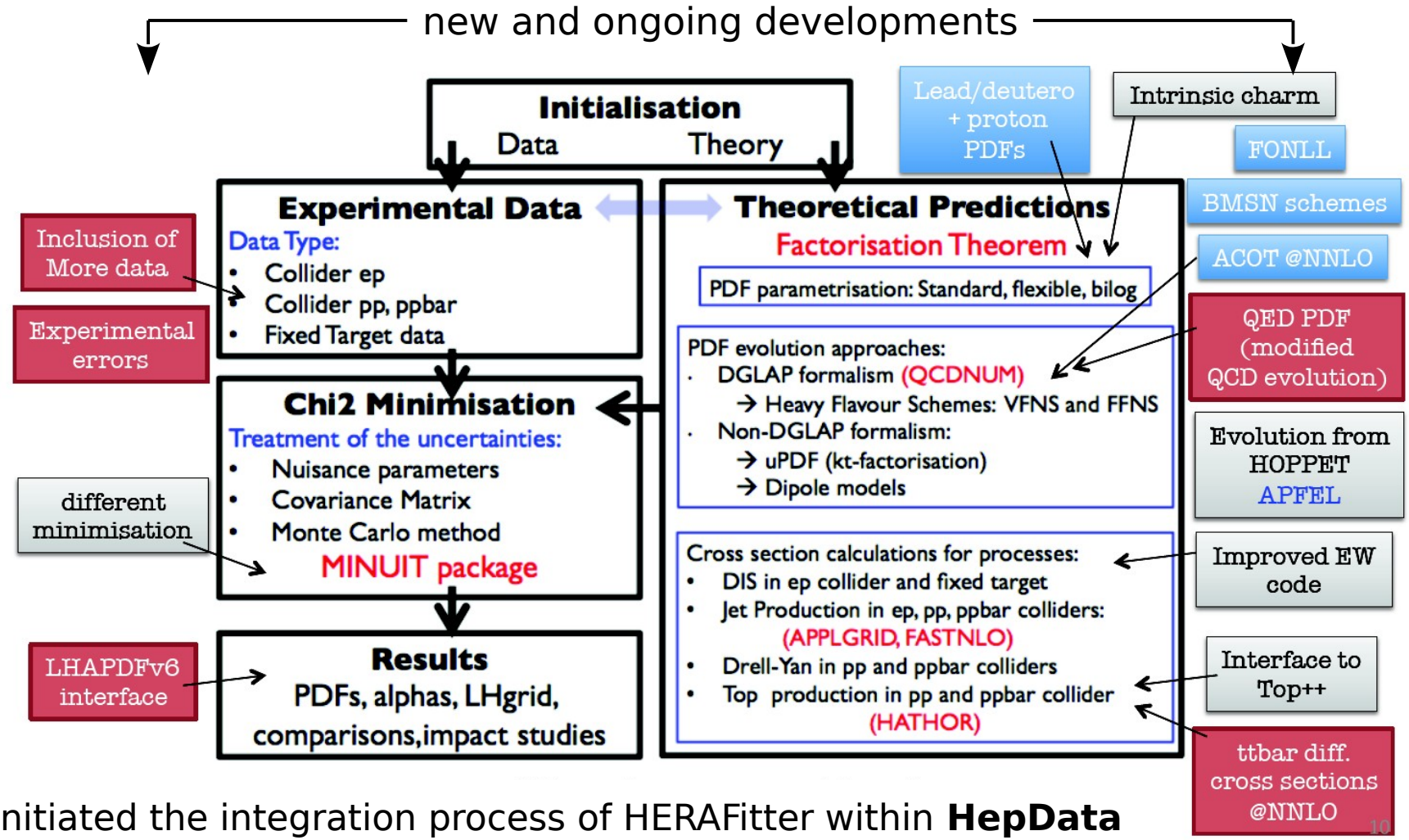




HERAFitter Overview

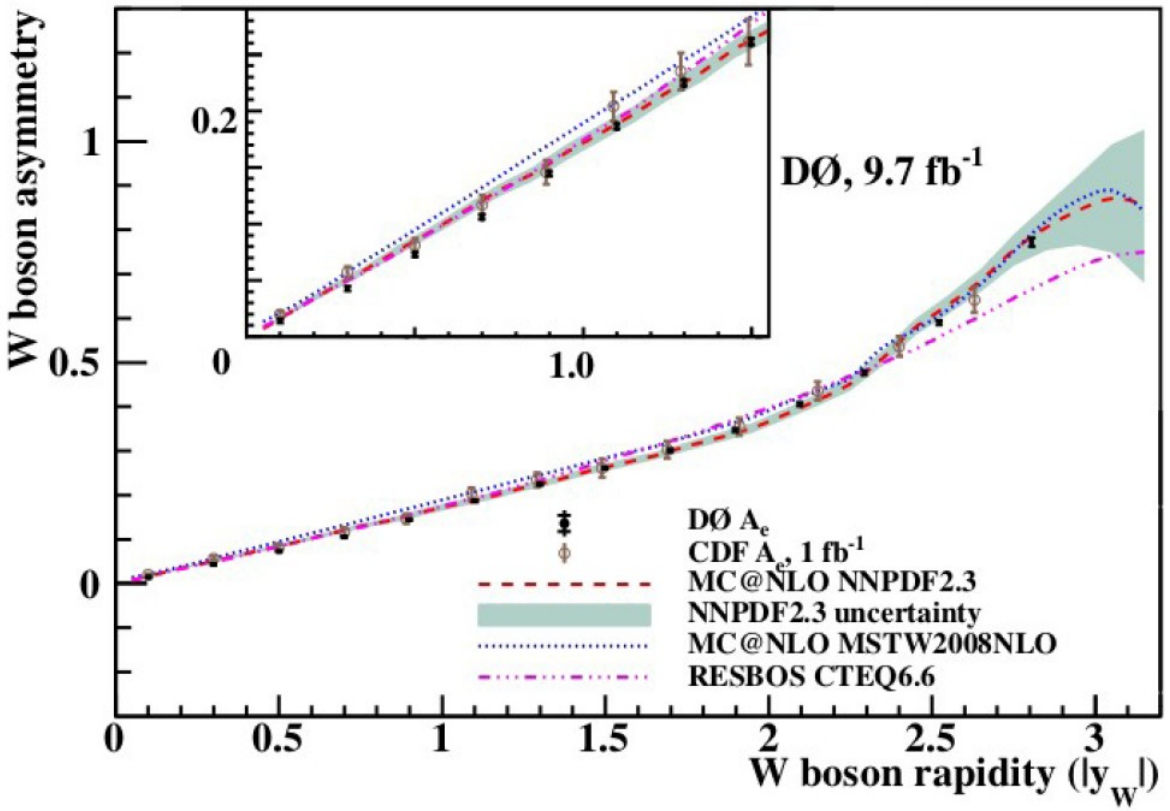
The first HERAFitter stable release (HERAFitter-1.1.0) available since Feb 2015

→ new developments ongoing since then



Initiated the integration process of HERAFitter within **HepData**

Comparison of W Asymmetry in CDF and D0



CDF and D0 measurements are defined in different kinematic space

CDF
no cuts

D0
$E_T(e) > 25$ GeV
$p_T(\nu) > 25$ GeV

Apparent tension between CDF and D0, if the comparison is performed without correcting for the different phase space definitions of the two measurements

S. Camarda, PDF4LHC, Apr 13

PDFs at LO, NLO, NNLO with correlated uncertainties between orders

DESY Report 2014-054

Parton distribution functions at LO, NLO and NNLO with correlated uncertainties between orders

HERAFitter developers' team ·
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C. Diaconu[3] · J. Feltesse[13] · A. Gizhko[1] · A. Glazov[1] · V. Kolesnikov[4] ·
K. Lohwasser[14] · A. Luszczak[5] · V. Myronenko[1] · H. Pirumov[1] ·
R. Plačakytė[1] · K. Rabbertz[6] · V. Radescu[1] · A. Sapronov[4] ·
A. Schöning[10] · S. Shushkevich[1] · W. Slominski[7] · P. Starovoitov[1] ·
M. Sutton[8] · J. Tomaszewska[9] · O. Turkot[1] · G. Watt[11] · K. Wichmann[1]
and M. Lisovyi[1]

Abstract Sets of parton distribution functions (PDFs) of the proton are reported for the leading (LO), next-to-leading (NLO) and next-to-next-to leading order (NNLO) QCD calculations. The parton distribution functions are determined with the HERAFitter program using the data from the HERA experiments and preserving correlations between uncertainties for the LO, NLO and NNLO PDF sets. The sets are used to study cross-section ratios and their uncertainties when calculated at different orders in QCD. A reduction of the overall theoretical uncertainty is observed if correlations between the PDF sets are taken into account for the ratio of WW di-boson to Z boson production cross sections at the LHC.

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1 Introduction

Accurate knowledge of the parton distribution functions (PDFs) of the proton is required for precision physics at the LHC. PDF sets are now available as determined by several groups [1,2,3,4,5,6] at leading-order (LO), next-to-leading-order (NLO) and next-to-next-to-leading-order (NNLO) accuracy in QCD. To obtain the cross-section predictions, the PDF sets should be paired with calculations of the coefficient functions at the matching order of the accuracy. Theoretical uncertainties for the predictions arise from both the PDF and coefficient-function uncertainties.

Most of the Standard Model processes at the LHC are calculated to NLO accuracy. The uncertainties due to missing higher orders for the coefficient functions are typically determined by varying factorisation and renormalisation scales. This leads to large uncertainties often as large as 10% of predicted cross sections, which usually exceed uncertainties due to the PDFs determination. For a handful of processes known at NNLO, the PDF uncertainties often exceed uncertainties due to missing higher orders in coefficient-function calculations.

The experimental precision achieved by the LHC experiments often exceeds the precision of theoretical calculations. Ultimately a more complete set of NNLO calculations should remedy the situation in future. At present, special methods are employed to reduce theoretical uncertainties. One such method is to measure

Motivation

The first **HERAFitter Developers Team** publication

→ addresses the correlations in PDF uncertainties at different orders

Parton distribution functions at LO, NLO and NNLO with correlated uncertainties between orders

HERAFitter developers' team ·
P. Belov[1,12] · D. Britzger[1] · S. Camarda[1] · A.M. Cooper-Sarkar[2] ·
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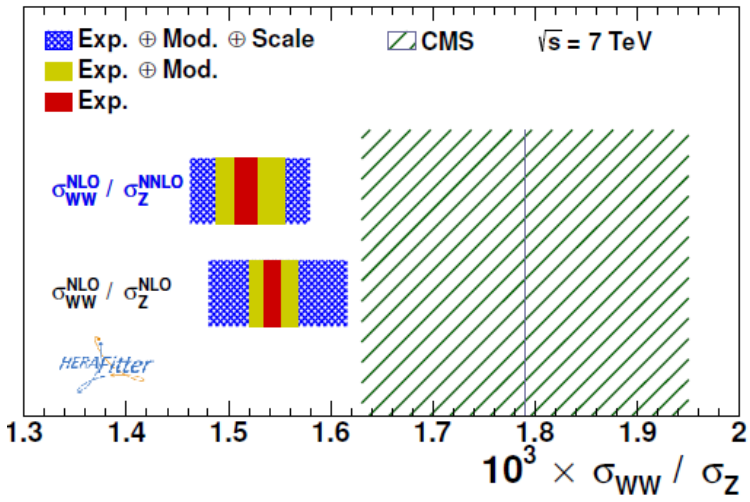
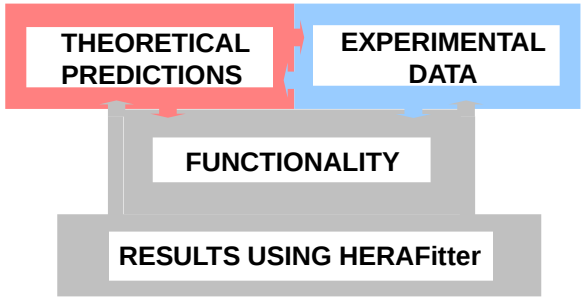
DESY 2014-054
arXiv:1404.4234

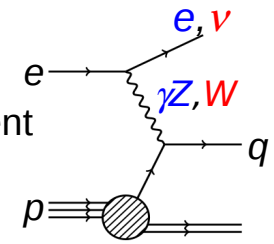
Abstract Sets of parton distribution functions (PDFs) of the proton are reported for the leading (LO), next-to-leading (NLO) and next-to-next-to leading order (NNLO) QCD calculations. The parton distribution functions are determined with the HERAFitter program using the data from the HERA experiments and preserving correlations between uncertainties for the LO, NLO and NNLO PDF sets. The sets are used to study cross-section ratios and their uncertainties when calculated at different orders in QCD. A reduction of the overall theoretical uncertainty is observed if correlations between the PDF sets are taken into account for the ratio of WW di-boson to Z boson production cross sections at the LHC.



Theoretical Predictions



DIS inclusive processes in *ep* and fixed target



DGLAP formalism:

different schemes of heavy quark treatment
VFNS: RT (MSTW), ACOT (CTEQ)
FFNS (pole and running mass)

Electroweak corrections for *ep* scattering

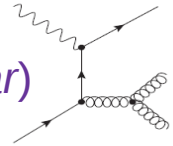
Diffractive PDFs

non-DGLAP formalism:

Dipole Models (GBW, IIM, BGK)
– an alternative approach for the low x region

Unintegrated PDFs
– based on CCFM evolution

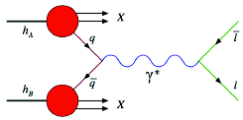
Jet production (*ep, pp, ppbar*)



FastNLO and APPLGRID techniques

- decoupled hard scattering coefficients from PDFs stored on grids

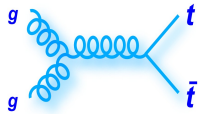
Drell-Yan processes (*pp, ppbar*)



LO calculation x NLO k-factors

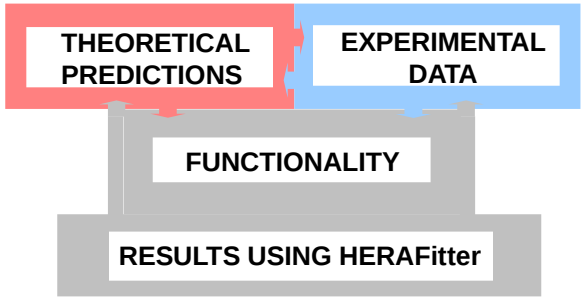
APPLGRID technique

Top pair production



total ttbar cross sections (Hathor)
(approx) differential (DiffTop)

Experimental Data



DIS inclusive processes in *ep* and fixed target

DGLAP formalism:

different schemes of heavy quark treatment
VFNS: RT (MSTW), ACOT (CTEQ)
FFNS (pole and running mass)

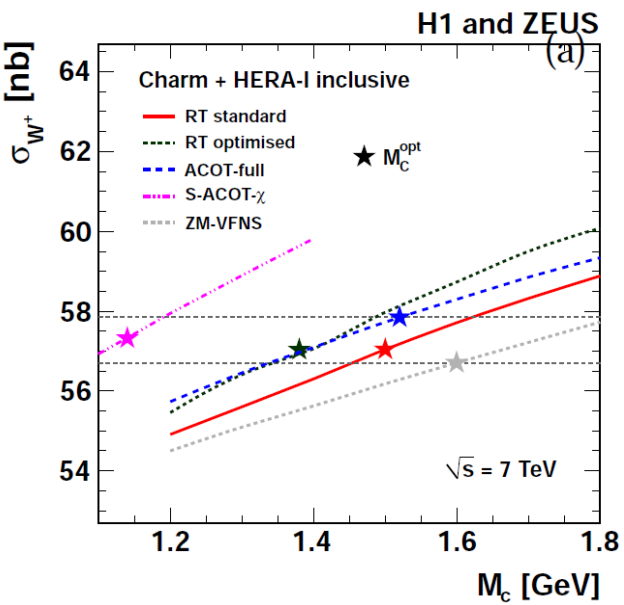
Combination and QCD Analysis of Charm Production in DIS at HERA

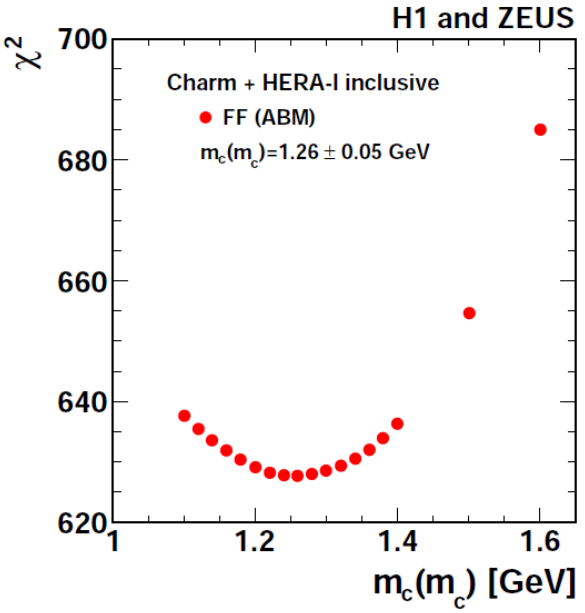
- various heavy flavour schemes and an impact on DY cross sections at LHC studied

  → possible only with HERAFitter

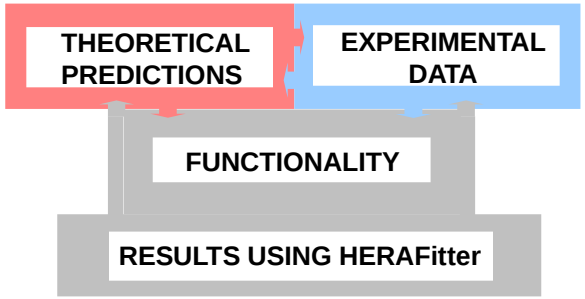
- running mass of charm quark determined

Eur. Phys. J. C73 (2013) 2311





Experimental Data



Drell-Yan processes (*pp, ppbar*)

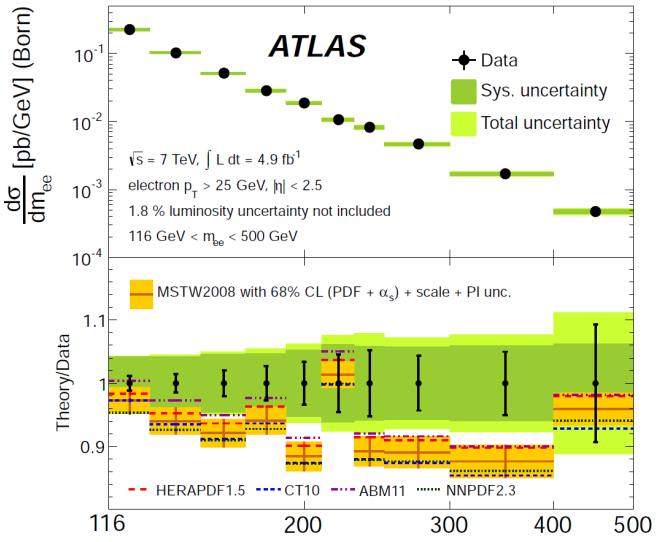
LO calculation x NLO k-factors

APPLGRID technique

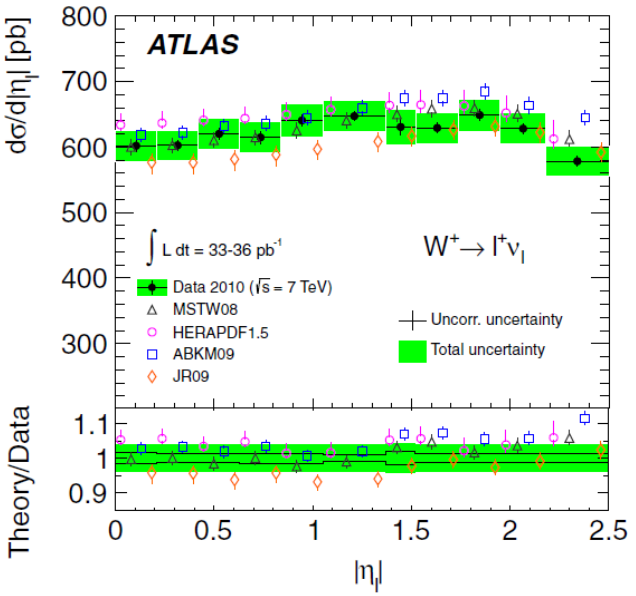
Measurement of the inclusive W and Z/γ cross-section in pp collisions at √s = 7 TeV*

Measurement of the high-mass Drell-Yan differential cross-section in pp collisions at √s = 7 TeV

- comparison with various PDFs
- determination of strange quark density from DY data



Phys. Lett. B 725 (2013) 223



Phys. Rev. D 85 (2012) 072004

HERAFitter Functionality

χ^2 function

→ nuisance parameters:

$$\chi^2 = \sum_i \frac{\left(D_i - T_i^*\right)^2}{\left(\delta_i^{unc}\right)^2} \qquad T_i^* = T_i + \sum_j \xi_j \delta_i^{cor.}$$

Correlated error

Nuisance parameter

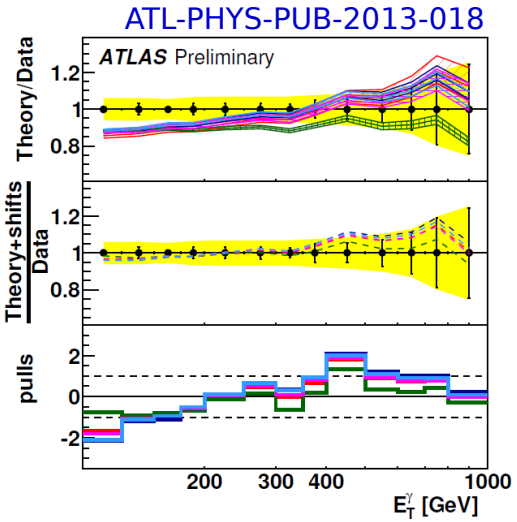
→ covariance matrix:

$$\chi^2 = \sum_{i,j} \left(D_i - T_i\right) Cov_{i,j}^{-1} \left(D_j - T_j\right)$$

→ mixed:

$$\chi^2 = \sum_{ij}^{N} \left(D_i - T_i - \sum_k^K r_k \beta_{ik} \right) C_{ij}^{-1} \left(D_j - T_j - \sum_k^K r_k \beta_{jk} \right)$$

Example:



	$\alpha_{EM} = 1/137$	1-loop running α_{EM}
CT10	52.6 (33.4)	44.9 (26.5)
MSTW2008	39.3 (32.3)	33.2 (25.9)
ABM11_5N	20.5 (20.2)	11.2 (11.1)
HERAPDF1.5	37.7 (32.6)	33.1 (27.5)
NNPDF2.3	39.5 (33.1)	37.3 (30.7)

Various types of the uncertainty treatment for data:

Hessian - error inflation by a tolerance (nuisance) parameter

Monte Carlo - MC replica method shifting data cross sections randomly within their uncertainties

Offset – correlated sources accommodated in uncertainties

Various forms of ansatz

→ HERAPDF, CTEQ style, Chebyshev, bi-log normal

HERAFitter Functionality

Interface to LHAPDF (v5 and v6):

Available PDFs in LHAPDF: HERAPDF1.0, HERAPDF1.5, ATLAS-epWZ12, LHECNLO(v5)

Drawing tools:

→ comparison of different PDFs

→ data to theory (or vs) ratio, shifts

→ printing of χ^2s and pulls, parameter values

→ drawing uncertainty bands (data and theory)

→ different options for result saving formats (root, pdf, eps, …)

Example:

recent studies of theoretical uncertainties for the measurement of the mass of the W boson at the LHC

ATL-PHYS-PUB-2014-015