HERAFitter Status and Plans

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on behalf of the HERAFitter's developers team

PDF4LHC, Benasque, 19.02.2015

HERAFitter Project: *www.herafitter.org*

HERAFitter Project was initiated in 2011 as a necessity to transfer the legacy and expertise on proton structure from HERA to LHC.

arXiv.org > hep-ph > arXiv:1410.4412

Search or Article-id

High Energy Physics - Phenomenology

HERAFitter, Open Source QCD Fit Project

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(Submitted on 16 Oct 2014 (v1), last revised 7 Nov 2014 (this version, v2))

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.

Comments: 18 pages, 8 figures
Subjects: **High Energy Physics - Phenomenology (hep-ph)**
Report number: DESY Report 14-188
Cite as: **arXiv:1410.4412 [hep-ph]**

HERAFitter provides a framework for:

- addressing theoretical differences and benchmarking
- studying impact / consistency of new data on PDFs

HERAFitter Project: *www.herafitter.org*

HERAFitter developers are

- collaborating with PDF groups (ABM, CT, MSTW, NNPDF)
  - ➔ Benefiting from expertise
  - ➔ Following recent developments
  - ➔ Implement calculation schemes from the PDF groups, maintain and arrange open access for them

- in contact both with ATLAS and CMS Fit Forums
  - ➔ making sure the latest measurements important for PDFs are implemented in the HERAFitter as they come out
  - ➔ adding functionalities such that HERAFitter is covers the needs of experiments

HERAFitter Structure

Modular structure of HERAFitter:

Initialization

Input Data

Data Type:
- collider ep
- collider pp, ppbar
- fixed target

Theory Predictions

Factorisation Theorem:
- PDF parametrisation
- QCD evalution
- cross section calculation

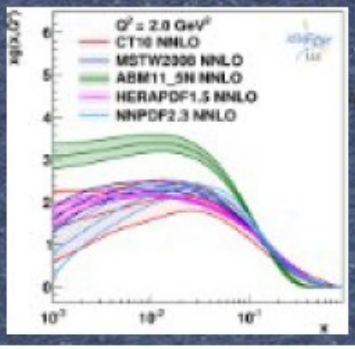
Minimisation

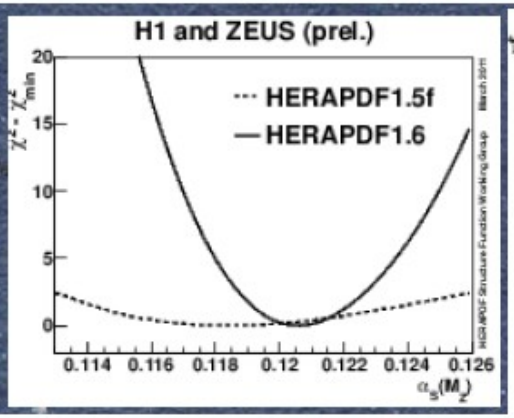
Treatment of uncertainties:
- Nuisance parameters
- Covariance matrix
- Monte Carlo method

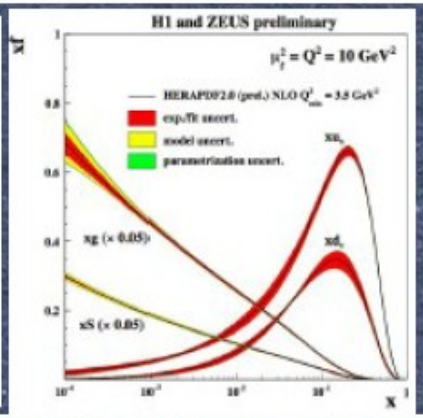
- Performance: 15min – 2h
- Fast tools needed to perform PDF fits: APPLGRID, FASTNLO

Results

- LHAPDF grids
- alphas, mc, …
- data to theory comparison
- χ^2, shifts, pulls







HERAFitter Releases

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

Date	Version	Files
02/2015	**1.1.1**	herafitter-1.1.1.tgz
09/2014	**1.1.0**	herafitter-1.1.0.tgz
12/2013	1.0.0	herafitter-1.0.0.tgz
06/2013	0.3.1	herafitter-0.3.1.tgz
03/2013	0.3.0	herafitter-0.3.0.tgz
07/2012	0.2.1	herafitter-0.2.1.tgz
05/2012	0.2.0	herafitter-0.2.0.tgz
09/2011	0.1.0	herafitter-0.1.0.tgz

Comming soon

Current release

Versioning convention: i.j.k with:

- i – stable release
- j – beta release
- k – bug fix release

Release	Date	Description
`herafitter-1.1.0`	29.09.2014	• 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

Status of the HERAFitter

- Current release herafitter-1.1.0
- Fixes to herafitter-1.1.0: on the way herafitter-1.1.1 —> being tested now
- Fixes and updates included
  - NNPDF reweighting code
    - ➔ Gluon ID differs in LHAPDFv5 and LHAPDFv6, fix makes reweighting work with LHAPDFv6
  - TMD code update
    - ➔ Updated to LHAPDFv6
    - ➔ Extracted required CERNLIB routines
    - ➔ Documentation updates
  - Added drawing options for Diffractive PDFs
  - New data: CMS inclusive jet, ATLAS low and high mass DY
  - Documentation updates

Developments towards HERAFitter-1.2.0

- Interface to APFEL (V. Bertone, S. Carrazza, J.Rojo)
- Features accessed from APFEL
  - ✔ QCD evolution and QCD+QED evolution
    - ➔ Pole and $\overline{\text{MS}}$ masses
    - ➔ Factorization, renormalization scale variation
  - ✔ Low x resummation (high x in future)
  - ✔ Heavy flavour schemes as used by NNPDF
    - ➔ FONLL variants with resummation
- Interface implemented in HERAFitter and being tested now

Developments towards HERAFitter-1.2.0

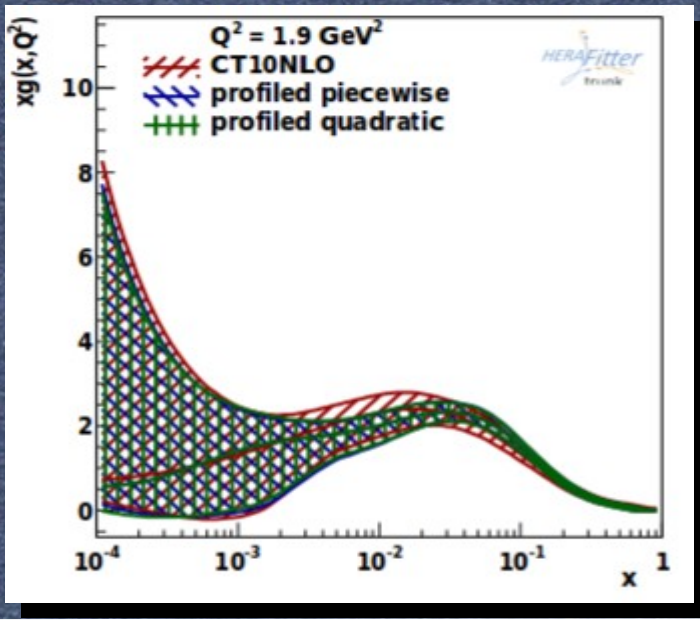
- QED+QCD PDFs (R. Sadykov):
  - ✔ Evolution of PDFs ($q,\bar{q},g,\gamma$) up to NNLO QCD + LO QED in FFNS and VFNS is realised using an add-on to QCDNUM
  - ✔ Cross-checked with MRST2004QED PDF set and APFEL
  - ✔ Currently available with QCDNUM beta version 17.01/0e
  - ➔ Implementation in HERAFitter is ongoing

- Maintaining of packages interfaces to which are not being developed at the moment, i.e. HATHOR
- Updated documentation
- Update user examples

Other Available Tools

A toolbox for manipulating the LHAPDFv6 files

- Symmetrization of PDF set with asymmetric error eigenvectors
- Rotation of PDF set according to "rediagonalization" procedure proposed by J. Pumplin *[arXiv:0904.2424]*
  - Reduces the number of eigenvectors to those essential for a particular observable.
- PDF profiling
  - Effect of data on PDF set is estimated by making a comparison of data to theoretical prediction using a χ^2 function, which treats PDF uncertainties in terms of nuisance parameters

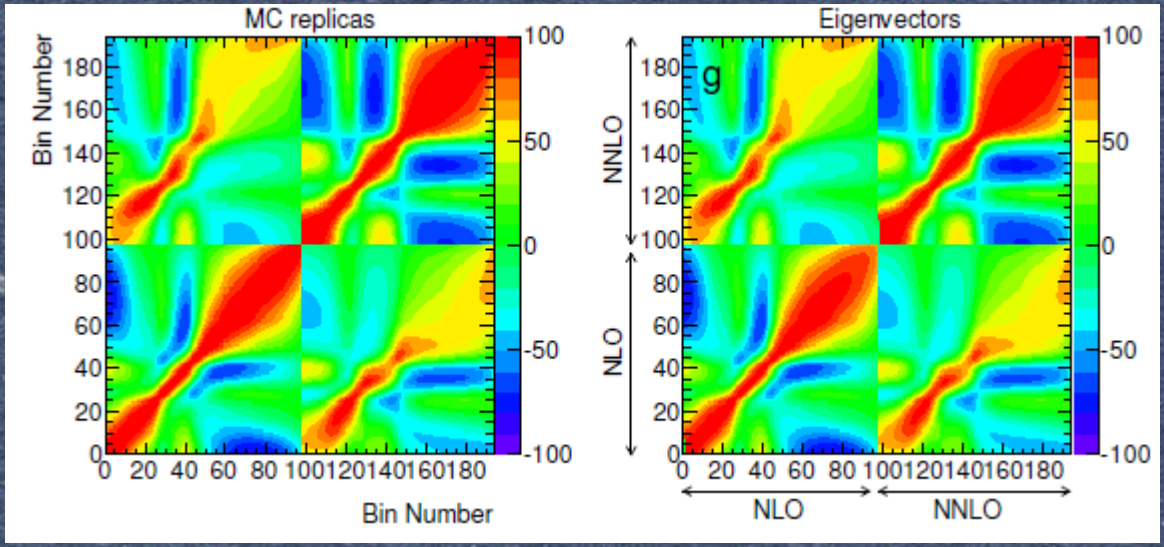


- Operations are performed using LHAPDFv6 grid files directly, at the PDF grid points.
- No additional evolution / interpolation required.

Other Available Tools

Conversion of MC to eigenvector representation preserving correlations:

- Covariance matrix C is build using MC replica for PDFs at the starting scale and 100 x-grid points for the 5 PDF flavours (500 x 500 matrix)
- C is diagonalized using eigenvector decomposition. Only few leading eigenvectors are needed to describe the correlations properly



- The method was successfully used in a publication by HERAFitter developer's team *[arXiv:1404.4234]*

Available Data Sets

- Currently 47 data sets from various experiments (BCDMS, HERA, LHC, Tevatron) are available in HERAFitter, including the latest measurements (i.e. ATLAS high and low mass Drell-Yann, CMS inclusive jets)
- Together with data sets are provided also APPLGrids and FastNLO grids (if required)
- If provided by the experiments, the corresponding correlation models are also included in HERAFitter (i.e. Tevatron W, Z measurements)

Longer Term Plans

- ACOT at NNLO
- Nuclear PDFs
- Intrinsic charm
- Minimization methods alternative to genetic algorithm and minuit
- Generalised parametrisation
  - User-defined functional forms for PDFs instead of predefined parametrisation styles available in steering

Application of HERAFitter

- **HERAPDF2.0** *[ZEUS-prel-14-0071, H1prelim-14-042] see also the talk by A.Cooper-Sarkar*
  - Final combined HERA I+II data used to extract sets of PDFs
- **Transverse momentum dependent gluon density from DIS precision data** *[arXiv:1312.7875]*
  - Combined HERA structure functions measurements are fitted using transverse momentum dependent QCD factorisation and CCFM evolution to extract gluon TMD
- **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** *[arXiv:1410.6765] see also the talk by M.Gouzevitch*
  - Combined α_S and PDF fit to CMS jet and DIS HERA I data, using HERAPDF style and NNPDF style (data driven regularisation) for PDF uncertainty determination
- **Studies of theoretical uncertainties on the measurement of the mass of the W boson at the LHC** *[ATL-PHYS-PUB-2014-015] see also the talk by A.Cooper-Sarkar*
  - χ^2 profiling method to study the effect of PDF uncertainties on the modeling of the low-p_T region of W/Z
- The full list of the results can be found on the website:

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

Summary

- HERAFitter is developing rapidly, more functionality is added frequently
- Data sets that are of a particular interest for PDFs are added to HERAFitter as soon as publicly available, together with all the available information on correlations
- General HERAFitter description paper accepted by EPJC *[arXiv:1410.4412]*
- **Latest release:**
  - herafitter-1.1.0, can be found at *www.herafitter.org*
- **A new releases:**
  - herafitter-1.1.1 release candidate is being tested now, provides fixes to known problems of the current release and includes some additional functionality
  - herafitter-1.2.0 new beta release is being developed