HERAFitter : An Open Source QCD Fit Framework

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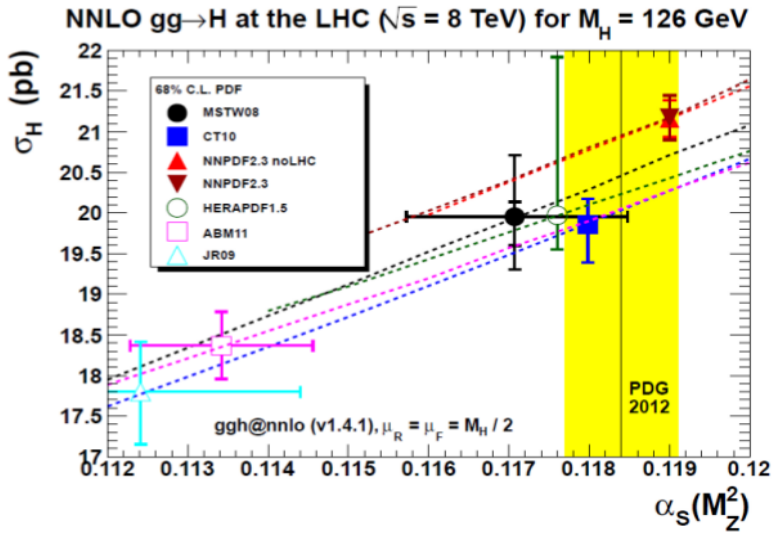
Outline

- Motivation
- Project overview
- HERAFitter functionality
- HERAFitter usage
- Summary

Motivation

- Necessity of a tool to study different data impact on PDFs
- PDF provided by fitting groups (CTEQ, MSTW, NNPDF, HERAPDF, ABM, JR) differs

Which lead to differences in the cross section predictions
PDF is one of the main theoretical uncertainties for Higgs production



(G.Watt, Nov 2012)

HERAFitter is a platform which can be used for studying such differences and produce new PDFs

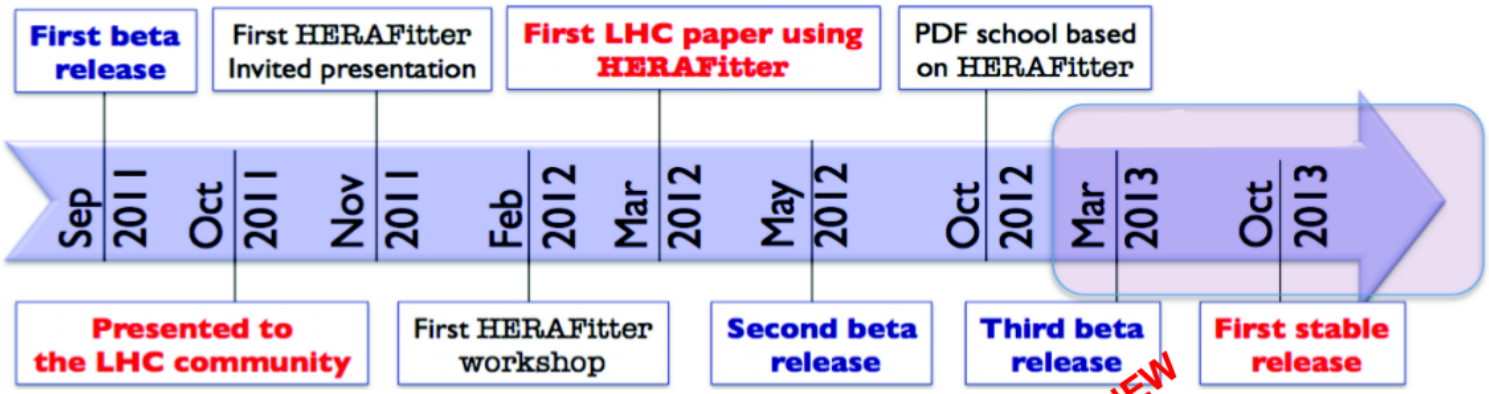
Project overview

open access via **www.herafitter.org** (no registration required)

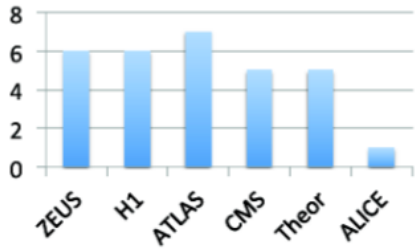
HERAFitter project is an open source QCD fit framework ready to extract PDFs and study the impact of new data

HERAFitter time-line :

HERAFitter project in a time-line:



Developers:



HERAFitter download and documentation

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.

Date	Version	Files (Readme)	Remarks (Detailed write-up)
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

- 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 c

Web access to SVN

- For users with a valid DESY account, the SVN repository is accessible on
- For users without DESY account, the SVN repository is accessible on the

Doxygen Documentation

- The doxygen documentation is located here

Links to external packages that are set to run with HERAFitter:

Package	Description	Remarks
QCDNUM	evolution code	./configure
APPLGRID	interfaced to MCFM, access to jets and DY calculations	./configure --enable-applgrid
LHAPDF	access to global PDFs	./configure --enable-lhapdf
HATHOR	ttbar cross section calculations	./configure --enable-hathor

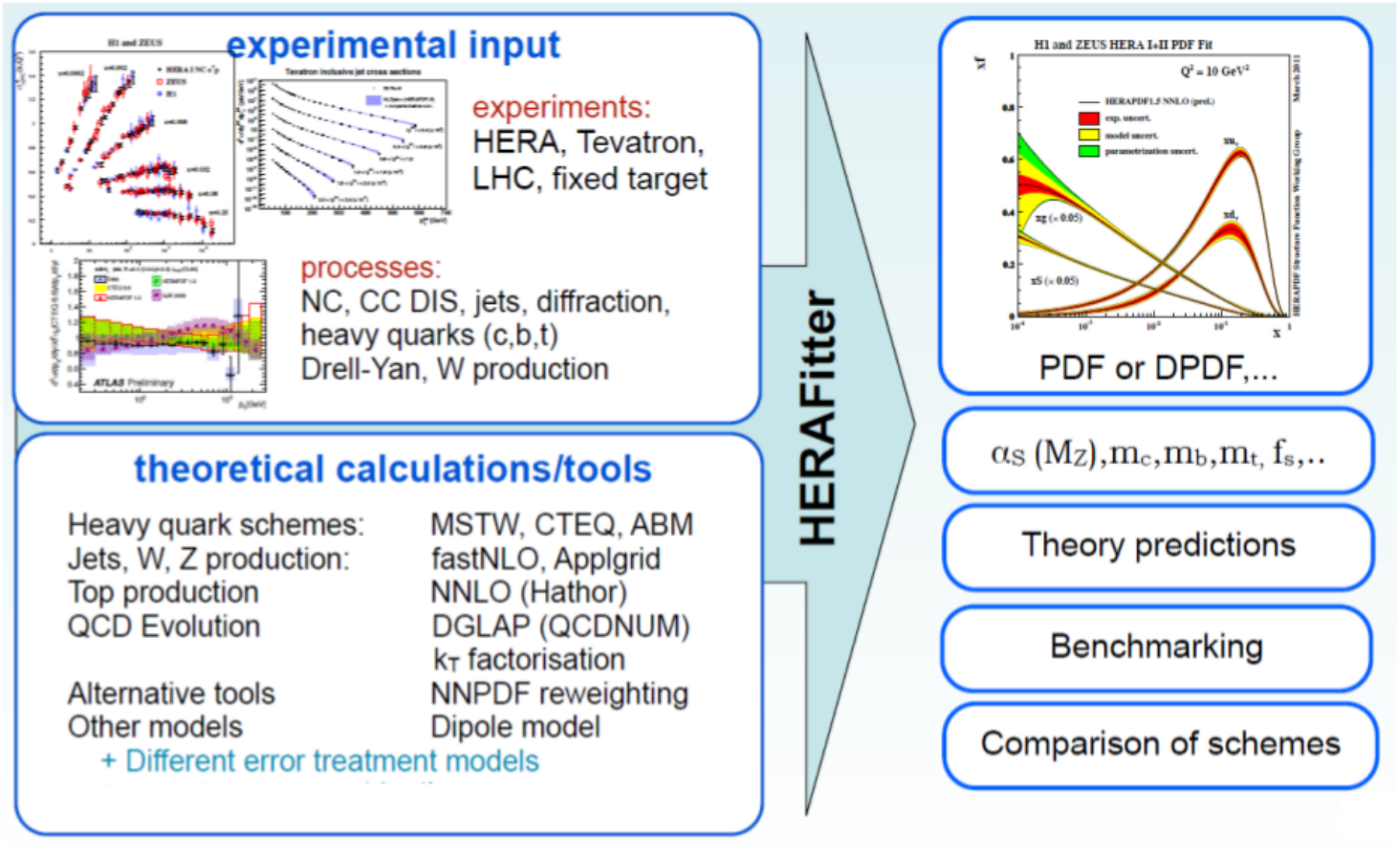
Links to external packages

External packages that could be run with HERAFitter via configuration flags can be accessed for convenience HERE .

HERAverager data combination package

Information can be accessed here https://wiki-zeuthen.desy.de/HERAverager.

HERAFitter structure



HERAFitter functionality : various data uncertainties treatment

Different chisquare representations:

- Simple form : $\chi^2_{exp}(\mathbf{m},\mathbf{b}) = \sum_i \frac{[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i]^2}{(\delta_{i,stat}\mu^i)^2 + (\delta_{i,uncor}\mu^i)^2} + \sum_j b_j^2$
- Scaled form : $\chi^2_{exp}(\mathbf{m},\mathbf{b}) = \sum_i \frac{[m^i - \sum_j \gamma^i_j m^i b_j) - \mu^i]^2}{\delta^2_{i,stat}\mu^i(m^i - \sum_j \gamma^i_j m^i b_j) + (\delta_{i,uncor} m^i)^2} + \sum_j b_j^2 +$ log penalty
- Mixed form (covariance and nuisance parameter): $\chi^2_{exp}(\mathbf{m},\mathbf{b}) =$

$$\sum_{ij}\left(m^i - \sum_l \Gamma^i_l(m^i) b_l - \mu^i\right) C^{-1}_{stat.ij}(m^i, m^j)\left(m^j - \sum_l \Gamma^j_l(m^j) b_l - \mu^j\right) + \sum_l b_l^2$$

HERAFitter functionality : various data uncertainties treatment

In HERAFitter following options for correlated systematics treatment and χ^2 defenitions implemented :

Modifier	Description
	Scaling properties
:M	Multiplicative scaling, m^i
:A	Additive scaling, μ^i
:P	Poisson scaling, $\sqrt{m^i \mu^i}$
	χ^2 treatment
:N	Nuisance parameter treatment
:C	Covariance matrix treatment
:O	Offset method treatment
:E	Nuisance parameter, included in MINUIT ("External")

For example you can choose each correlated systematical errors will be treated as additive or as multiplicative.

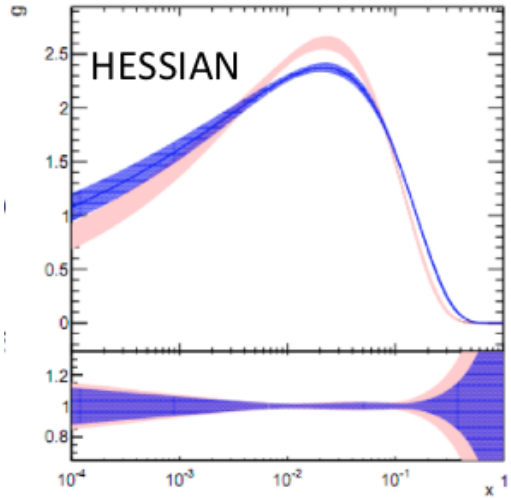
HERAFitter functionality : uncertainties treatment

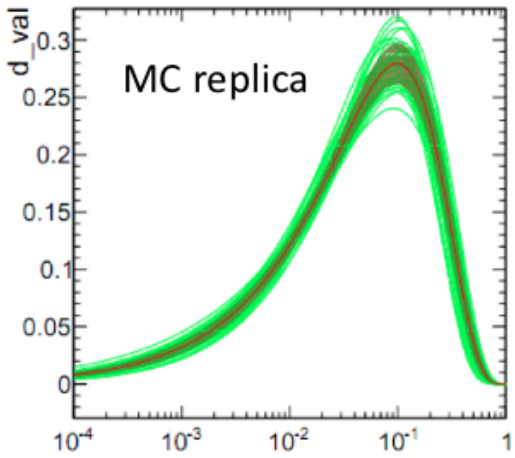
There is an alternative to standard Hessian method (χ^2*calculation*) of PDF uncertainties estimation. Monte Carlo technique is also can be used for this purpose.

Method consists in preparing many replicas (>100) of data sets allowing the central values of cross sections to fluctuate within their systematic and statistical uncertanties taking into account all point to point correlations.

For each MC replica, NLO QCD fit is performed to extract the N PDF sets

Errors on the PDFs are estimated from the RMS of the spread of the N curves corresponding to the N individual extracted PDFs





HERAFitter functionality : heavy flavour schemes

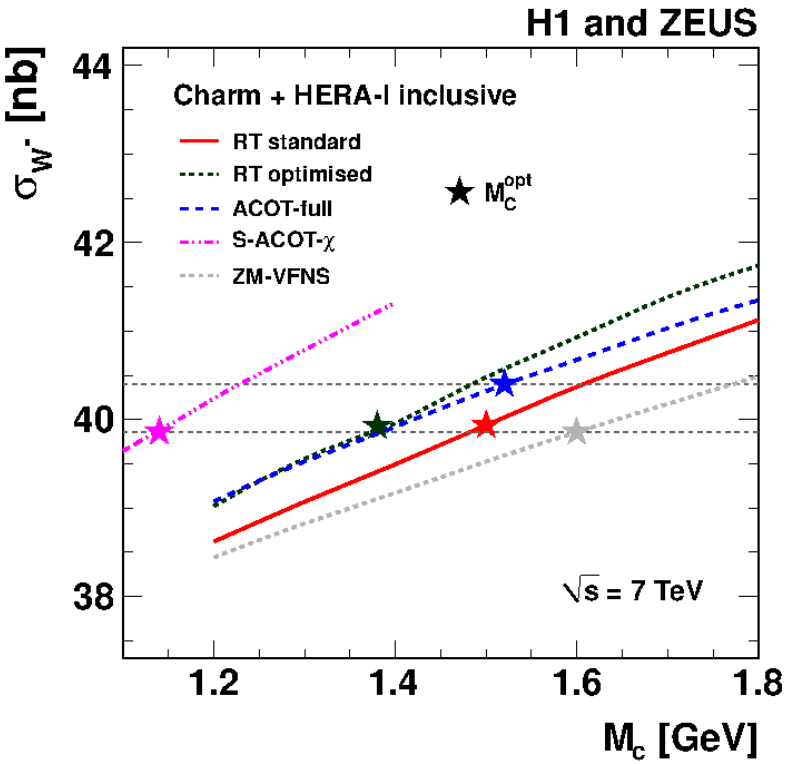
For the DIS process there are several prescriptions how to treat heavy quarks in DGLAP formalism :

Variable flavour number schemes:

- ACOT prescriptions
  (ACOT Full, ACOT χ)
- RT-VFNS prescriptions
  (RT Standard, RT Optimal)
- Zero Mass (via QCDNUM, ACOT)

Fixed Flavour Number Scheme :

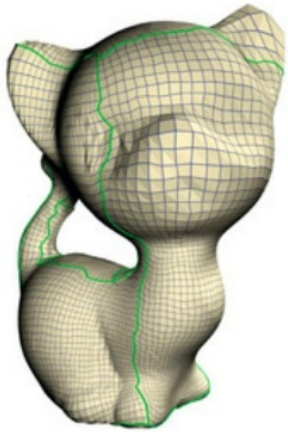
- ABM (openqcdrad-1.6)
  (pole and running mass)
- QCDNUM
  (pole mass, for Neut. Current only)

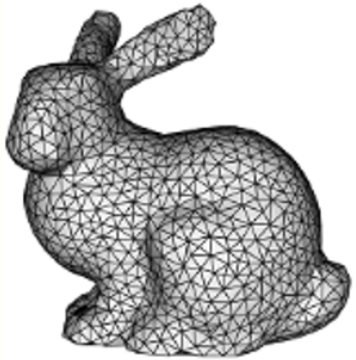


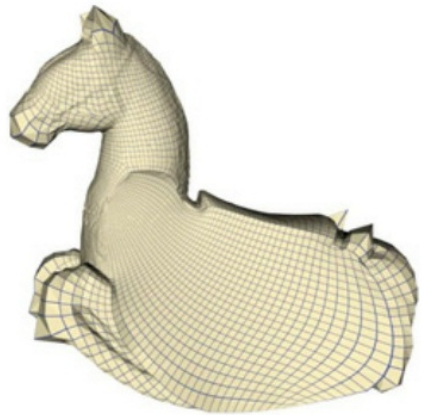
HERAFitter functionality : PDF parametrisation

In HERAFitter there are several different PDF parametrisation implemented :

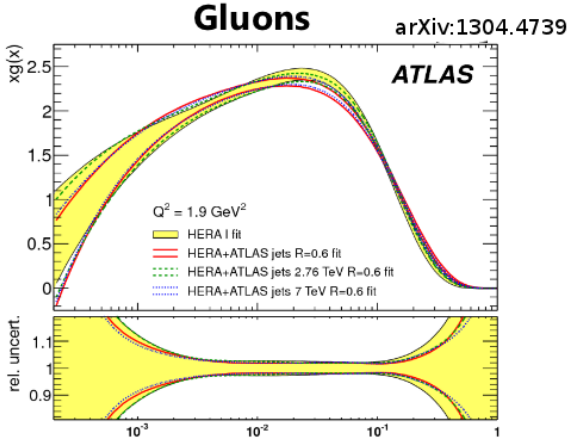
- HERAPDF style
- CTEQ style
- Bi-Log-Normal Functional Form
- Chebyshev Polynomial Functional Form

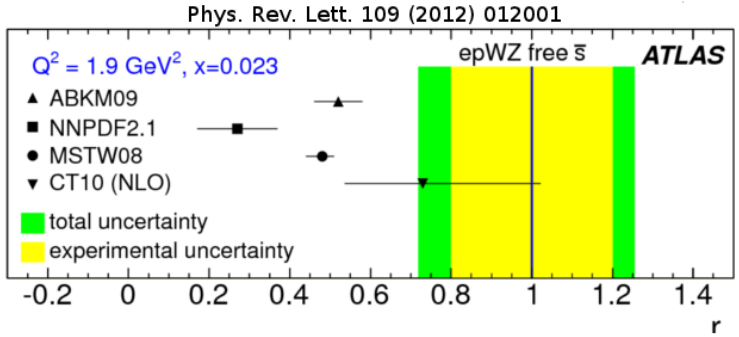


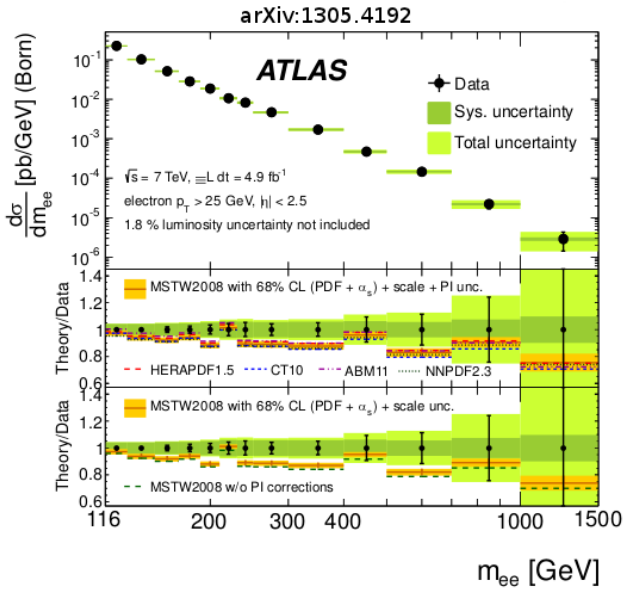


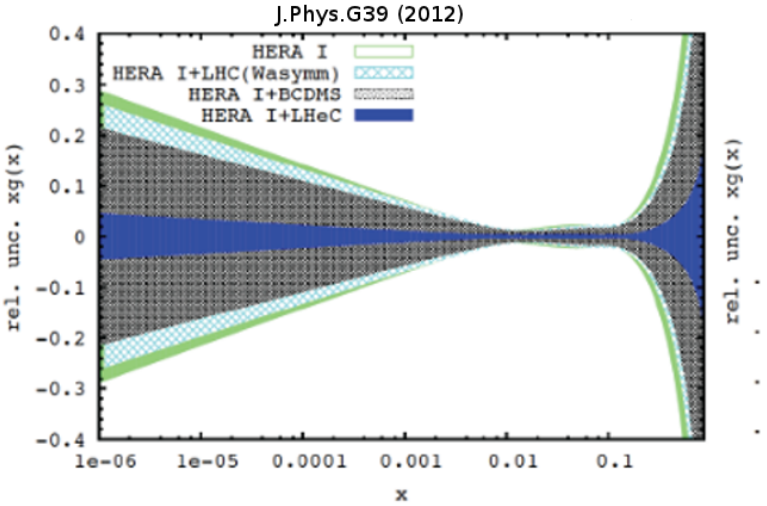


HERAFitter usage : LHC









HERAFitter usage : HERA results

HERA results obtained using HERAFitter :

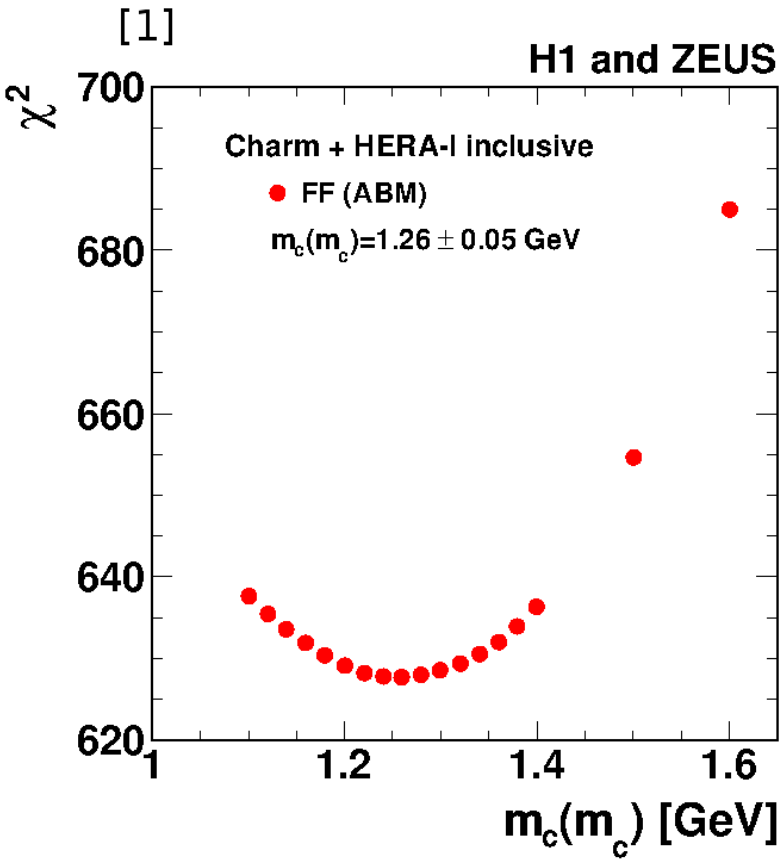
- [1] "Combination and QCD Analysis of Charm Production Cross Section Measurements in Deep Inelastic ep Scattering at HERA"(Eur.Phys.J.C73(2013)2311)
- [2] "Inclusive Deep Inelastic Scattering at High Q2 with Longitudinally Polarised Lepton Beams at HERA"(JHEP 1209 (2012) 061)

Upcoming:
ZEUS beauty mass measurement in progress
Theory side -

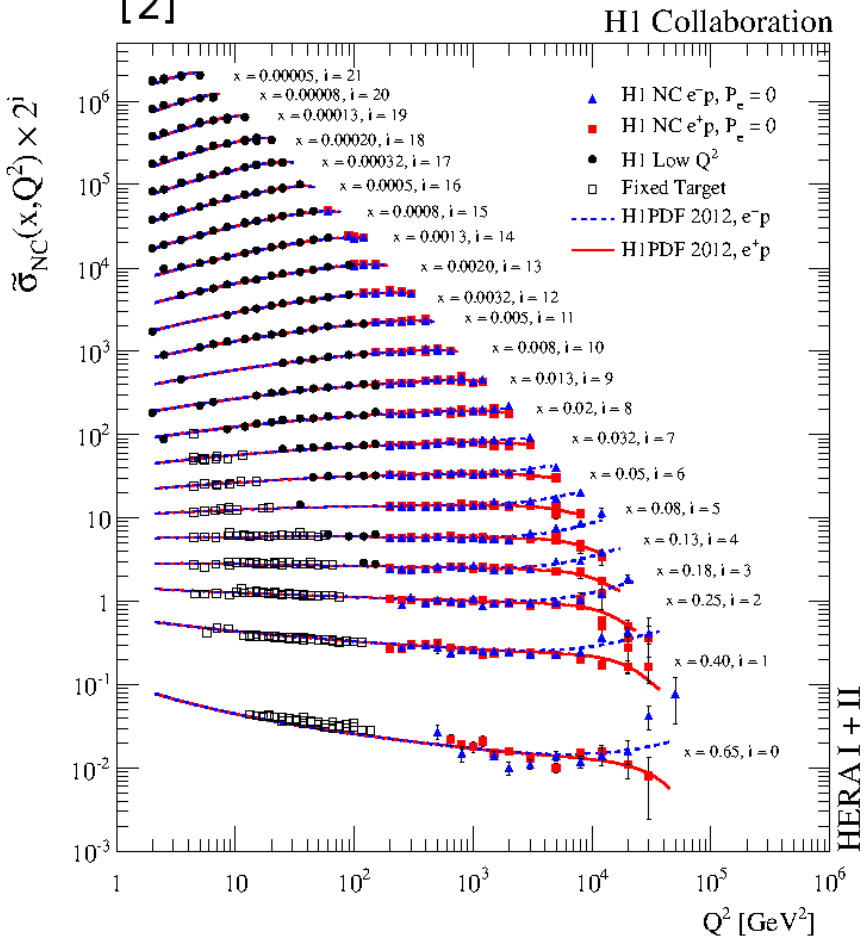
- updates of ACOT scheme module (with CTEQ group)
- inclusion of photon PDF in QCDNUM (publication is planned)

HERAFitter usage : HERA results

[1]



[2]



Important upcoming developments

- $t\bar{t}$ in HATHOR
- QED + QCD PDFs
- ACOT NNLO
- Nuclear PDFs
- Intrinsic charm
- APPLGRID interfaces to DYNNLO
- fitting photon PDFs

Summary

- HERAFitter project is a multi-functional QCD framework well integrated into the high energy community (both, experimental and theory)
- HERAFitter is open to everyone and anyone can contribute
- First stable release is planned in October 2013 together with a publication

BACKUP

BACKUP

HERAFitter usage :LHC

ATLAS results obtained using HERAFitter :

- [1] "Determination of the strange quark density of the proton from ATLAS measurements of the W $\to l\nu$ and Z $\to ll$ cross sections"(Phys.Rev.Lett.109 (2012) 012001
- [2] "Measurement of the inclusive jet cross section in pp collisions at $\sqrt{s} = 2.76$ TeV and comparison to the inclusive jet cross section at $\sqrt{s} = 7$ TeV using ATLAS detector"(ATLAS-CONF-2012-128)
- [3] "Measurement of the high-mass Drell-Yan differential cross-section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector"(arXiv:1305.4192)

[4] LHeC impact studies J.Phys.G39 (2012)

Upcoming:

In **CMS** several analyses are using HERAFitter for PDF constaraints.