HERAFitter update

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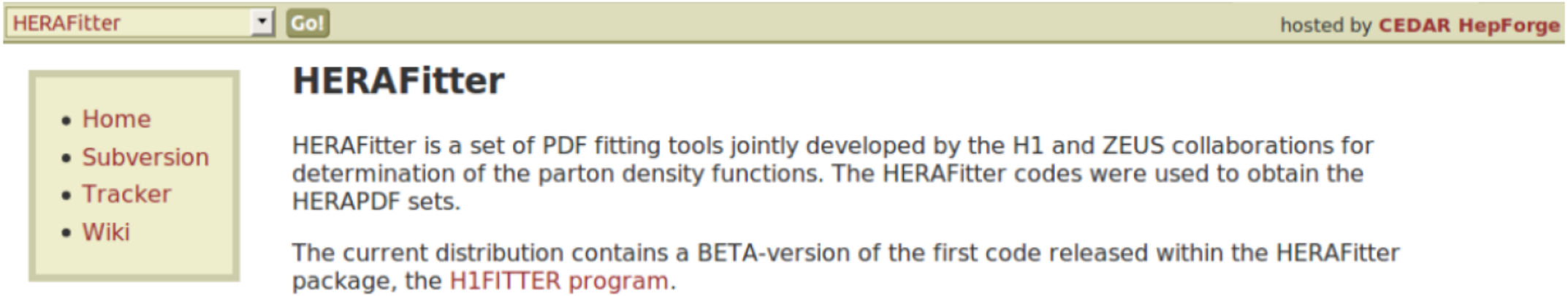
PDF4LHC, Durham, 26^{h} September 2012

Introduction

A fitting tool available for fast feedback to analysers and studies within the experimental working groups



Available at: http://projects.hepforge.org/herafitter

Developers: H1, ZEUS, CMS, ATLAS, theory groups

First **Beta** version released in September 2011
Beta2 version released in May 2012

Beta release functionality

released IX 2011

Input:

- DIS
- W and Z cross sections, asymmetry
- jets
- error treatment: correlated, uncorrelated, Hessian, MC methods
- diffractive data
- ttbar cross sections

Parametrization:

- Standard functional form
- Chebyshev
- PDFs from LHAPDF

Theory:

- FastNLO (NLOJET++)
- Applgrid (NLOJET++, MCFM)
- ZM-VFNS (QCDNUM)
- VFNS RT
- VFNS ACOT
- FFNS ABM
- DIPOLE models (GBW)
- HATHOR

Output:

- Pdfs at predefined scales
- LHAPDF grids
- NNPDF reweighing tool

Beta 2 release upgrades

released V 2012 (bug-fix patch VII 2012)

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Since beta 2 release:
- Covariance matrix based χ^2
- Flexible parametrisation support + regularisation
- Improved systematics treatment
- Updated FastNLO code,
- New dipole models
- Unintegrated PDFs activity
- HERAverager
- Nuclear PDFs
- QED fits

Covariance matrix representation

A new χ^2 calculation method available based on a full covariance matrix inversion

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

- When no statistical correlations used the new method is exactly equivalent to the original HERAFITTER approach (based on nuisance parameters)
- Important when statistical correlations need to be taken into account

I. Autocorrelations in the inclusive jet measurement

$150 < Q^2 < 200$ GeV^2		jet			
		1 a	1 b	1 c	1 d
jet	1 a	100	16	5	1
	1 b	16	100	12	2
	1 c	5	12	100	8
	1 d	1	2	8	100

II. Correlations between inclusive and dijet measurements

$150 < Q^2 < 200$ GeV^2		2-jet			
		1 a	1 b	1 c	1 d
jet	1 a	59	19	2	0
	1 b	22	72	12	1
	1 c	0	19	77	6
	1 d	0	0	16	78

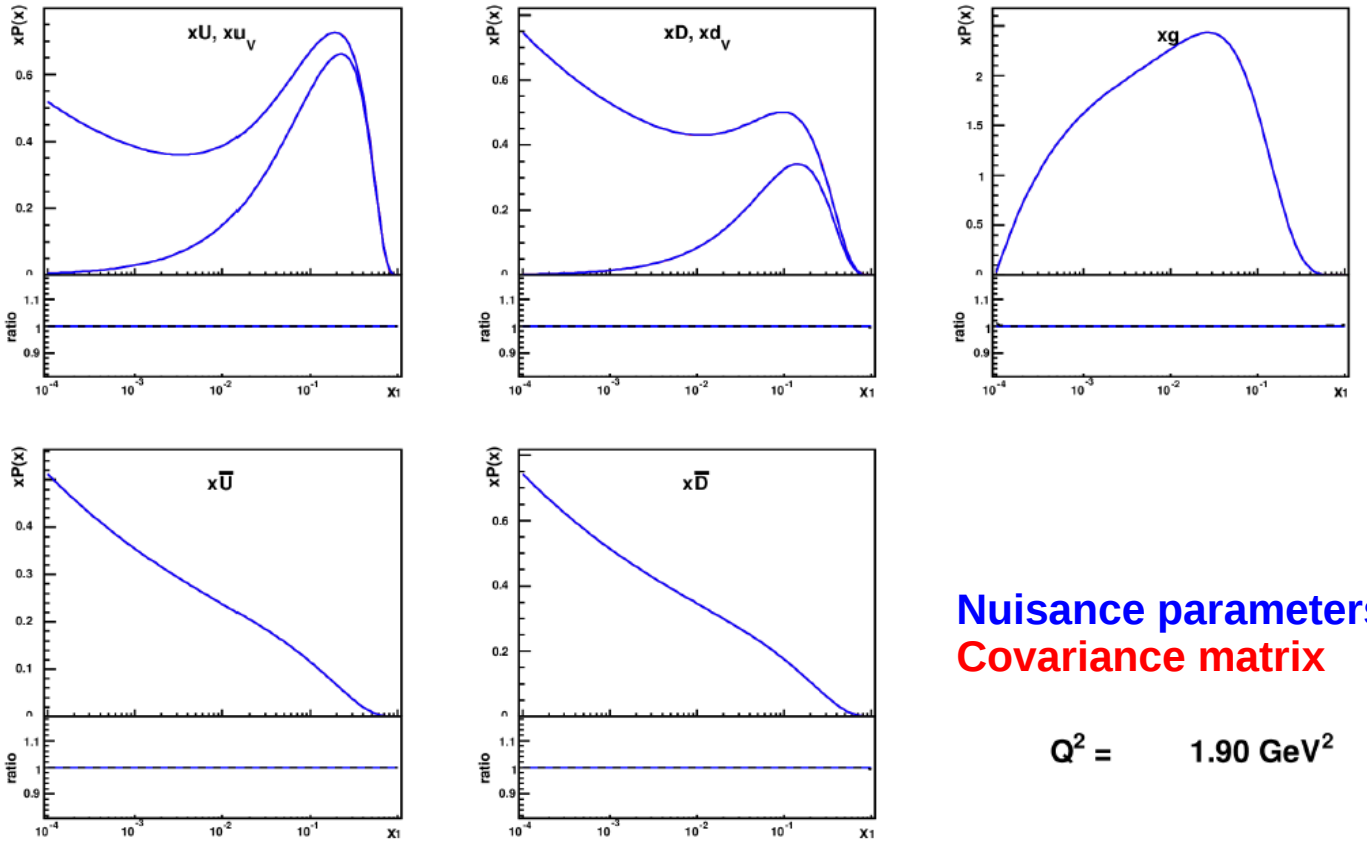
III. Unfolded measurements often come with the full covariance matrix information

Now all of this can be correctly treated with the HERAFITTER

Covariance matrix representation

Cross check of HERAPDF 1.6 (inclusive DIS + jets) fitted using
nuisance parameters and **covariance matrix** methods

- Almost perfectly the same result (verification whether method is working)
- Here autocorrelations of inclusive jets do not make much difference



Redundant parametrisation

Extraction of PDFs from fits relies on ansatz such as parametrisation, which may introduce a bias and has some associated uncertainty

HERAPDF (and HERAFITTER) estimates uncertainty on PDF parametrisation by adding parameters to the basic functional form, $xf(x,Q^2) = Ax^B(1-x)^C$ until χ^2 saturation

The same used in HERAFITTER.

Now we can use more flexible parametrisation with 22 instead of 13 free parameters

$$xf(x,Q^2) = Ax^B(1-x)^C(1+Dx+Ex^2)$$

- A - normalisation
- B - low x behaviour
- C - high x behaviour
- D,E - medium x tuning

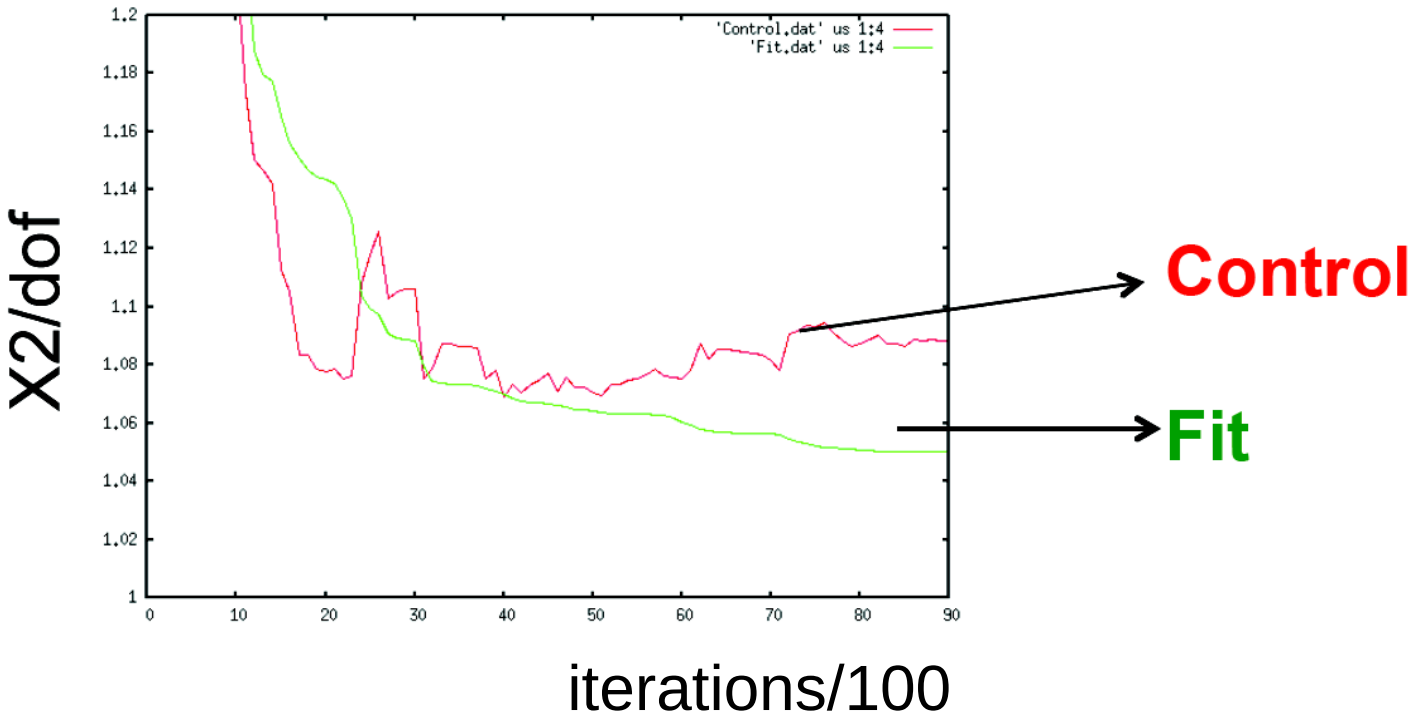
HERAFITTER includes regularisation mechanisms for underconstrained fit:

1. Redundant parametrisation with data driven stopping criteria (a la NNPDF)
2. Redundant parametrisation with χ^2 regularisation

Redundant parametrisation 1

Data points split randomly into **Fit** and **Control** sample
Fit sample used to determine PDF parameters, semi-monotonically decreasing χ^2
Control sample used to protect against over-fitting,

Stopping criteria bound to minimum in the χ^2(iterations) of the **Control** sample
Uncertainty bands estimated using a set of fits with different random splits (MC method)

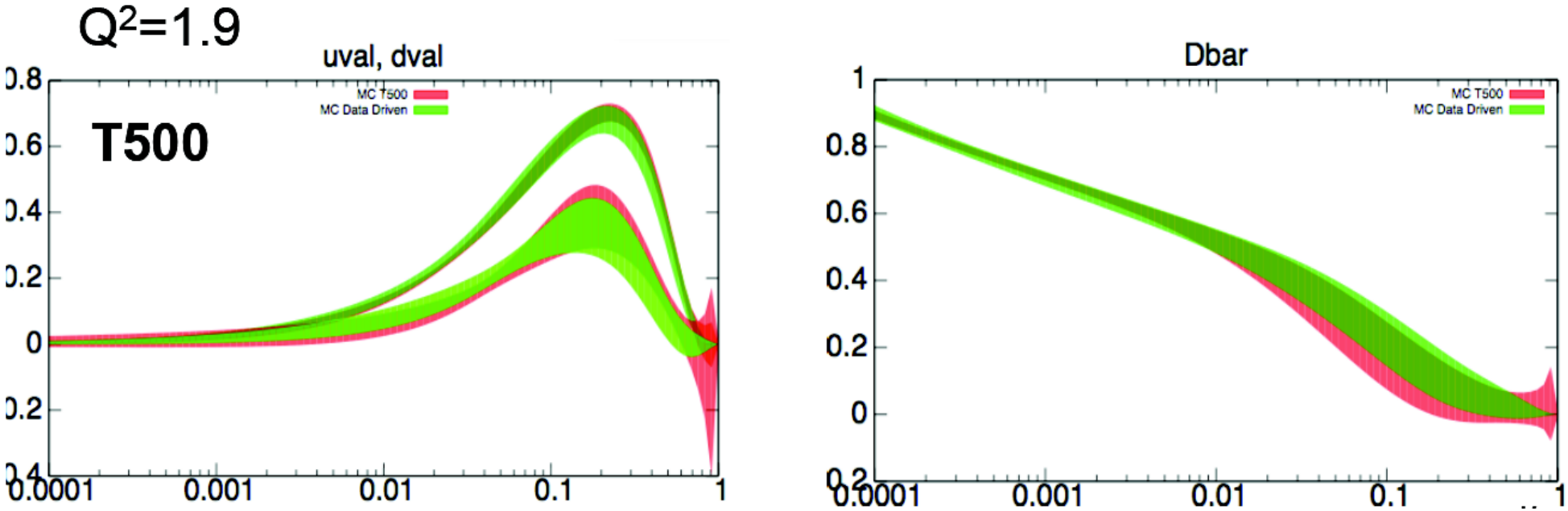


Redundant parametrisation 2

2. Use a parameters considered as redundant in a regularisation criteria as a χ^2 penalty term:

$$\chi^2_{reg} = T \sum_f \left(\left(\frac{D_f}{\Delta D} \right)^2 + \left(\frac{E_f}{\Delta E} \right)^2 \right)$$

Comparison of the error bands obtained with two redundant parametrisation methods:



Both methods are now implemented in the HERAFITTER

HERA averager

A new package containing (rewritten) code used to combine H1 and ZEUS data is now included in the HERAFITTER

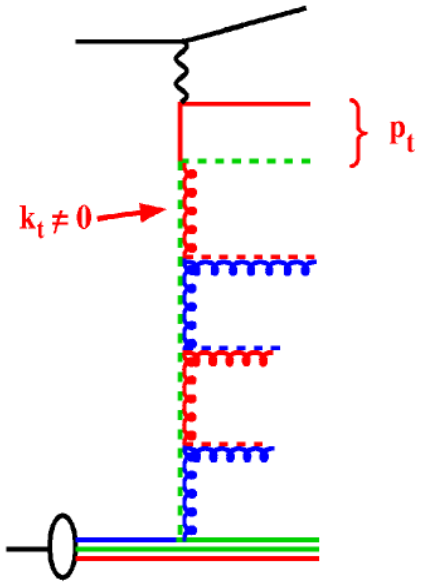
Procedure consist of two parts:
- swimming: data points are moved to a common binning
- averaging: based on a χ^2 minimisation

$$\chi^2(m,b) = \sum_i \frac{[m^i - \sum_j \Gamma^i_j b_j - \mu^i]^2}{\Delta_i^2} + \sum_j b_j^2$$

Input files and steering conformed to HERAFITTER standard

- μ_i is a measured central value
- m_i is a prediction for the measurement
- Γ^i_j is a matrix of correlated systematics
- Δ_i^2 is a squared sum of squared stat. and uncorr syst. uncertainties
- b_j^2 is a shift of the corr. systematic

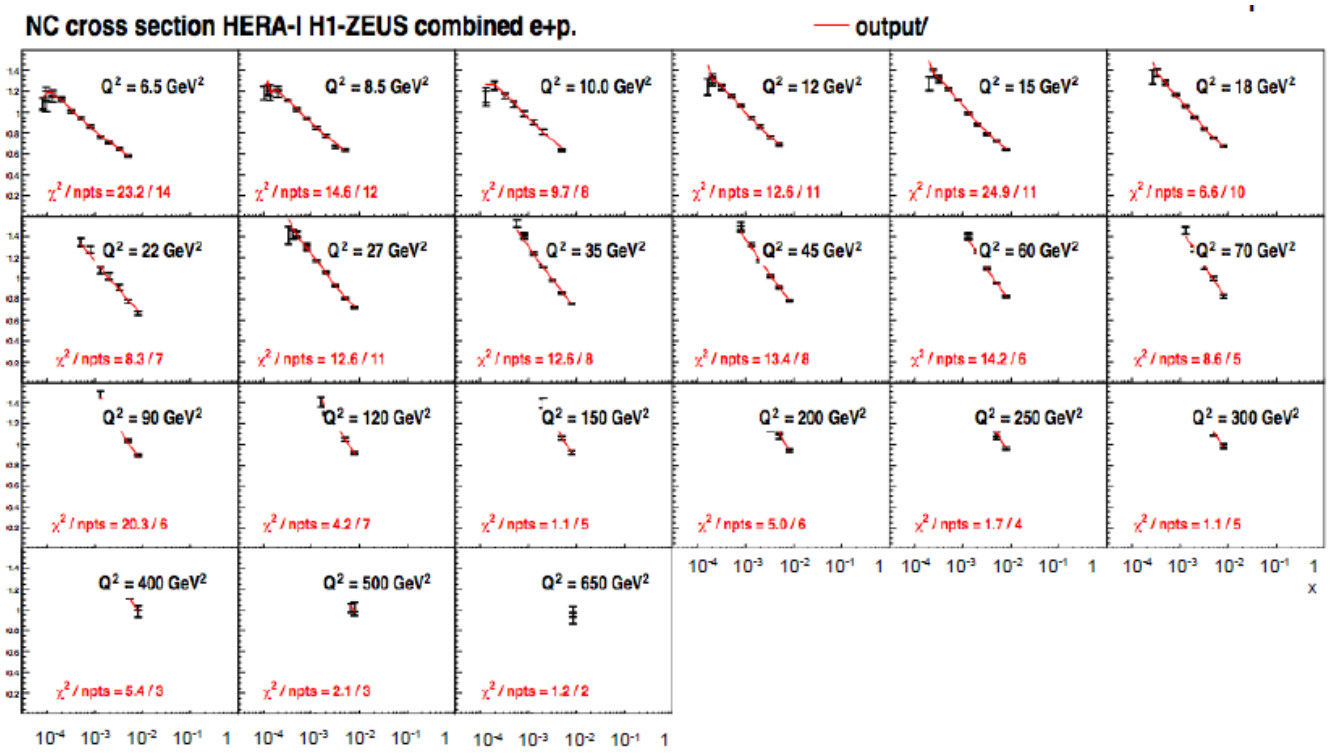
Unintegrated PDFs



Work in progress on integrating uPDF in the HERAFITTER (H. Jung)

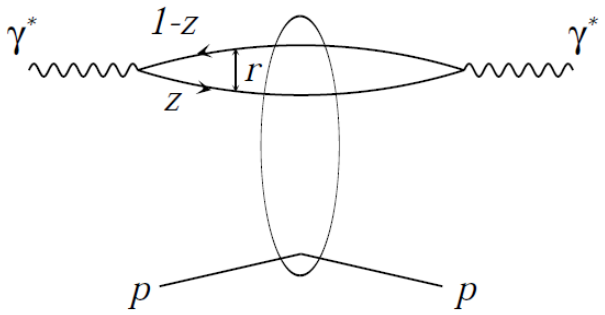
$$\frac{d\sigma}{dxdQ^2} = \int dx_g \left[dk_\perp^2 x_g \mathcal{A}_i(x_g, k_\perp^2, p) \right] \hat{\sigma}(x_g, k_\perp^2, x, Q^2)$$

For the moment only gluon uPDF fitted and using only NC DIS – first step!



New dipole model implementation

Dipole model of DIS as small x in the proton rest frame



r - dipole size

z - longitudinal momentum fraction of the quark/antiquark

Factorisation theory: **dipole formation** + **dipole interaction**

$$\sigma^{\gamma p} = \frac{4\pi^2 \alpha_{em}}{Q^2} F_2 = \sum_f \int d^2r \int_0^1 dz \, |\Psi^\gamma(r, z, Q^2, m_f)|^2 \;\; \hat{\sigma}(r, x)$$

Already in beta2: Golec-Biernat Wuesthoff (GBW): $\hat{\sigma}(r,x) = \sigma_0 \left(1 - \exp(-r^2/R_s^2)\right),$

Now also Bartels-Golec-Kowalski (BGK) interaction parametrisation:

$$\hat{\sigma}(r,x) = \sigma_0 \left\{1 - \exp\left[-\pi^2 r^2 \alpha_s(\mu^2) x g(x,\mu^2)/(3\sigma_0)\right]\right\}$$

Gluon PDF evolved by DGLAP equation

In addition / planned...

Updates and work ongoing in few more areas:
- Updated treatment of correlated systematic uncertainties (offset method, additive errors)
- Updated FastNLO
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- New data/theory files (distributed a la LHAPDF grids)

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Summary

Since beta 2 release a lot of activities, new users attracted, new functionalities added
Steady growing number of developments, all in one place in an open format, easy verification, cross-model benchmarking etc.
New release planned for beginning of 2013

PDF school at DESY with HERAFITTER tutorial: 22-24 October