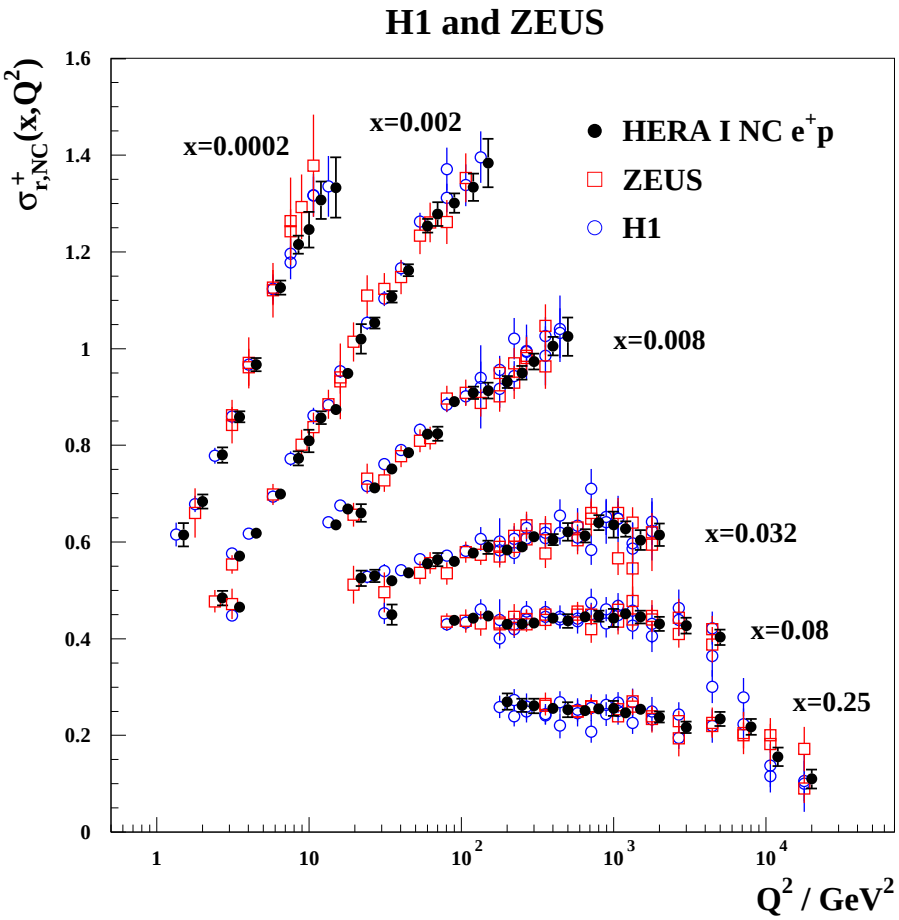
Highlights of HERAPDF fits.

S. Glazov, DESY.

- Data.
- Fits.
- HERAPDF1.0.
- New preliminary results.
- Extra studies.

Trento, Sept 2010.

Combination of HERA data



Ultimate precision is obtained by combining H1 and ZEUS measurements.

Average H1 and ZEUS data before applying QCD analysis.

Achieved by fitting σ_r values, global normalisations and the correlated systematic uncertainties.

Experiments cross calibrate each other: total uncertainties reduced, sometimes better than $\sqrt{2}$. Good consistency of the data:

$$\chi^2/dof = 637/656$$

χ^2 definition

Self-consistency of the HERA data allows to use standard definition of uncertainties using $\Delta\chi^2 = 1$ criterion.

Definition of χ^2:

$$\chi^2_{\text{exp}}(\boldsymbol{m}, \boldsymbol{b}) = \sum_i \frac{\left[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right]^2}{\delta^2_{i,\text{stat}}\,\mu^i\left(m^i - \sum_j \gamma^i_j m^i b_j\right) + \left(\delta_{i,\text{uncor}}\, m^i\right)^2} + \sum_j b_j^2.$$

- Correlated error can be treated using Hessian, offset methods and be added in quadrature.
- For Hessian fits, correlated errors nuisance parameters b_j modify predicted values m^i.
- Statistical error is re-calculated using expected number of events, uncorrelated systematic errors re-calculated using expected cross sections.

Packages and Settings

- Evolution code: publicly available QCDNUM package, version 17.00 (http://www.nikef.nl/h24/qcdnum/index.html) . Active exchange with the M. Botje. Cross-check: QCDFIT package.
- Two independent fitting packages: results are double-checked.
- Different approaches to experimental uncertainties: Hessian, offset, adding in quadrature.
- Error propagation for PDFs: Hessian and MC method.
- NLO and NNLO evolution.
- Several codes for heavy flavor treatment: RT from R. Thorne, flavours of ACOT from F. Olness, F_2^{cc} at NNLO from S. Alekhin.
- Fits to inclusive and F_2^{cc} data.

HERA Combined results can be found at

https://www.desy.de/h1zeus/combined_results/index.php?do=proton_structure

HERAPDF1.0 Fit Settings

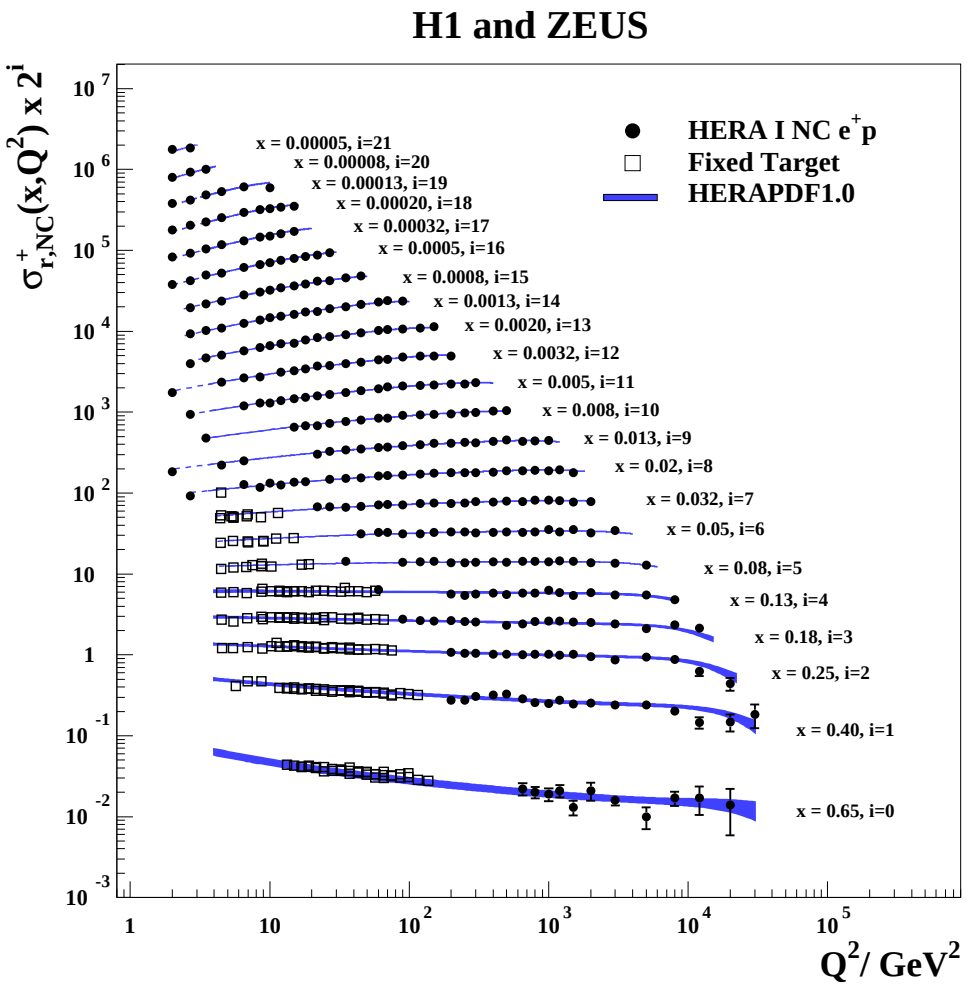
- Input: combined HERA-I data for $e^{\pm}p$ NC and CC scattering.
- $\Delta\chi^2 = 1$, treat experimental errors as uncorrelated, 3 procedural uncertainties with offset method.
- NLO evolution, RT-VFNS for charm and bottom, $\alpha_S = 0.1176$.
- Evolution starting scale $Q^2 = 1.9\ \mathrm{GeV}^2$, below $m_c^{\mathrm{model}} = 1.4$ GeV. Start fitting data at $Q^2_{min} = 3.5\ \mathrm{GeV}^2$.
- Fitted PDFs are xg, xu_v, $xd_v(x)$, $x\bar{U}$, $x\bar{D}$ where $x\bar{U} = x\bar{u}$ and $x\bar{D} = x\bar{d} + x\bar{s}$ at the starting scale. For the strange, $x\bar{s} = f_s x\bar{D}$ with $f_s = 0.31$ is assumed.
- Standard parameterisation form

$$xf(x) = Ax^B(1-x)^C(1 + \epsilon\sqrt{x} + Dx + Ex^2)$$

  with only significant ϵ, D and E terms kept.

- A_g, A_{u_v}, A_{d_v} fixed by sum rules. Extra constraints for small x behaviour of d and u-type quarks: $B_{u_v} = B_{d_v}$, $B_{\bar{U}} = B_{\bar{D}}$, $A_{\bar{U}} = A_{\bar{D}}(1 - f_s)$

HERAPDF1.0 fit



Combination of the published H1/ZEUS data collected at HERA-I for CC,NC, $e^{\pm}p$ mode. 14 publications, 1402 input and 741 output σ_r measurements, 110 correlated experimental error sources. For NC e^+p, $6 \cdot 10^{-7} < x < 0.65$ and $0.045 < Q^2$ 30000 GeV^2.

Combination:

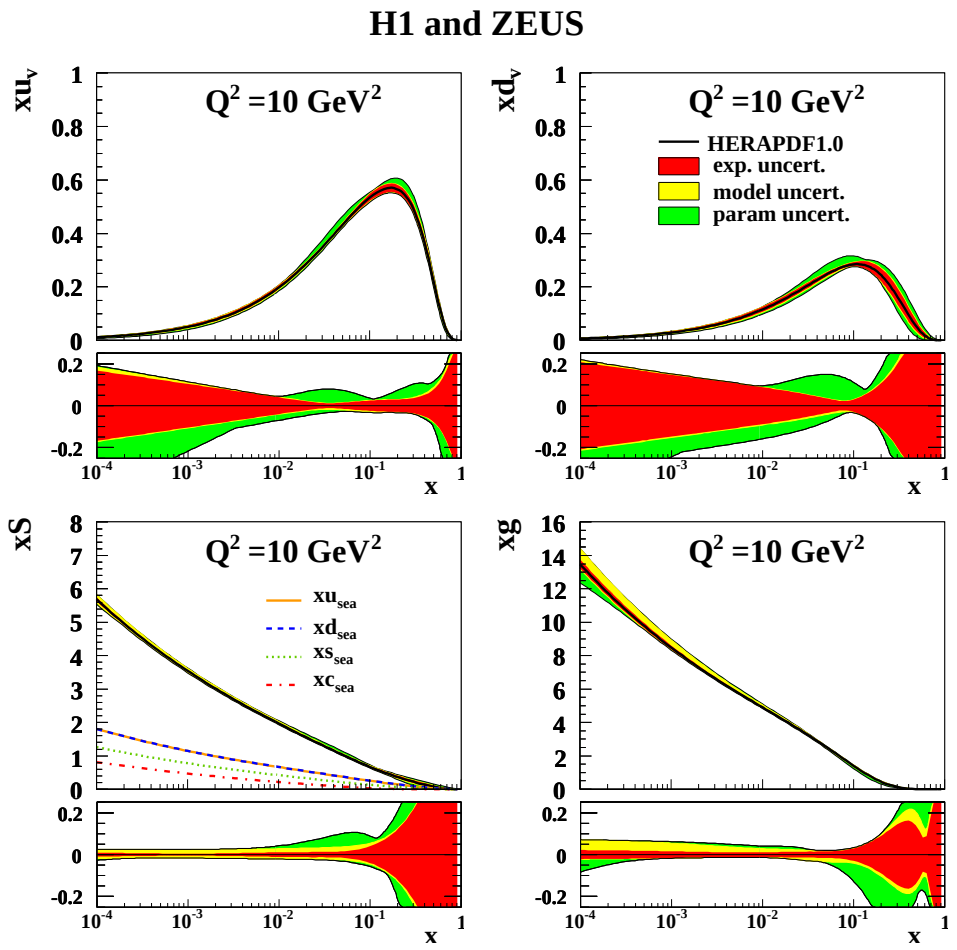
$$\chi^2/dof = 637/656$$

QCD Fit (to the combined HERA data with $Q^2 \geq 3.5$ GeV^2):

$$\chi^2/dof = 574/582$$

Good consistency between H1 and ZEUS. Stringent test of DGLAP evolution.

PDF uncertainties



HERAPDF1.0 — NLO QCD analysis of the combined HERA data.

Separation of experimental, model and parameterisation uncertainties.

Accurate xS and xg at low x due to precise measurement of F_2.

Model and Parameterisation variations

Model variations are:

- Change in strangeness fraction from $f_s = 0.31$ to 0.23 and 0.38.
- Change of Q^2_{min} cut from $Q^2_{min} = 3.5\ \text{GeV}^2$ to $2.5\ \text{GeV}^2$ and $5.0\ \text{GeV}^2$.
- Change of m_c^{model} from 1.4 GeV to 1.35 and 1.6 GeV.
- Change of m_b^{model} from 4.75 GeV to 4.3 and 5.0 GeV.

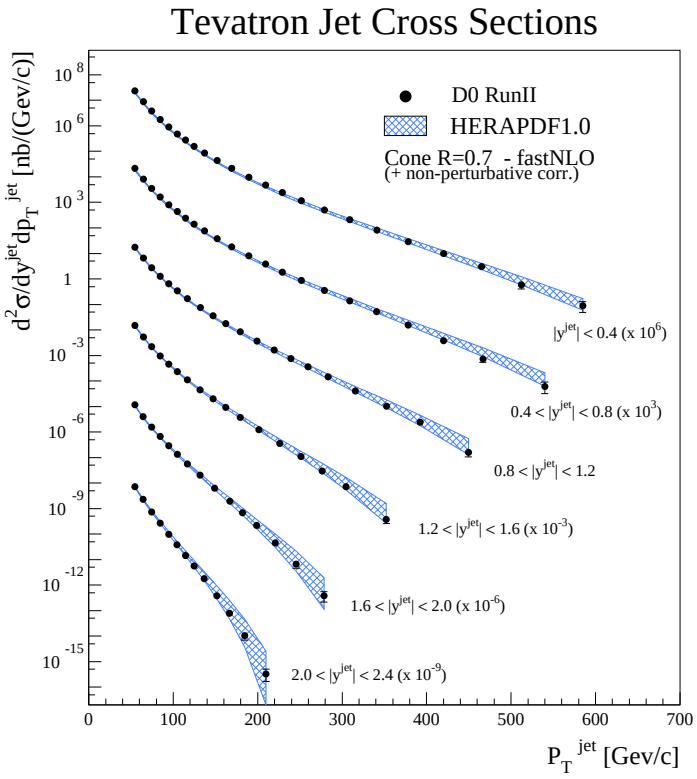
they are evaluated as by adding in quadrature + and – deviations from the central fit.

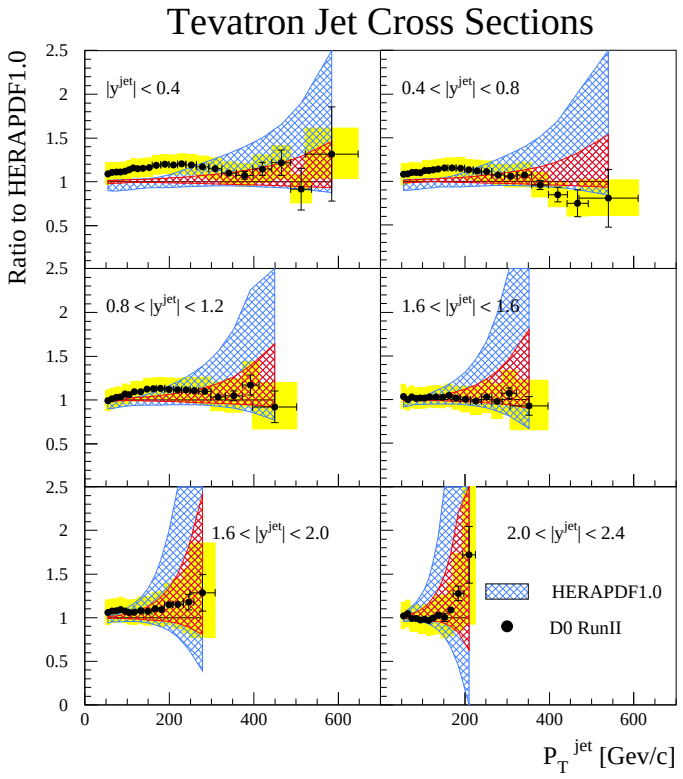
Parameterisation variations are:

- Change of the evolution starting scale to $Q_0^2 = 1.5\ \text{GeV}^2$ using flexible gluon parameterisation term, $xg(x) = A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{25}$.
- Change of Q_0^2 to $2.5\ \text{GeV}^2$ with increase of $m_c^{\text{model}} = 1.6$ GeV.
- Extra parameters D_{u_v}, $D_{\bar{U}}$ and $D_{\bar{D}}$.

they are evaluated by building envelope of maximal deviations.

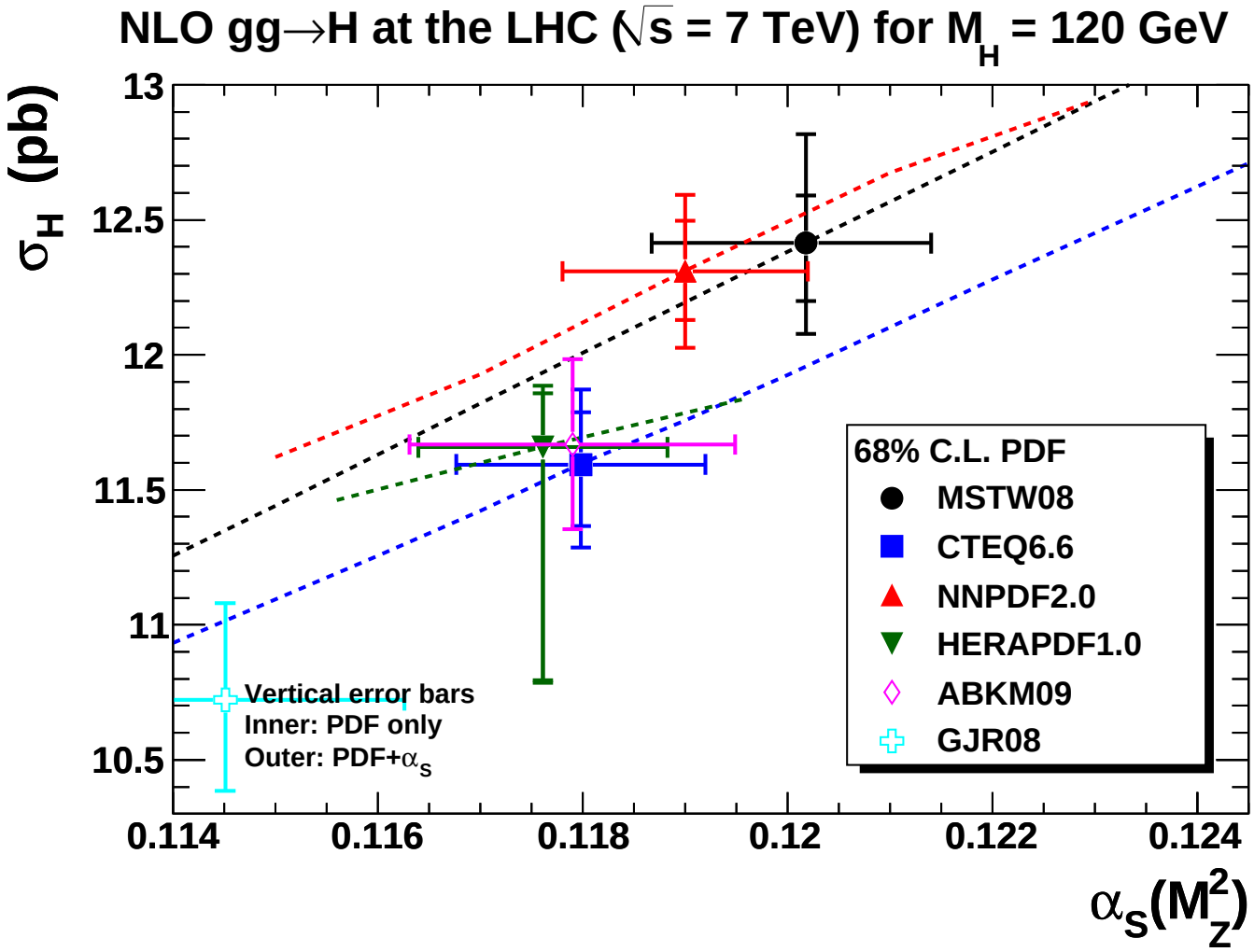
HERAPDF1.0 vs Tevatron





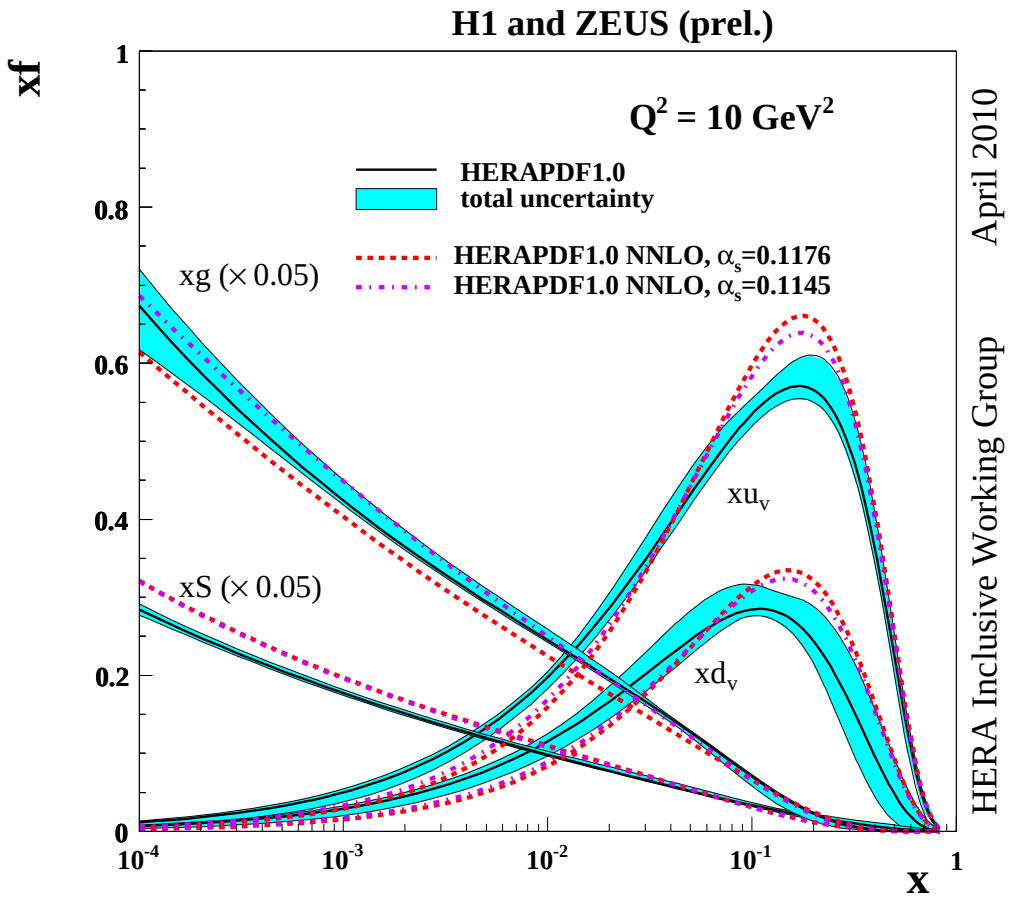
HERAPDF1.0 does not include Tevatron jet data but can make accurate predictions for them.

HERAPDF1.0 vs other sets



HERAPDF1.0 does not include jet data from the Tevatron. Notice that α_S uncertainty for HERA result is smaller vs other sets.

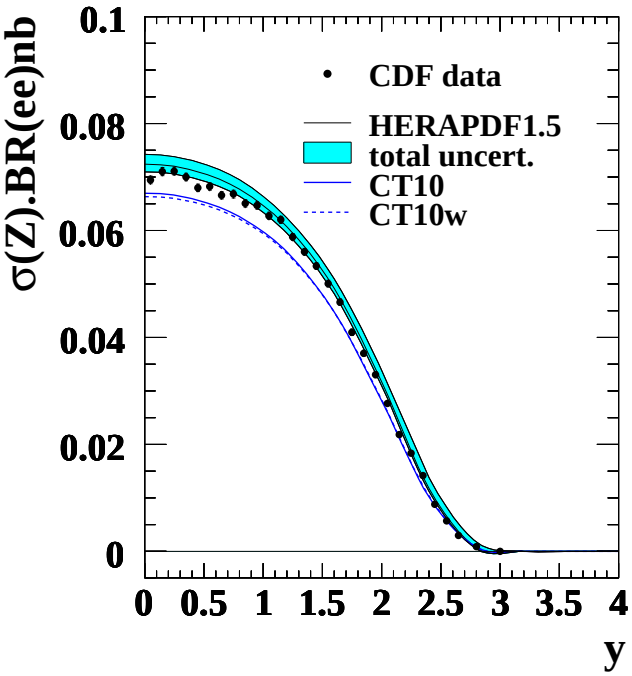
HERAPDF at NNLO

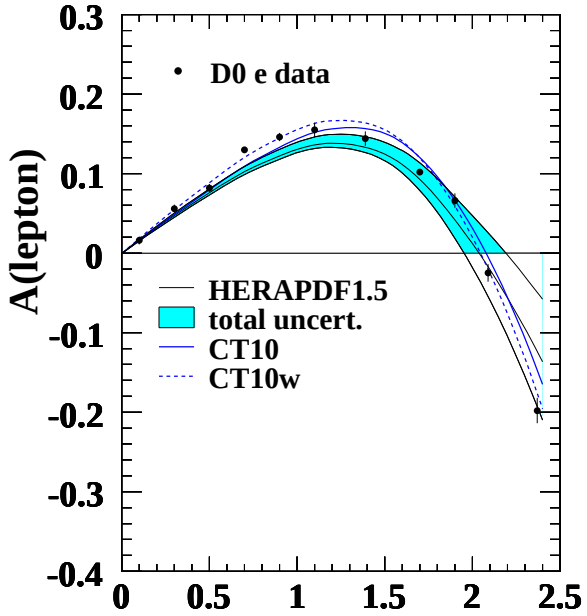


HERAPDF1.0 is also available at NNLO.

https://www.desy.de/h1zeus/combined_results/proton_structure/Fits/HERAPDF1.0_NNLO_1176.LHgrid.gz
https://www.desy.de/h1zeus/combined_results/proton_structure/Fits/HERAPDF1.0_NNLO_1145.LHgrid.gz

New Results



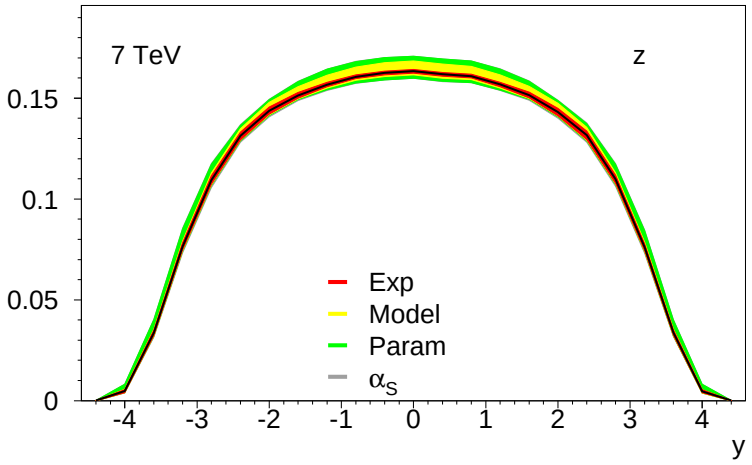


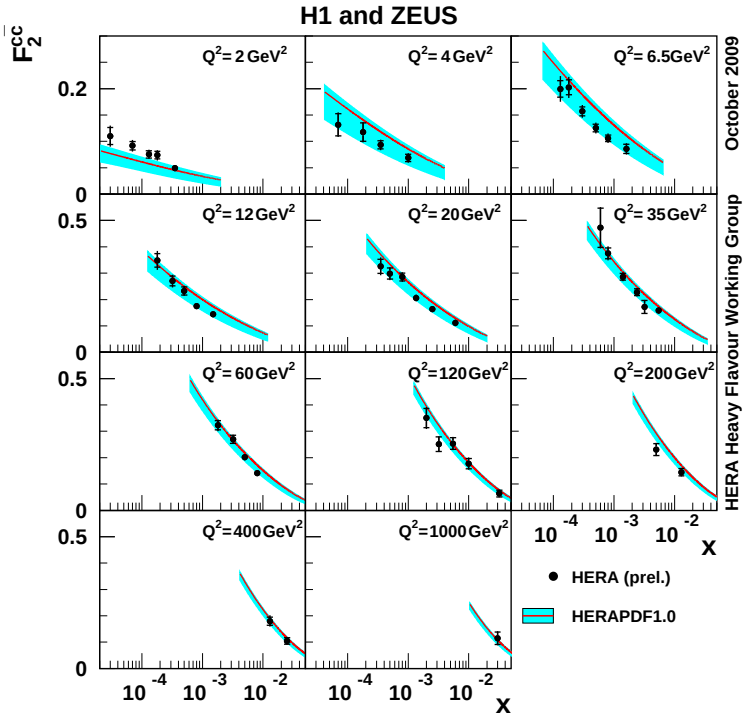
HERA fits use recent preliminary H1 and ZEUS combined data:

- Inclusive cross-section measurement at reduced $E_p = 460$ and $E_p = 575$ GeV.
- High Q^2 NC and CC cross-section data from HERA-II — HERAPDF1.5 set.

→ for more details see Voica's and Mandy's talks

Flavour separation at low x

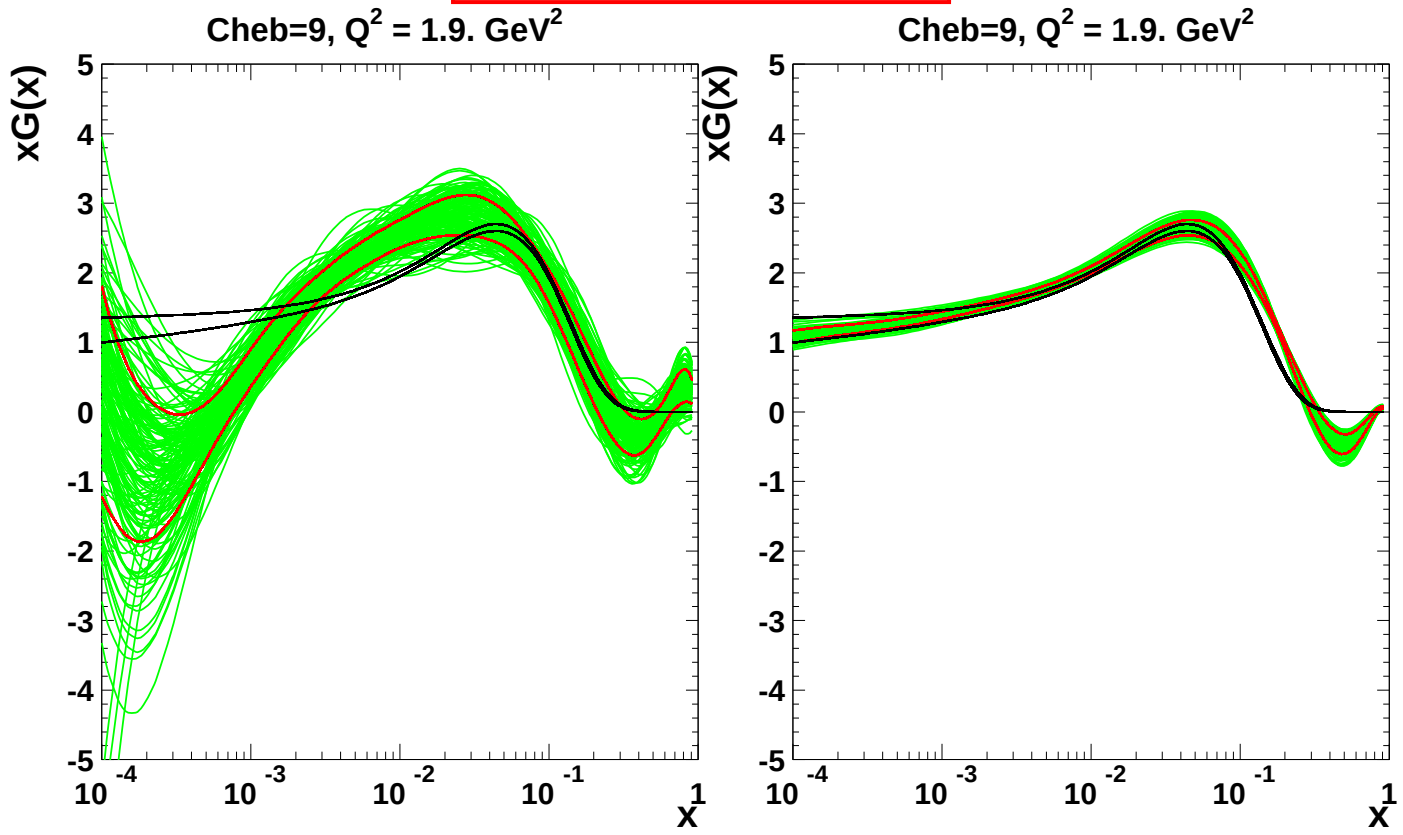




- Variation of m_c^{model} leads to dominant model uncertainty for W, Z production at the LHC.
- Variation considered in HERAPDF1.0 covers recent preliminary F_2^{cc} data.

→ precision of the data should allow to reduce uncertainty of W, Z production cross sections at the LHC. See Ringaile's talk tomorrow.

Extra Studies



- Flexible Chebyshev parameterisation to study effects of parameterisation bias.
- MC error estimation — compared to the standard Hessian error propagation.
- Study of adding explicit smoothness prior.

(S. Glazov, S. Moch, V Radescu.)

Summary

- HERAPDF fits use self-consistent set of HERA data, which allows for rigorous treatment of experimental errors.
- DIS data for scattering off proton has small theoretical uncertainties.
- HERA fits are used for studies of all types of uncertainties.
- New HERA data play important role for improving PDF precision, have significant impact for the LHC observables.