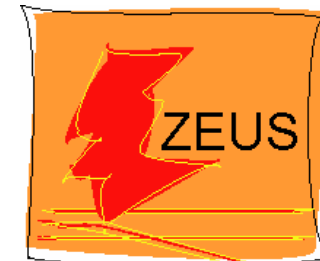


QCD NLO analysis of inclusive, charm and jet data (HERAPDF 1.7)



Krzysztof Nowak
on behalf of
H1 and ZEUS
collaborations



- ✓ *HERAPDF development*
- ✓ *HERAPDF 1.7*
- ✓ *Results and Conclusions*



HERAPDF strategy outline

Input data restricted to purely HERA measurements

Good understanding of input

Data cross checked between H1 and ZEUS

Data cross calibrated between two experiments

In-depth understanding of correlations

Only ep data: no need for nuclear corrections

Different approach providing a valuable challenge for other “global” fitting groups

HERAPDF 1.0

JHEP 1001:109,2010
arXiv:0911.0884 [hep-ex]

Fit to combined H1-ZEUS NC and CC, e^+p , e^-p data

Neutral current:

$$\frac{d^2 \sigma_{NC}^{\pm}}{dx dQ^2} = \frac{2 \alpha \pi^2}{x Q^4} (Y_+ F_2 \mp Y_- x F_3 - y^2 F_L)$$

$$F_2 \propto \sum_i e_i^2 (x q_i + x \bar{q}_i)$$

quark distributions
gluon from scaling violation

$$x F_3 \propto \sum_i (x q_i - x \bar{q}_i)$$

valence quarks

$$F_L \propto \alpha_s \times g$$

gluon at NLO

Charged current:

$$\frac{d^2 \sigma_{CC}^-}{dx dQ^2} = \frac{G_F^2}{2 \pi} \frac{M_W^2}{M_W^2 + Q^2} (u + c + (1 - y^2)(\bar{d} + \bar{s}))$$

$$\frac{d^2 \sigma_{CC}^-}{dx dQ^2} = \frac{G_F^2}{2 \pi} \frac{M_W^2}{M_W^2 + Q^2} (\bar{u} + \bar{c} + (1 - y^2)(d + s))$$

flavour
decomposition

Jun 2011 **HERAPDF 1.7**
NC, CC, F2c, jets

Mar 2011 **HERAPDF 1.6**
NC, CC, jets

Aug 2010 **HERAPDF 1.5**
charm
NC, CC, F2c

Jul 2010 **HERAPDF 1.5**
NC, CC

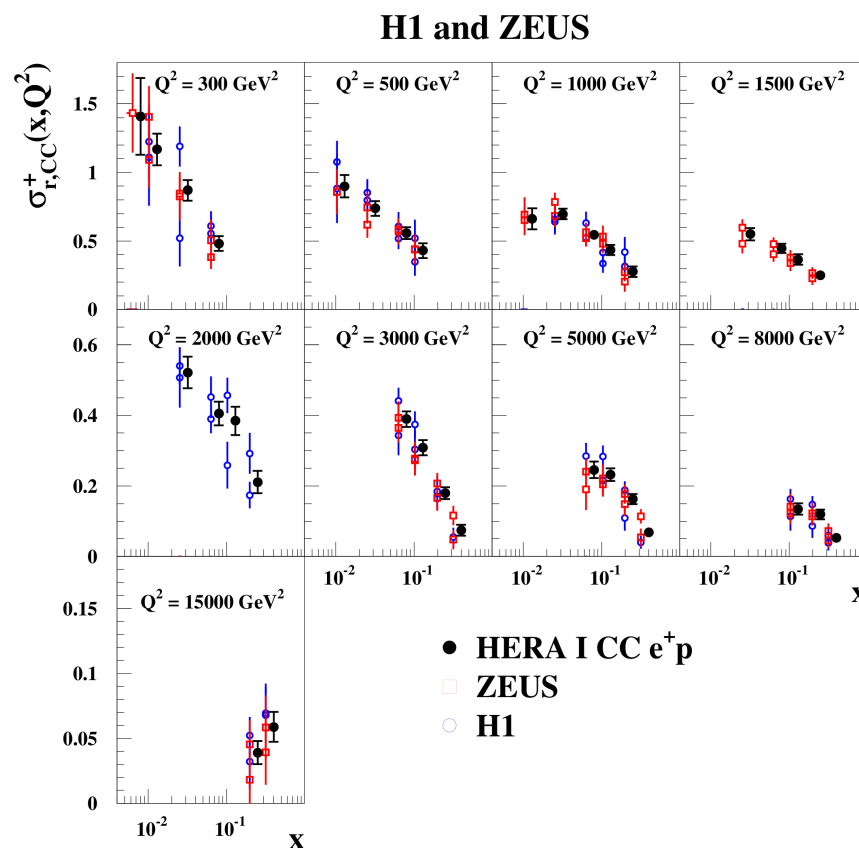
Nov 2009 **HERAPDF 1.0**
NC, CC

HERAPDF 1.0

JHEP 1001:109,2010
arXiv:0911.0884 [hep-ex]

Fit to combined H1-ZEUS NC and CC, e^+p , e^-p data

- *HERA I period, ($\sim 63 \text{ pb}^{-1}$ per experiment)*
- *Combination significantly reduces uncertainty*



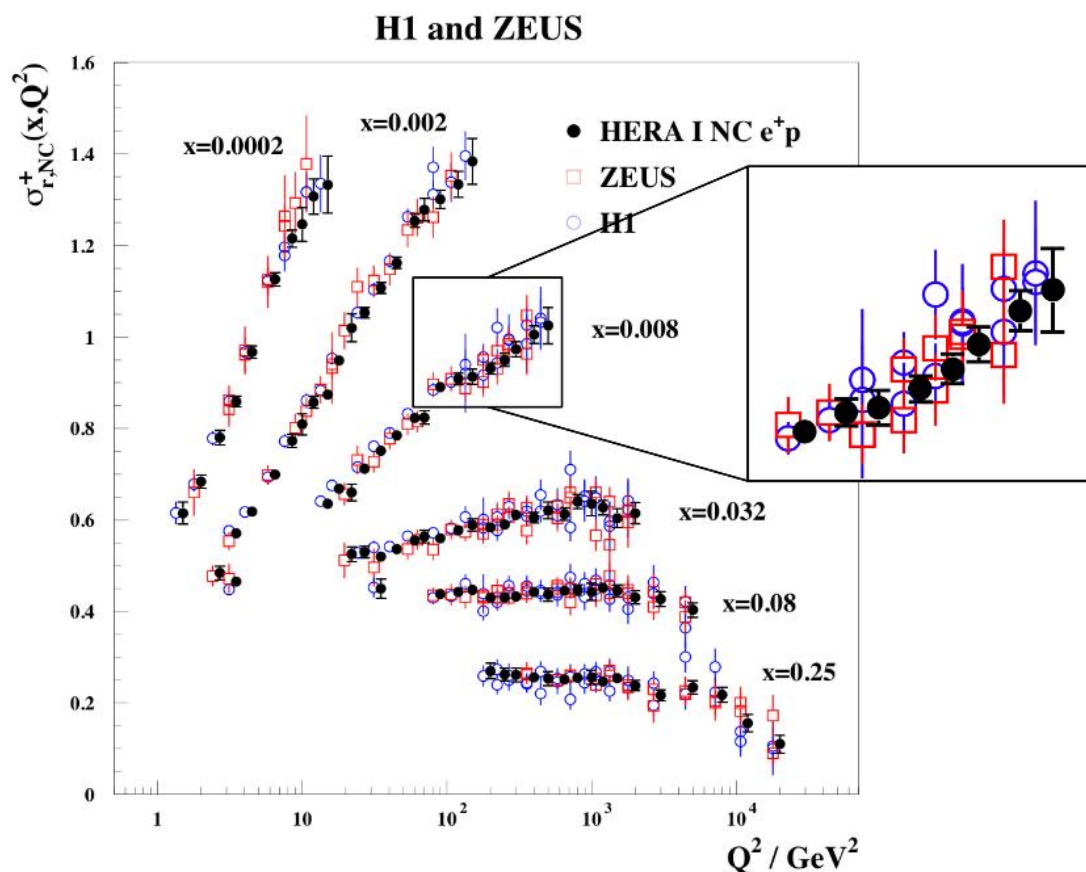
HERAPDF 1.0

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Fit to combined H1-ZEUS NC, CC, e^+p , e^-p data

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Mar 2011	HERAPDF 1.6 NC, CC, jets
Aug 2010	HERAPDF 1.5 charm NC, CC, F2c
Jul 2010	HERAPDF 1.5 NC, CC
Nov 2009	HERAPDF 1.0 NC, CC



HERAPDF 1.5

H1prelim-10-142
ZEUS-prel-10-018

Fit to combined H1-ZEUS NC, CC, e^+p , e^-p data

- Preliminary HERA I+II combination ($\sim 0.5 \text{ fb}^{-1}$ per exp.)
- Further reduction of uncertainty
- This is the currently recommended set

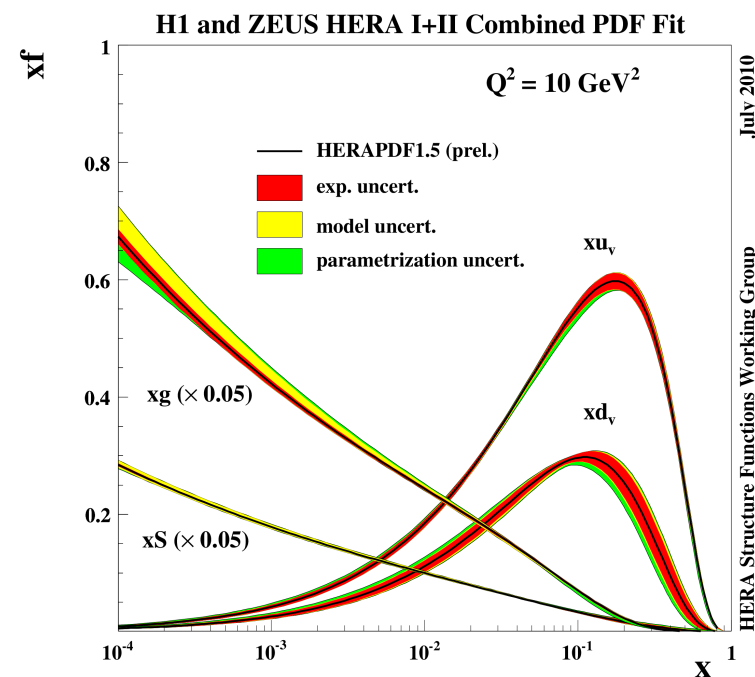
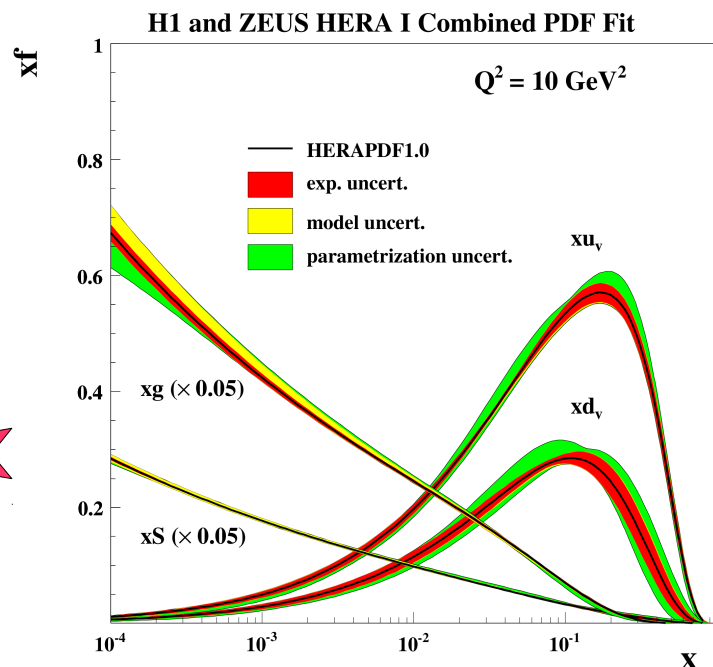
Jun 2011 HERAPDF 1.7
NC, CC, F2c, jets

Mar 2011 HERAPDF 1.6
NC, CC, jets

Aug 2010 HERAPDF 1.5
charm
NC, CC, F2c

Jul 2010 HERAPDF 1.5
NC, CC

Nov 2009 HERAPDF 1.0
NC, CC



HERAPDF 1.0 m_c scan

H1prelim-10-143
ZEUS-prel-10-019

Fit to combined H1-ZEUS NC, CC and F_2^{cc} data

- 9 H1 and ZEUS measurements used in combination

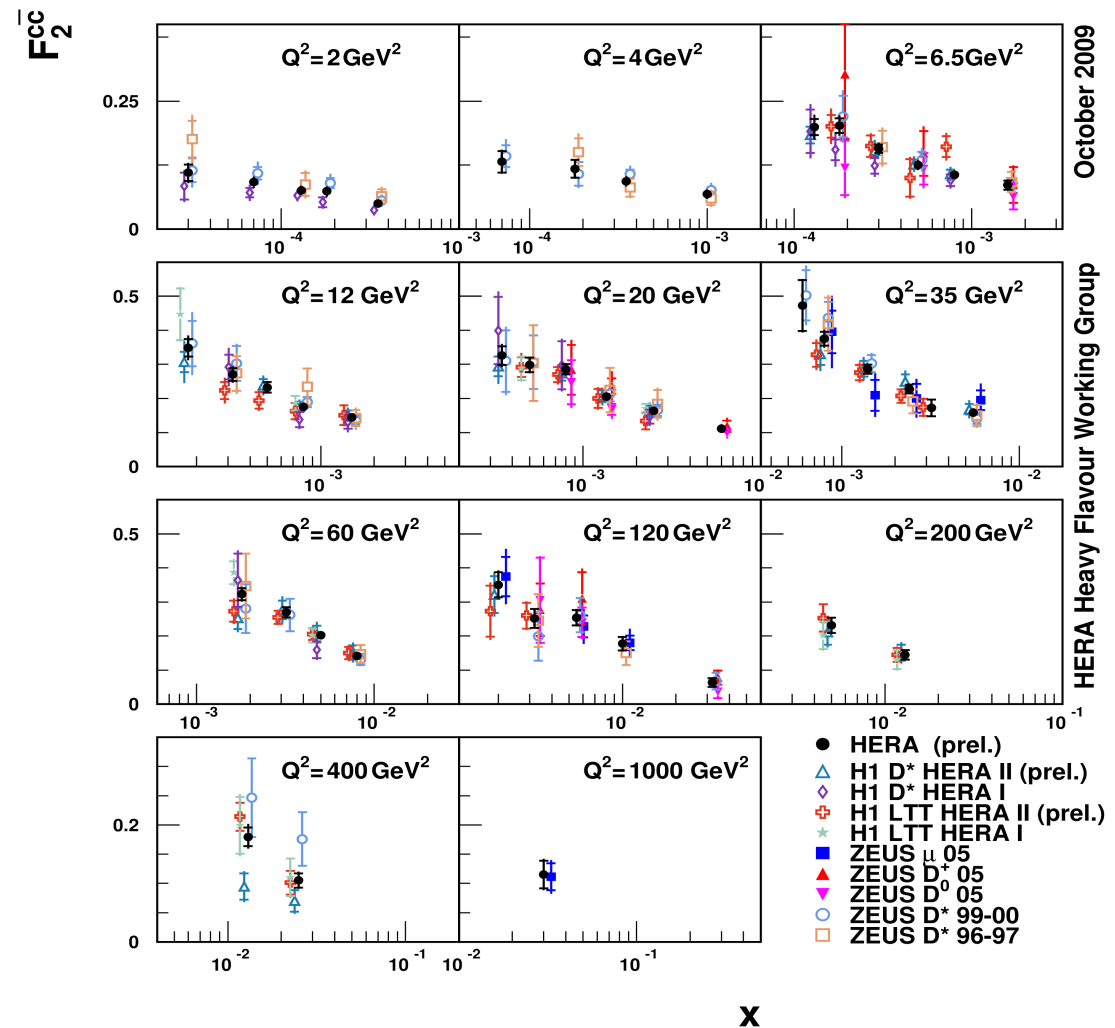
Jun 2011 HERAPDF 1.7
NC, CC, F2c, jets

Mar 2011 HERAPDF 1.6
NC, CC, jets

Aug 2010 HERAPDF 1.0
charm
NC, CC, F2c

Jul 2010 HERAPDF 1.5
NC, CC

Nov 2009 HERAPDF 1.0
NC, CC

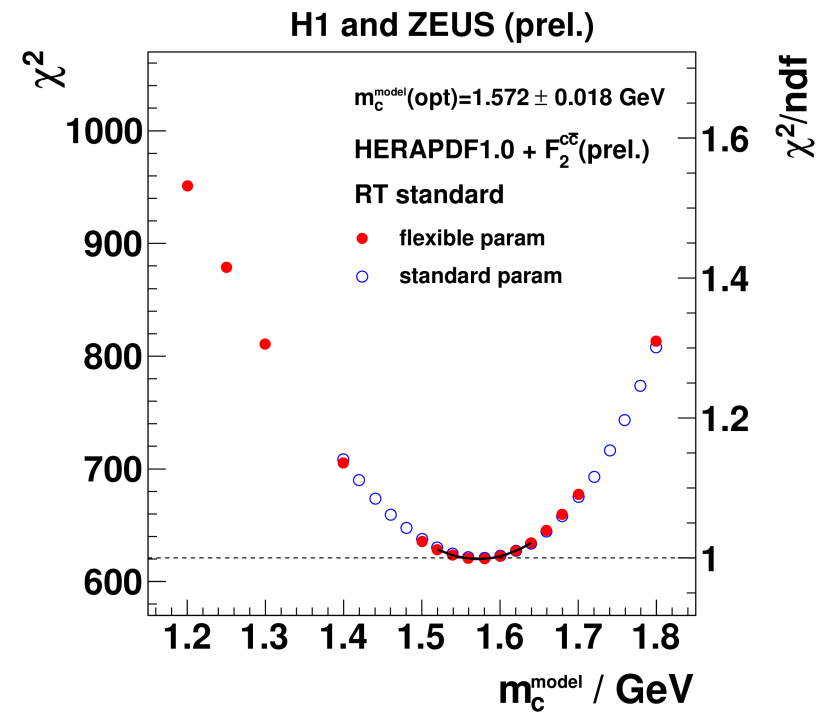
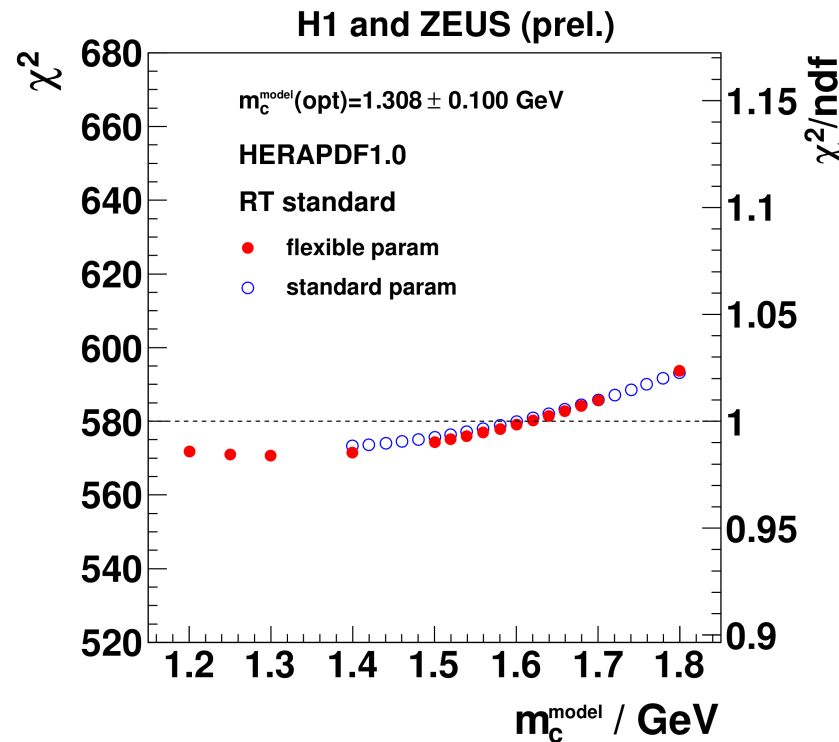


HERAPDF 1.0 m_c scan H1prelim-10-143 ZEUS-prel-10-019

Fit to combined H1-ZEUS NC, CC and F_2^{cc} data

- 9 H1 and ZEUS measurements used in combination
- F_2^{cc} data allows determination of an optimal m_c parameter

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Jul 2010	HERAPDF 1.5 NC, CC
Nov 2009	HERAPDF 1.0 NC, CC

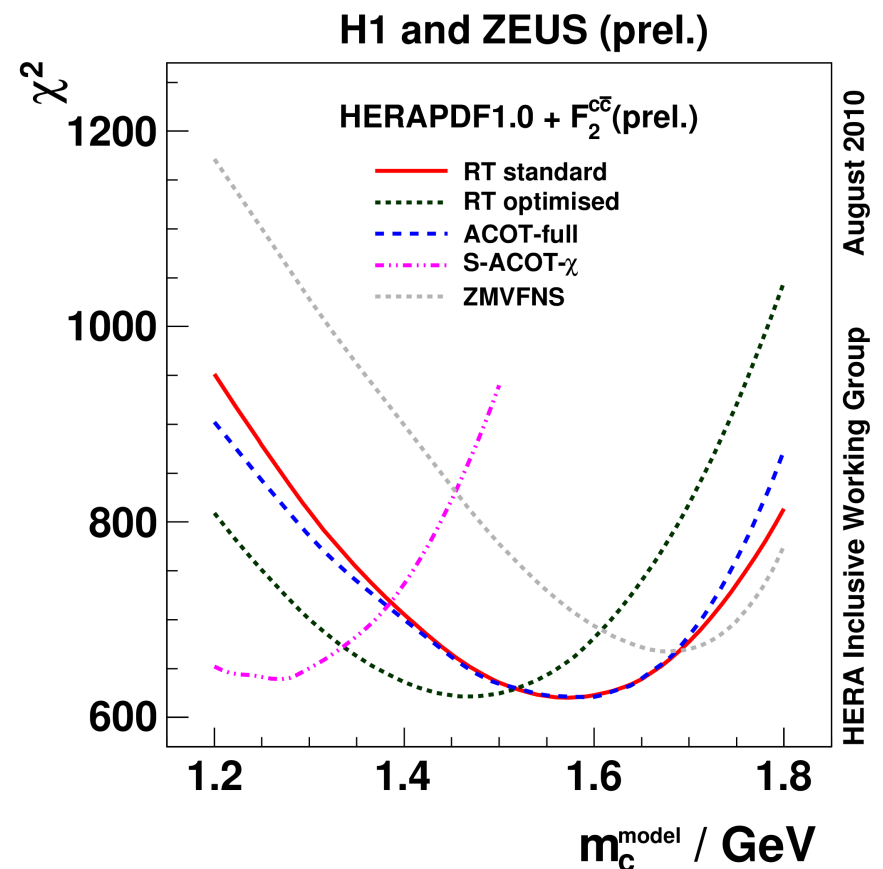
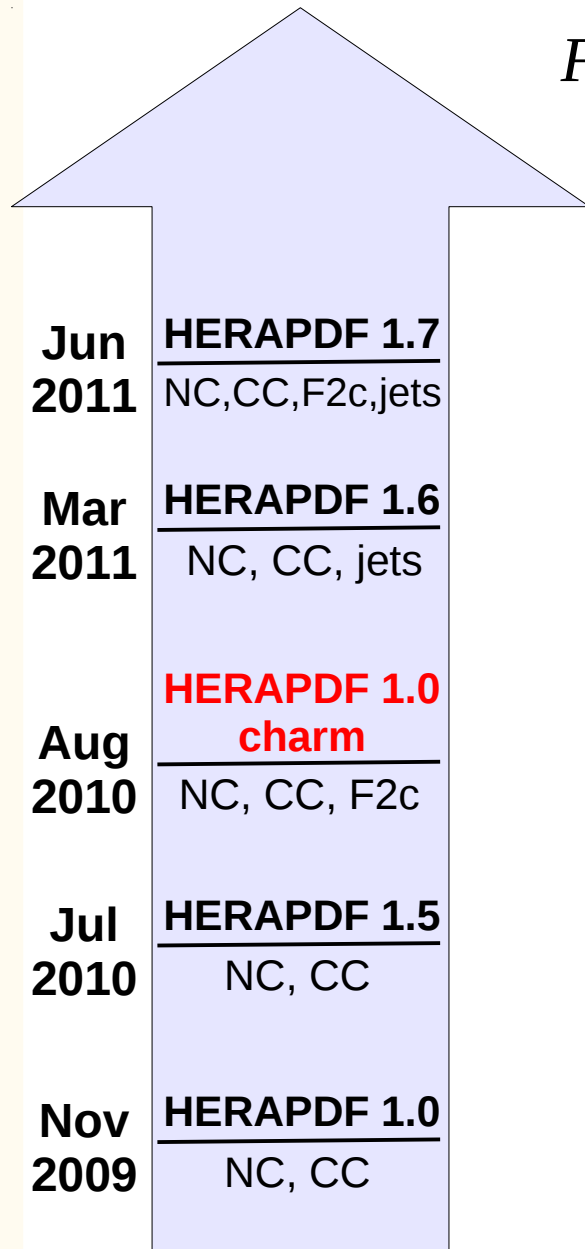


HERAPDF 1.0 m_c scan

H1prelim-10-143
ZEUS-prel-10-019

Fit to combined H1-ZEUS NC, CC and F_2^{cc} data

- 9 H1 and ZEUS measurements used in combination
- F_2^{cc} data allows determination of an optimal m_c parameter
- Optimal m_c depends on the scheme
- All schemes describe data if proper m_c used



HERAPDF 1.6

Fit to combined H1-ZEUS NC, CC and jet data

Jun 2011 HERAPDF 1.7
NC, CC, F2c, jets

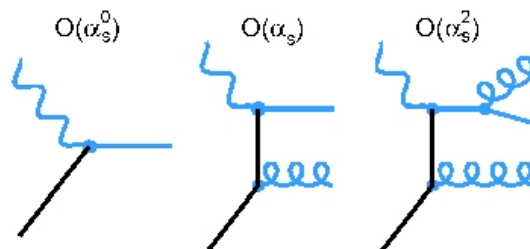
Mar 2011 **HERAPDF 1.6**
NC, CC, jets

Aug 2010 HERAPDF 1.0
charm
NC, CC, F2c

Jul 2010 HERAPDF 1.5
NC, CC

Nov 2009 HERAPDF 1.0
NC, CC

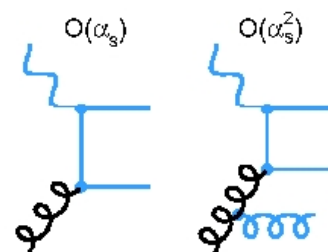
$\Delta(x)$
singlet



DIS cross sections at leading order sensitive to

$$\sigma_{DIS} \propto \Delta$$

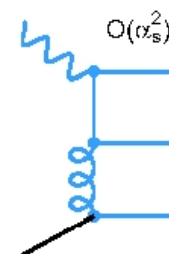
$G(x)$
gluon



Jet cross sections at leading order sensitive to

$$\sigma_{jet} \propto \alpha_s (c_G G + c_\Delta \Delta)$$

$\Sigma(x)$
non-singlet



Simultaneous α_s and PDF extraction

HERAPDF 1.6

Fit to combined H1-ZEUS NC, CC and jet data

- 2 inclusive jet measurements from H1
- 2 inclusive jet measurements from ZEUS

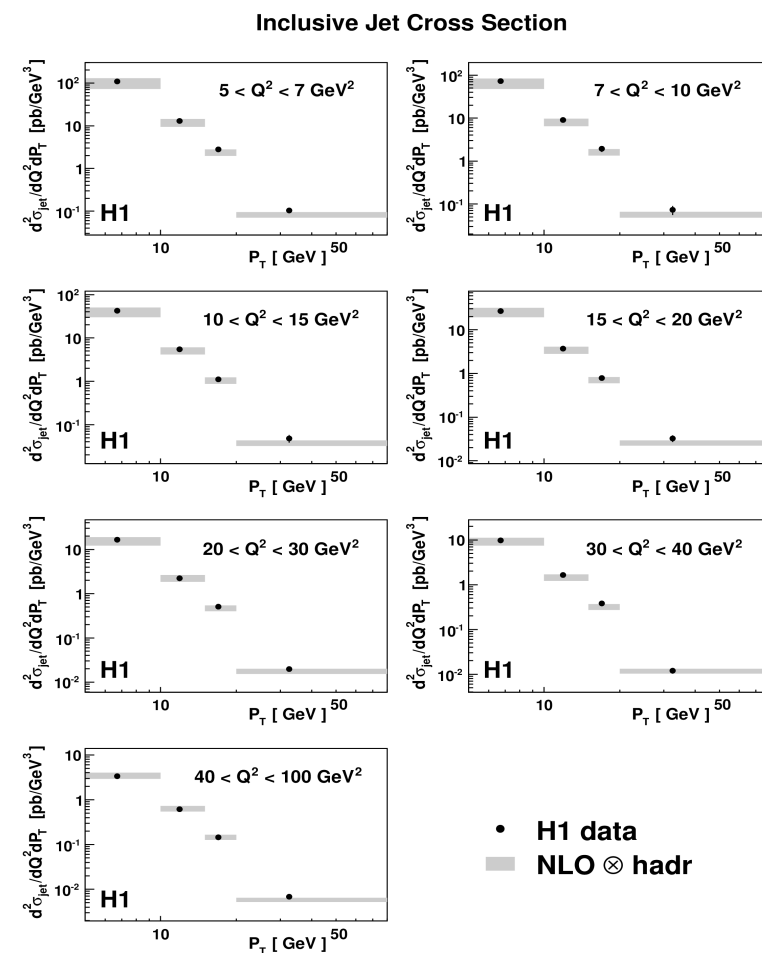
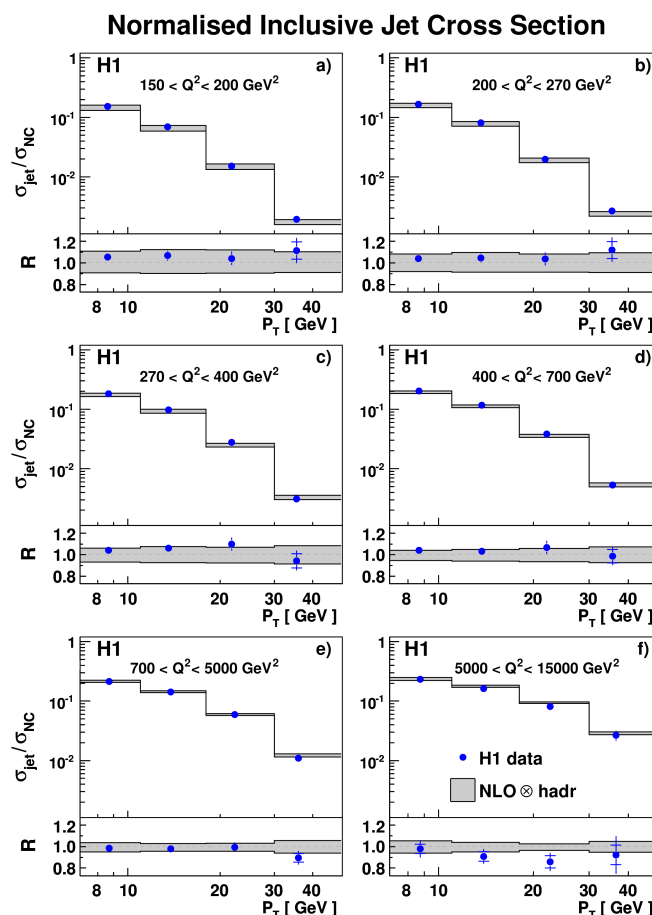
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NC, CC, F2c, jets

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NC, CC, jets

Aug 2010 **HERAPDF 1.0**
charm
NC, CC, F2c

Jul 2010 **HERAPDF 1.5**
NC, CC

Nov 2009 **HERAPDF 1.0**
NC, CC

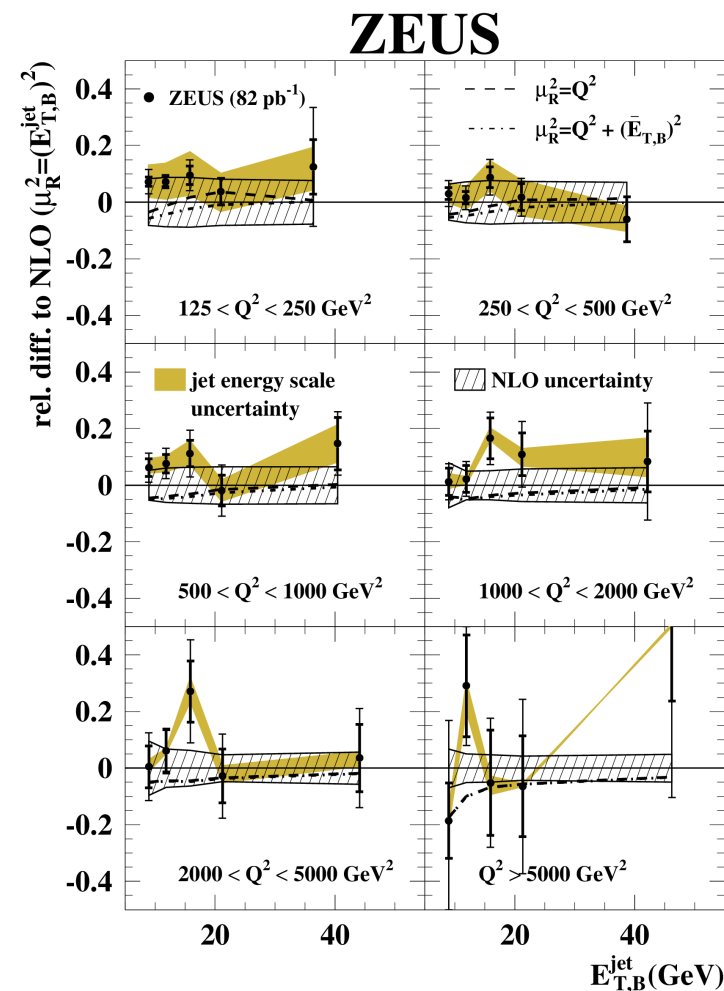
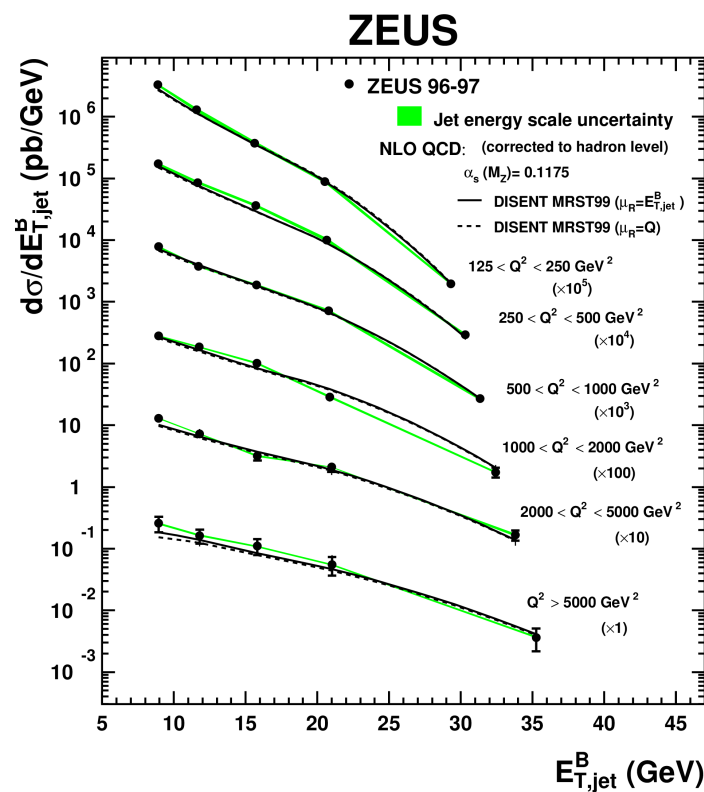


HERAPDF 1.6

Fit to combined H1-ZEUS NC, CC and jet data

- 2 inclusive jet measurements from H1
- 2 inclusive jet measurements from ZEUS

Jun 2011	HERAPDF 1.7 NC, CC, F2c, jets
Mar 2011	HERAPDF 1.6 NC, CC, jets
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Nov 2009	HERAPDF 1.0 NC, CC

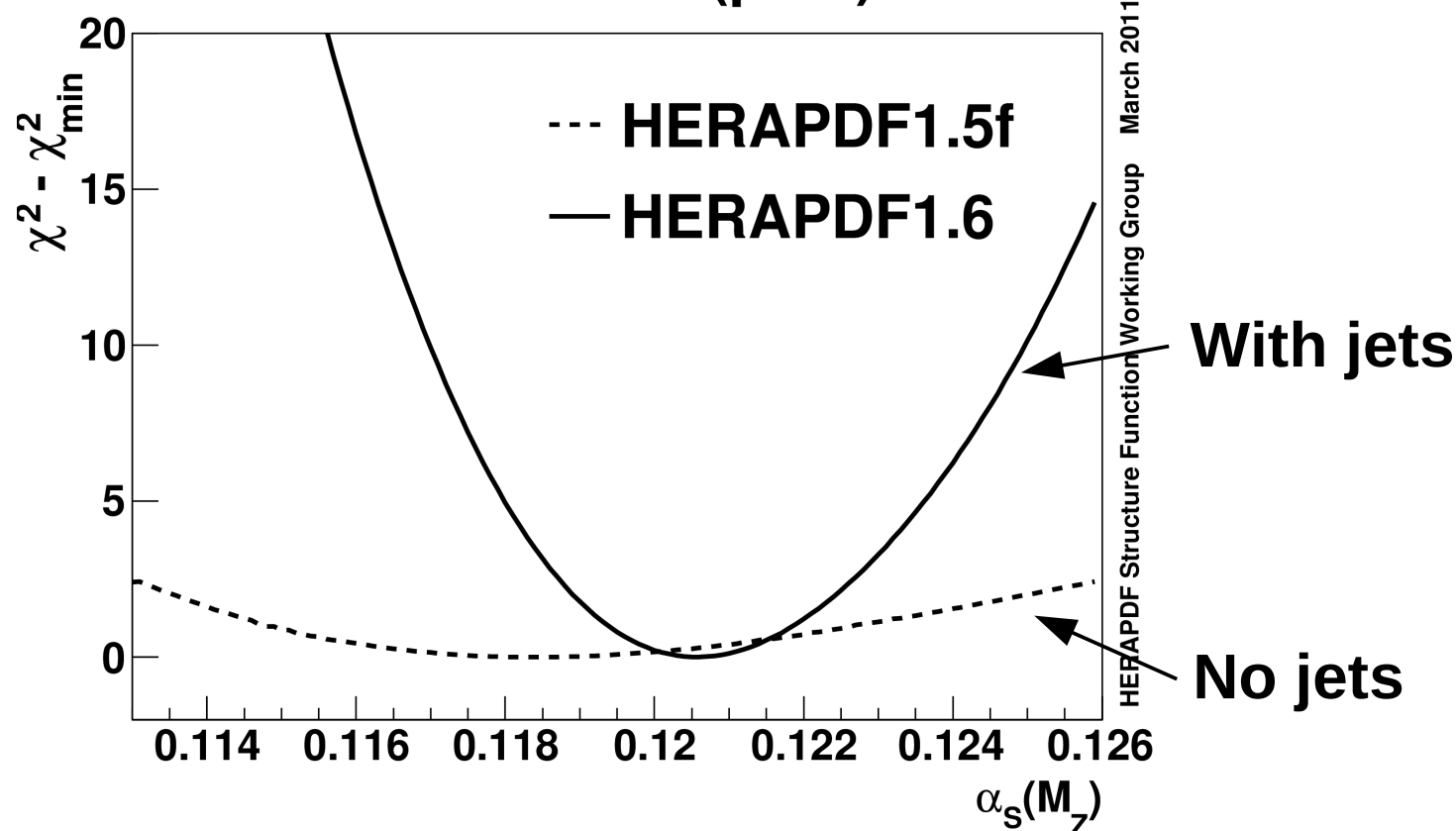


HERAPDF 1.6

Fit to combined H1-ZEUS NC, CC and jet data

- 2 inclusive jet measurements from H1
- 2 inclusive jet measurements from ZEUS

H1 and ZEUS (prel.)



Jun 2011	HERAPDF 1.7 NC, CC, F2c, jets
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Aug 2010	HERAPDF 1.0 charm NC, CC, F2c
Jul 2010	HERAPDF 1.5 NC, CC
Nov 2009	HERAPDF 1.0 NC, CC

HERAPDF 1.6

H1prelim-11-034
ZEUS-prel-11-001

Fit to combined H1-ZEUS NC, CC and jet data

- 2 inclusive jet measurements from H1
- 2 inclusive jet measurements from ZEUS

Jun 2011
HERAPDF 1.7
NC, CC, F2c, jets

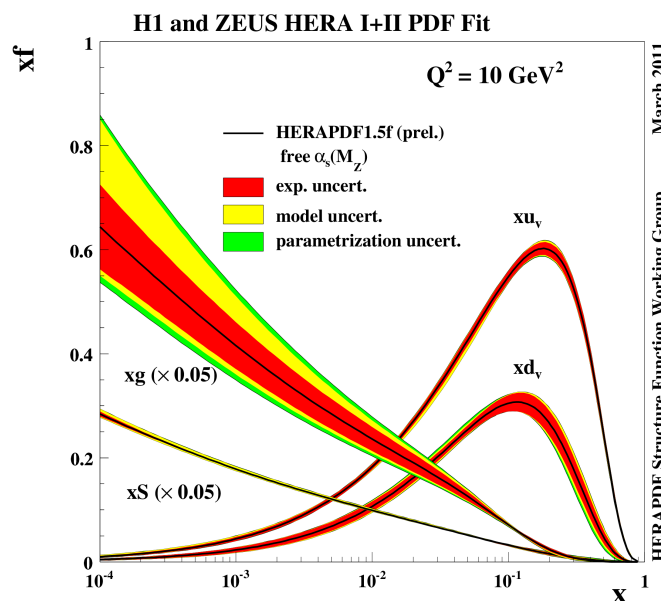
Mar 2011
HERAPDF 1.6
NC, CC, jets

Aug 2010
HERAPDF 1.0
charm
NC, CC, F2c

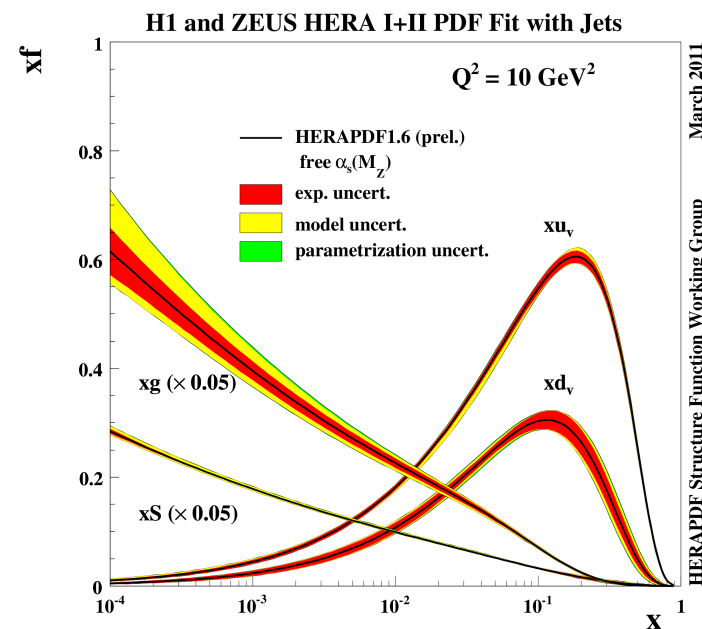
Jul 2010
HERAPDF 1.5
NC, CC

Nov 2009
HERAPDF 1.0
NC, CC

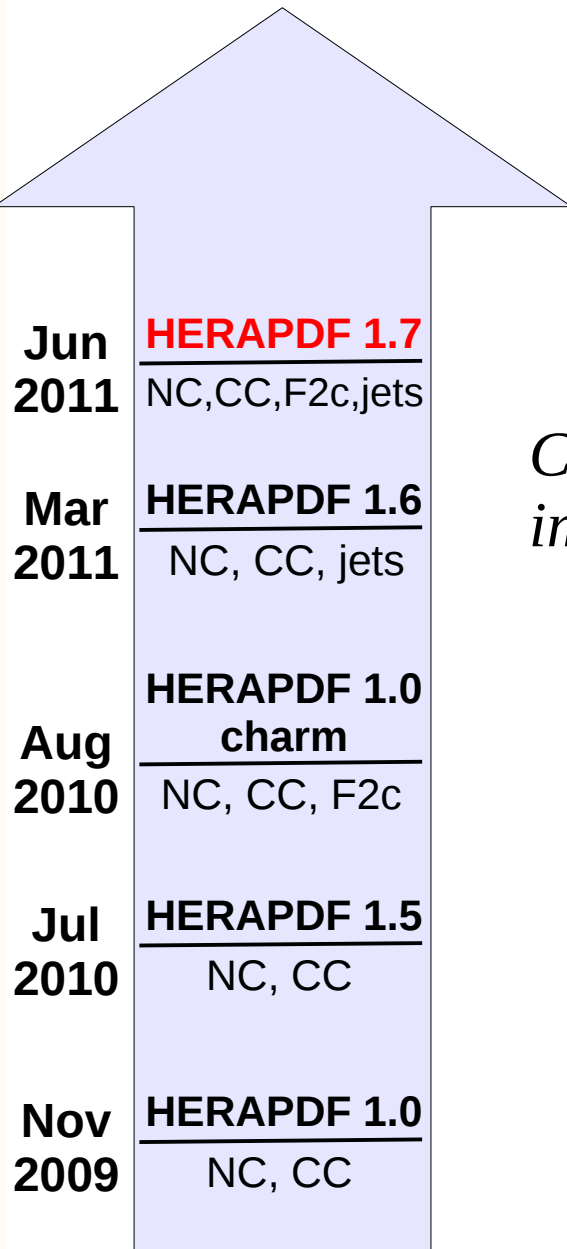
No jets, α_s free



With jets, α_s free



HERAPDF 1.7



Combination of all the previously mentioned developments, important study of the data consistency

- *Combined H1-ZEUS NC, CC (674 data points)*
- *F_2^{cc} combination (41 data points)*
- *H1 and ZEUS inclusive jet data (106 data points)*
- *Low energy data (224 data points)*
- *Modified RT scheme*
- *Charm mass $m_c = 1.5 \text{ GeV}$*
- *Strong coupling constant $\alpha_s(M_Z) = 0.119$*

Parametrization changes

Parametrization at the starting scale $Q_0^2 = 1.9 \text{ GeV}^2$:

10-parameter fit

(HERAPDF1.0, HERAPDF1.5)

$$xg(x) = A_g x^{B_g} (1-x)^{C_g}$$

$$xu_v(x) = A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1 + E_{u_v} x^2)$$

$$xd_v(x) = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}}$$

$$x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}}$$

$$x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}}$$

Additional constrains:

A_g, A_{u_v}, A_{d_v} calculated by sum rules

$$A_{\bar{U}} = A_{\bar{D}} (1 - f_s)$$

$$B_{\bar{U}} = B_{\bar{D}}$$

$$B_{u_v} = B_{d_v}$$

14-parameter fit

(HERAPDF1.6)

$$xg(x) = A_g x^{B_g} (1-x)^{C_g} - A'_g x^{B'_g} (1-x)^{25}$$

$$xu_v(x) = A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1 + D_{u_v} x + E_{u_v} x^2)$$

$$xd_v(x) = A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}}$$

$$x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}}$$

$$x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}}$$

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Parametrization changes

Parametrization at the starting scale $Q_0^2 = 1.9 \text{ GeV}^2$:

14-parameter fit (HERAPDF1.6)

$$\begin{aligned} xg(x) &= A_g x^{B_g} (1-x)^{C_g} - A'_g x^{B'_g} (1-x)^{25} \\ xu_v(x) &= A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1 + D_{u_v} x + E_{u_v} x^2) \\ xd_v(x) &= A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}} \\ x\bar{U}(x) &= A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}} \\ x\bar{D}(x) &= A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}} \end{aligned}$$


Additional constrains:

A_g, A_{u_v}, A_{d_v} calculated by sum rules

$$A_{\bar{U}} = A_{\bar{D}} (1 - f_s)$$

$$B_{\bar{U}} = B_{\bar{D}}$$

13-parameter fit (HERAPDF1.7)

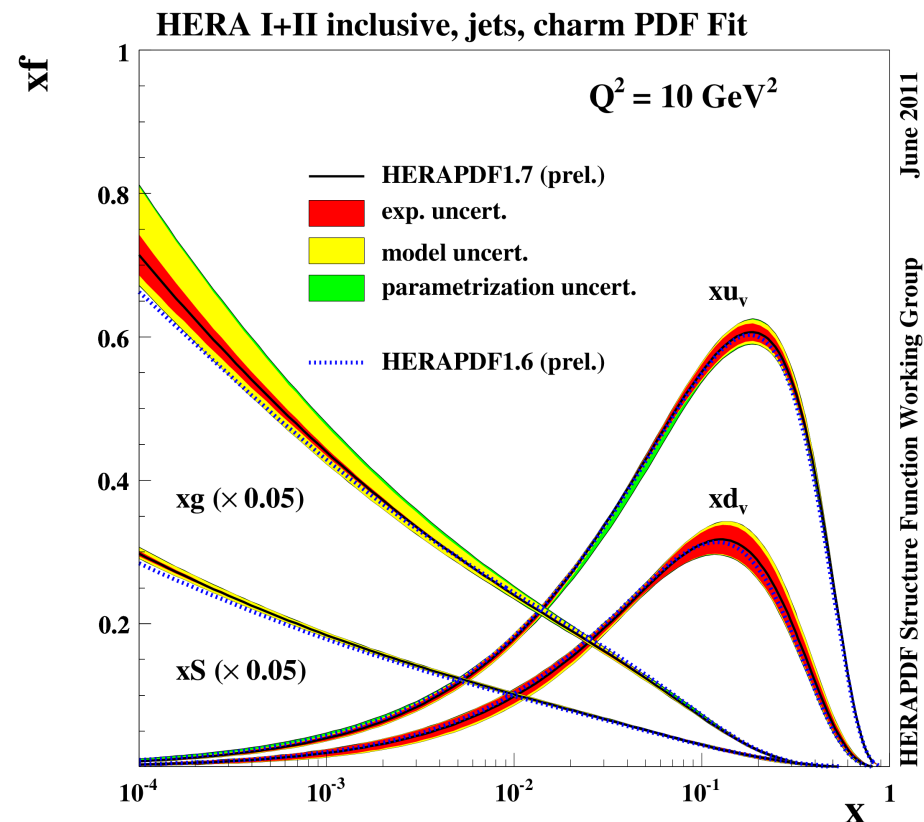
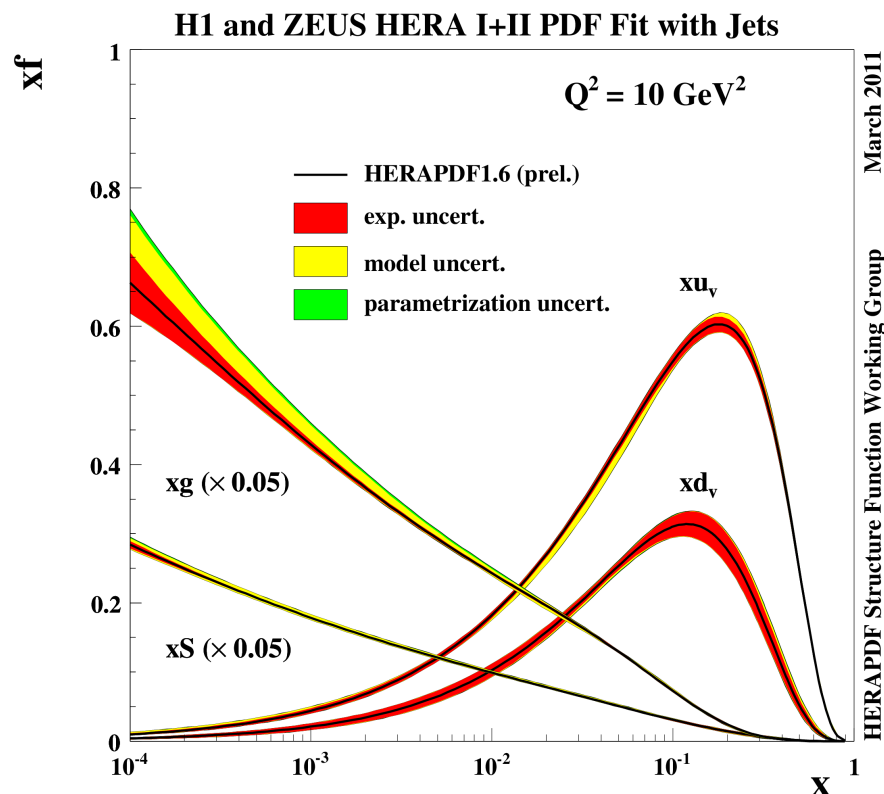
$$\begin{aligned} xg(x) &= A_g x^{B_g} (1-x)^{C_g} - A'_g x^{B'_g} (1-x)^{25} \\ xu_v(x) &= A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1 + E_{u_v} x^2) \\ xd_v(x) &= A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}} \\ x\bar{U}(x) &= A_{\bar{U}} x^{B_{\bar{U}}} (1-x)^{C_{\bar{U}}} \\ x\bar{D}(x) &= A_{\bar{D}} x^{B_{\bar{D}}} (1-x)^{C_{\bar{D}}} \end{aligned}$$

Additional constrains:

A_g, A_{u_v}, A_{d_v} calculated by sum rules

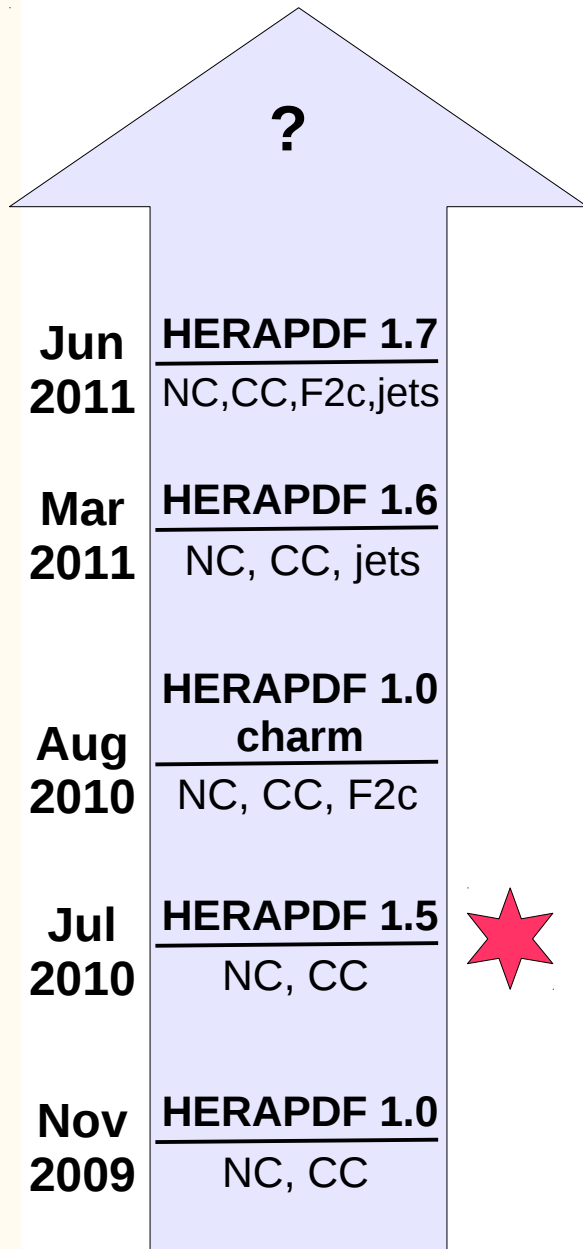
$$A_{\bar{U}} = A_{\bar{D}} (1 - f_s)$$

$$B_{\bar{U}} = B_{\bar{D}}$$



- ✓ *Steeper gluon*
- ✓ *Model uncertainty transferred partially into parametrization uncertainty for u_v (and high- x gluon)*
- ✓ *All HERA data sets consistent*

Summary



- ✓ *Continuous development and improvement of PDF fits using solely HERA data*
- ✓ *We try to understand fit based on preliminary data*
- ✓ *Fit with inclusive DIS, charm, jet and low energy data performed*
- ✓ *Interesting exercise proves consistency of all used HERA data sets*
- ✓ *HERAPDF 1.5 continues to be the recommended pdf*
- ★ ✓ *Software released as open HERA-fitter project, available for download (see dedicated talk tomorrow)*