QCD analysis with determination of α_s based on HERA inclusive and jet data

Krzysztof Nowak
on behalf of
H1 and **ZEUS**
collaborations

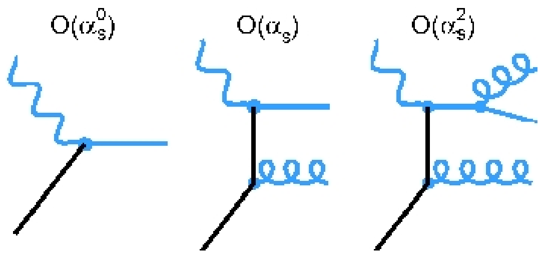
- Introduction
- H1 and ZEUS data
- Fit results

Simultaneous PDF + α_s determination

HERAPDF fit uses external information about α_s

HERA data sensitive to α_s – simultaneous PDF and α_s fit possible

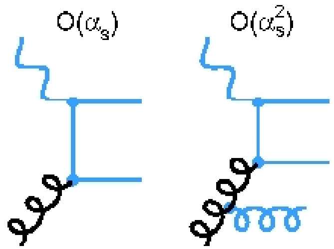
$\Delta(x)$
singlet



DIS cross sections at leading order sensitive to

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

$G(x)$
gluon

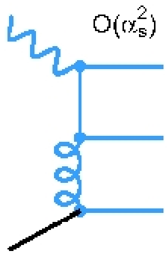


Jet cross sections at leading order sensitive to

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

Remark: α_s - G correlation

$\Sigma(x)$
non-singlet



Jet data needed to determine α_s with reasonable precision: HERAPDF1.6

HERAPDF 1.6

Using the same same DIS data as HERAPDF1.5:
HERA I+II, NC+CC, H1ZEUS combined data

In addition four inclusive jet measurements:

- *HERA I + II high Q^2 normalized jets (H1)*
- *HERA I low Q^2 jets (H1)*
- *96-97 high Q^2 jets (ZEUS)* } *HERA I*
- *98-00 high Q^2 jets (ZEUS)*

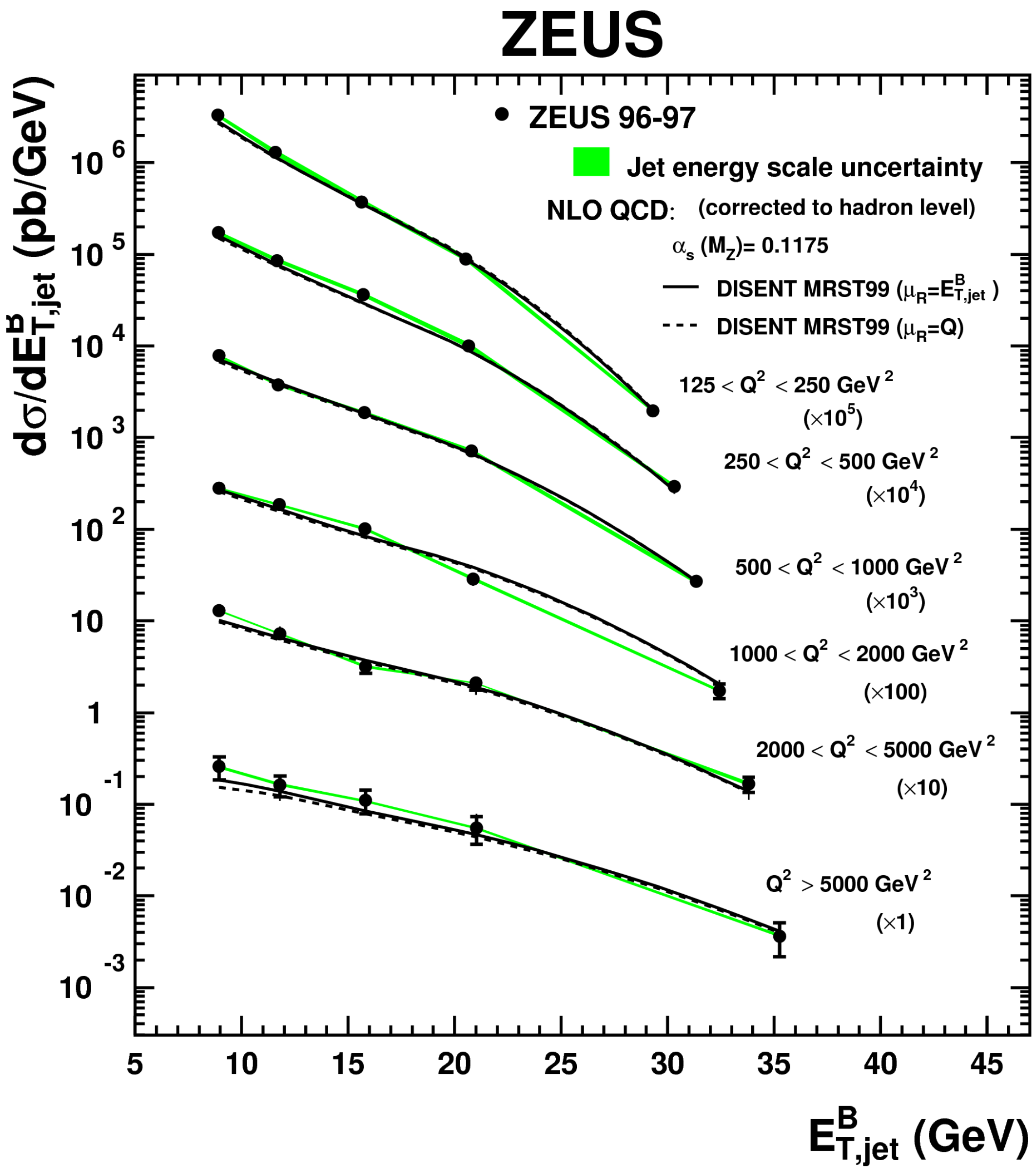
DIS data calculated by QCDNUM 17
Jet cross sections calculated by NLOJet++ / FastNLO
Correlated error between jet measurement taken into account

Inclusive jet cross section at high Q^2

Phys. Lett. B 547, 164 (2002)

- *ZEUS 96/97 data (L = 38.6 pb^{-1})*
- *$Q^2 > 125\ GeV^2$*
- *In bins of P_T and Q^2 (30 points)*
- *Average experimental error:*
  ± 15% (unc.)   ± 4% (cor.)

- *Average theoretical error:*
  ± 5% … 10%

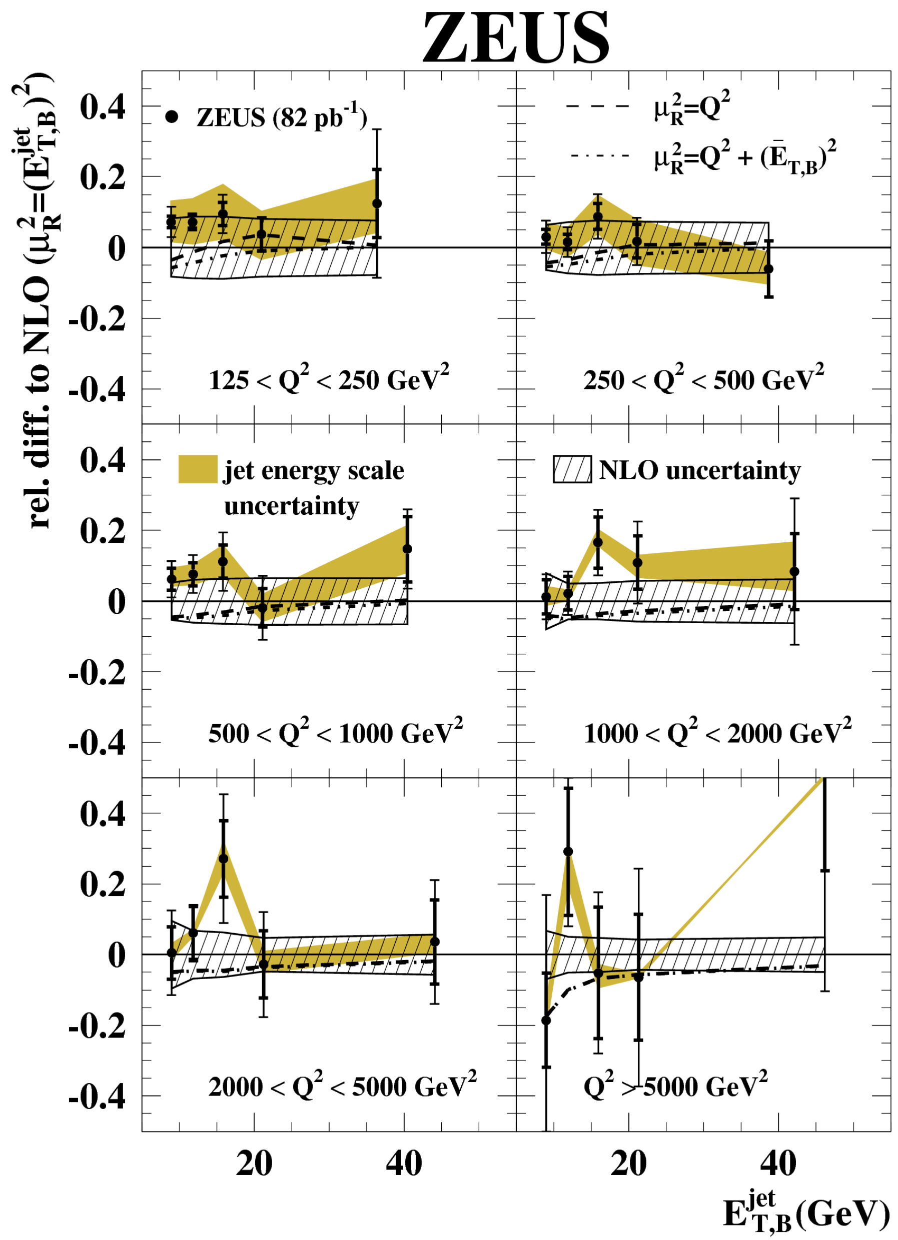


Inclusive jet cross section at high Q^2

Nucl. Phys. B 765, 1 (2007)

- *ZEUS 98-00 data ($L = 82\ pb^{-1}$)*
- *$Q^2 > 125\ GeV^2$*
- *In bins of P_T and Q^2 (30 points)*
- *Average experimental error:*
  ± 13% (unc.)   ± 4% (cor.)

- *Average theoretical error:*
  ± 5% … 10%

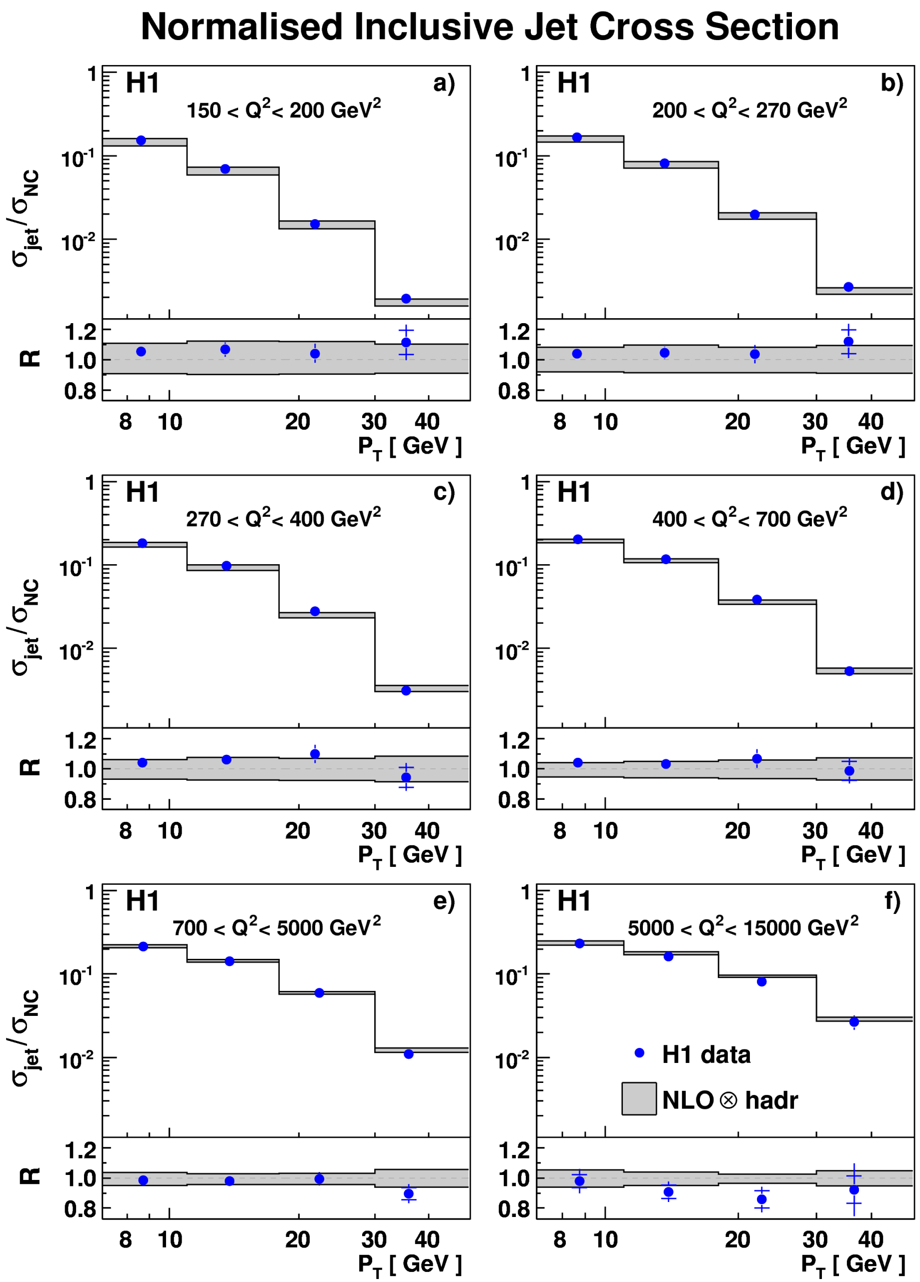


Inclusive jet cross section at high Q^2

Eur. Phys. J. C65, 363 (2010)

- *H1 HERA I + II data ($L = 395\ pb^{-1}$)*
- *$150 < Q^2 < 15000\ GeV^2$*
- *Normalized to DIS cross sections*
- *In bins of P_T and Q^2 (24 points)*
- *Average experimental error:*
  ± 6% (unc.) ± 3% (cor.)

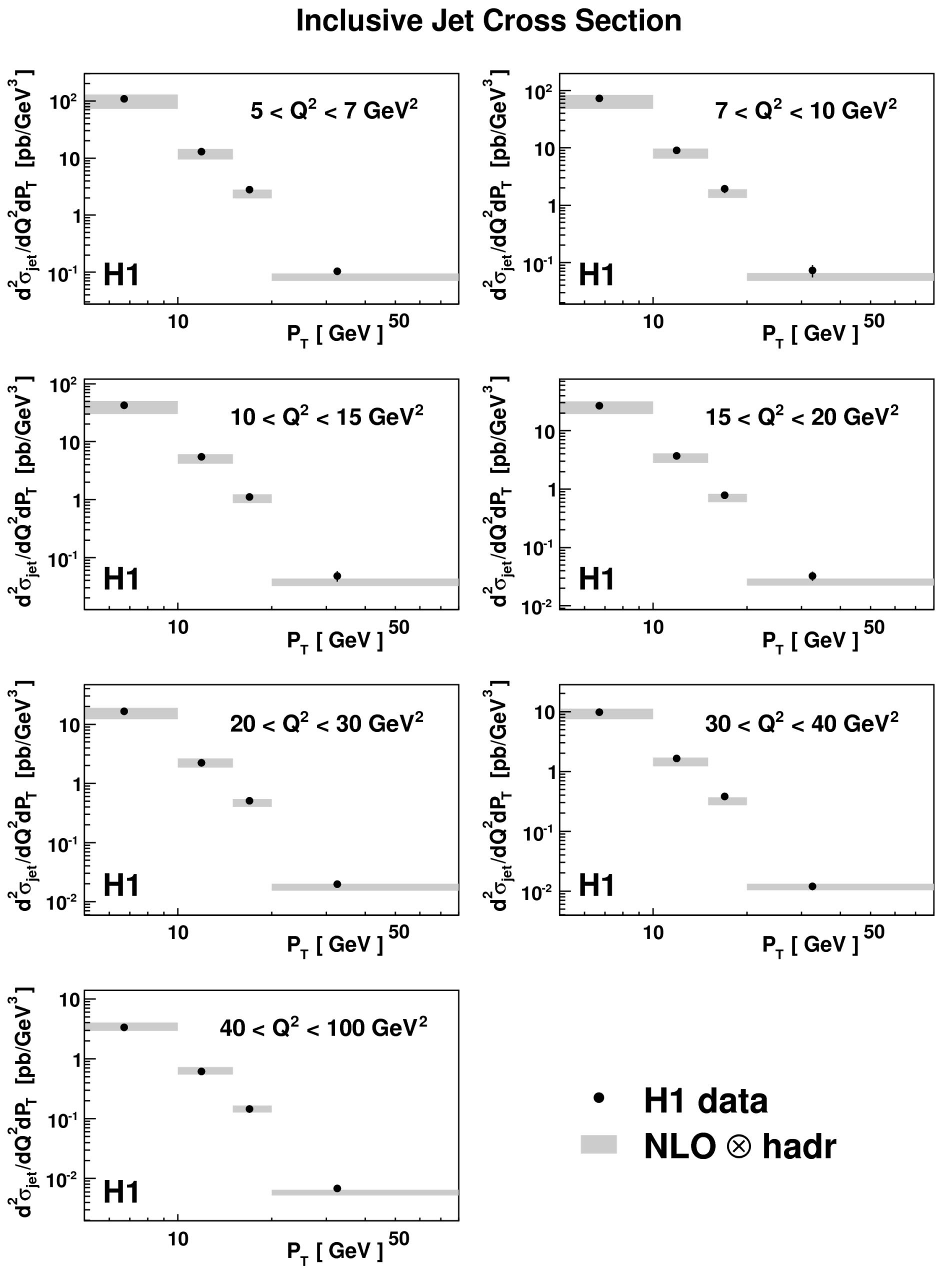
- *Theoretical error:*
  ± 5% … 10%



Inclusive jet cross section at low Q^2

Eur. Phys. J. C67, 1 (2010)

- *H1 HERA I data ($L = 43.5\ pb^{-1}$)*
- *$5 < Q^2 < 100\ GeV^2$*
- *Average experimental error:*
  ± 9% (unc.)   ± 8% (cor.)
- *Theoretical error:*
  ± 10% … 30%
- *Low Q^2: higher orders more important*
- *Using only points with NLO/LO < 2*
  (22 points)



Parametrization

- ***Parametrization at the starting scale Q_0^2 = 1.9 GeV^2:***

$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2) \quad [for \quad f = g, u_v, d_v, \bar{U}, \bar{D}]$$

With some additional constrains (more details in backup):

10 free parameters ***(HERAPDF1.0, HERAPDF1.5)***

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- ***Recent HERAPDF activities (jet data, charm data, NNLO fit) show need for more flexibility, particularly for gluon pdf:***

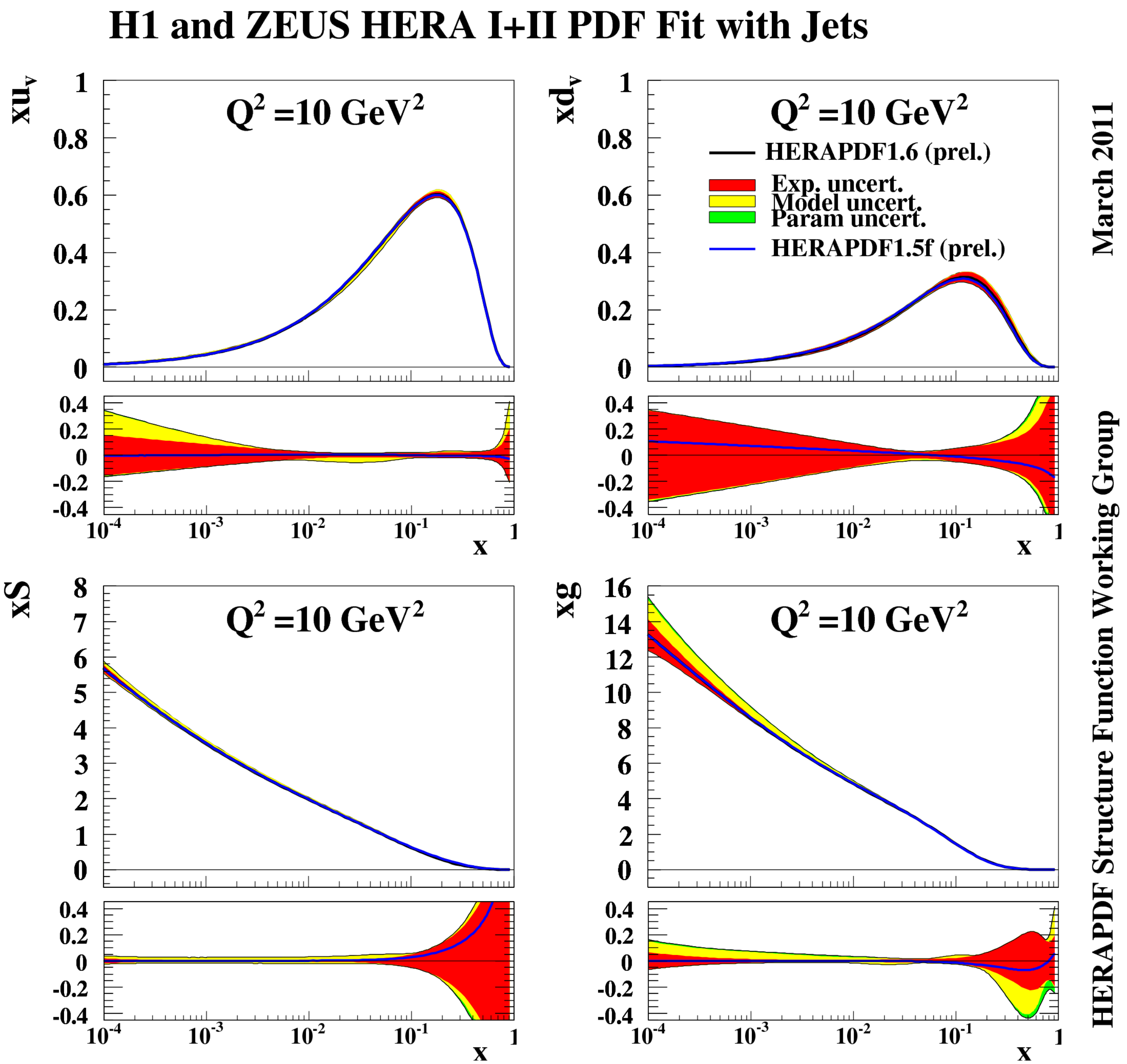
$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2) \quad [for \quad f=u_v, d_v, \bar{U}, \bar{D}]$$

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

Additional constrains $B_{d_v} = B_{u_v}$ ***and*** $D_{u_v} = 0$ ***have been dropped***

14 free parameters ***(HERAPDF1.5f, HERAPDF1.6)***

Fit with fixed $\alpha_s(M_Z) = 0.1176$

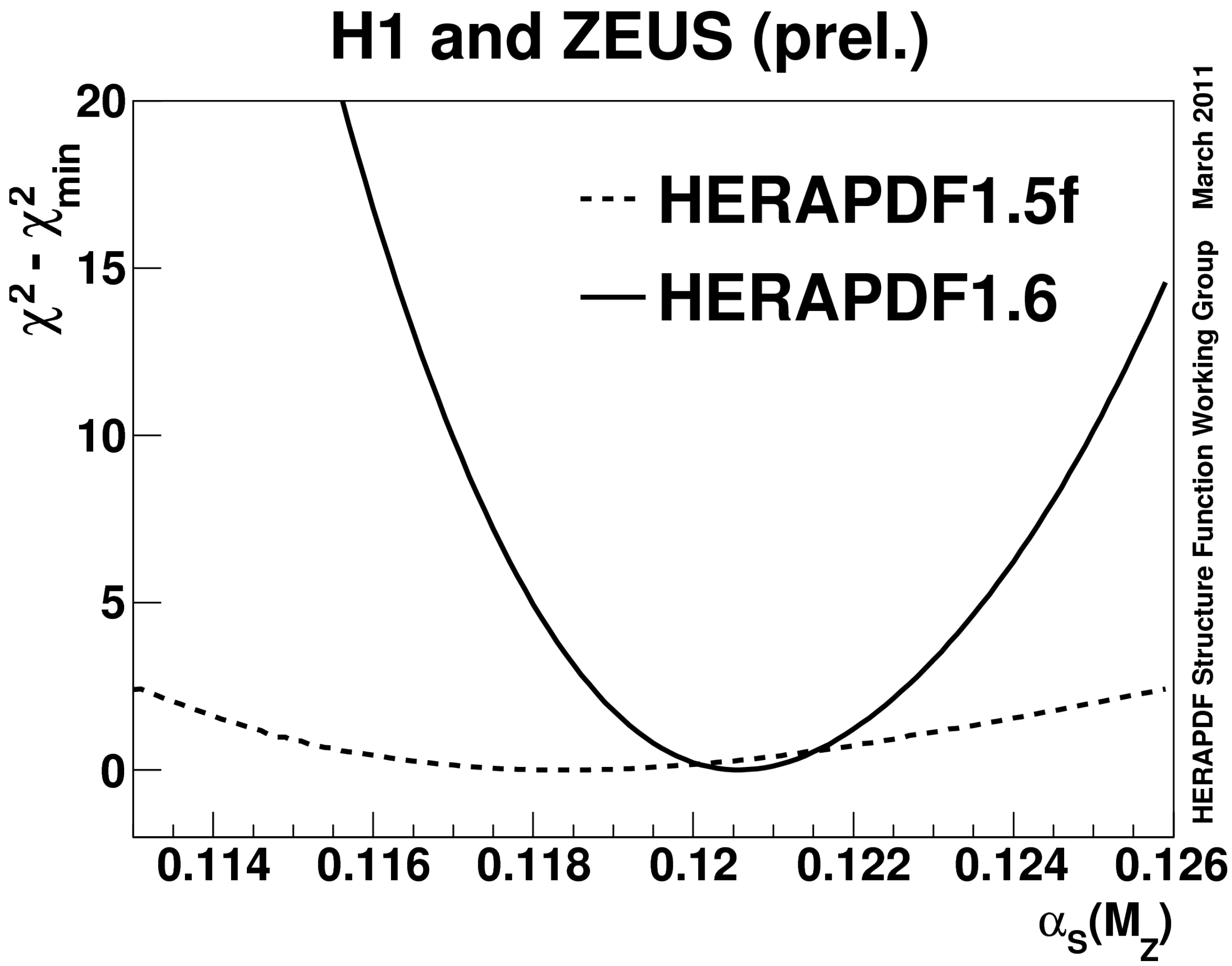


- *Jet data sensitive to gluon PDF already at LO*
- *One might look for improvements in terms of gluon uncertainty, regardless on α_s*

- *Very little difference observed (small improvement for high-x)*
- *Softer sea distribution*

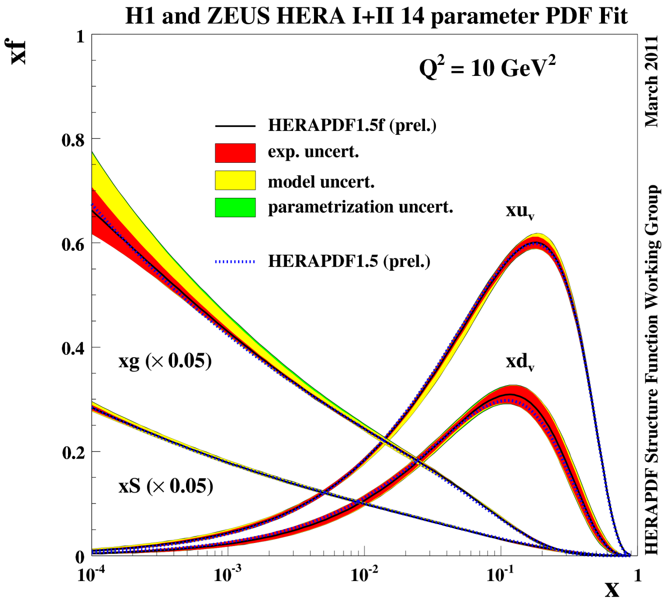
χ^2 scan of $\alpha_s(M_Z)$

- *Fit without jet data (HERAPDF1.5f) exhibits shallow χ^2 minimum, little sensitivity to α_s*
- *Addition of jets (HERAPDF1.6) allows precise α_s determination*



Transition to free $\alpha_s(M_Z)$

No jets, α_s fixed



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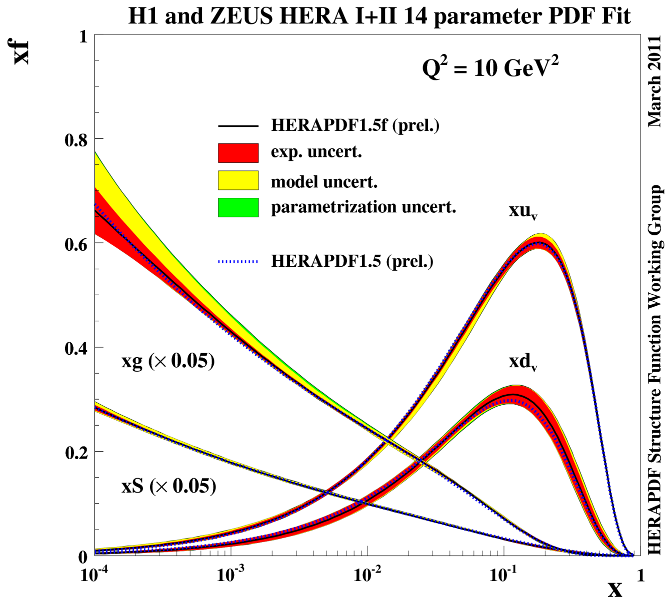
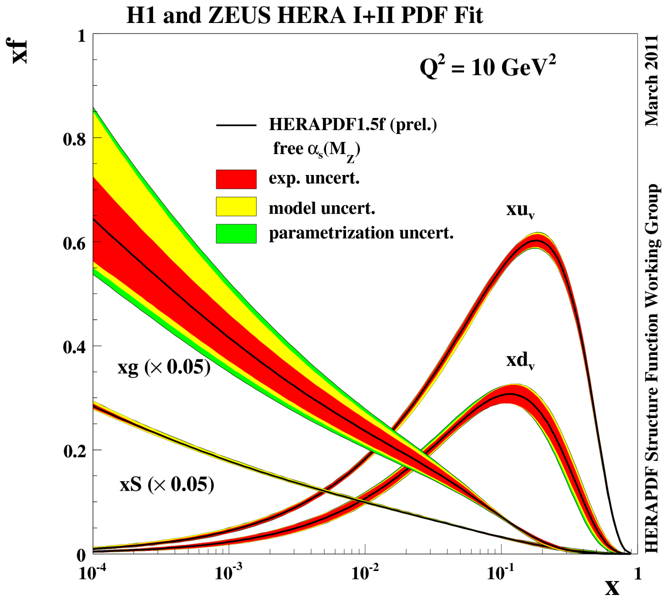


No jets, α_s free



- *Due to gluon – α_s correlation, freeing α_s lead to increase of gluon uncertainty*

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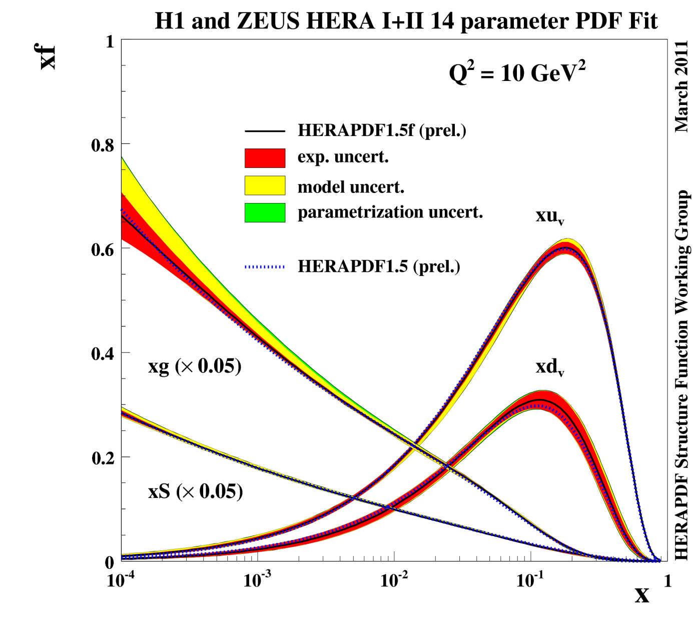
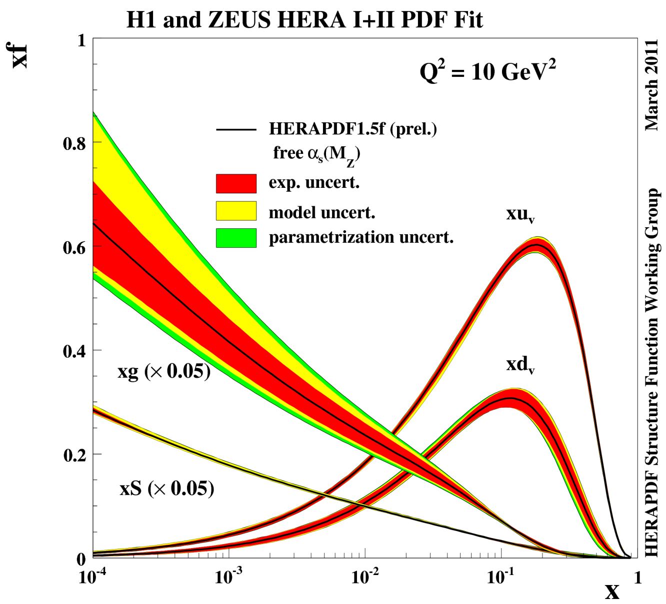
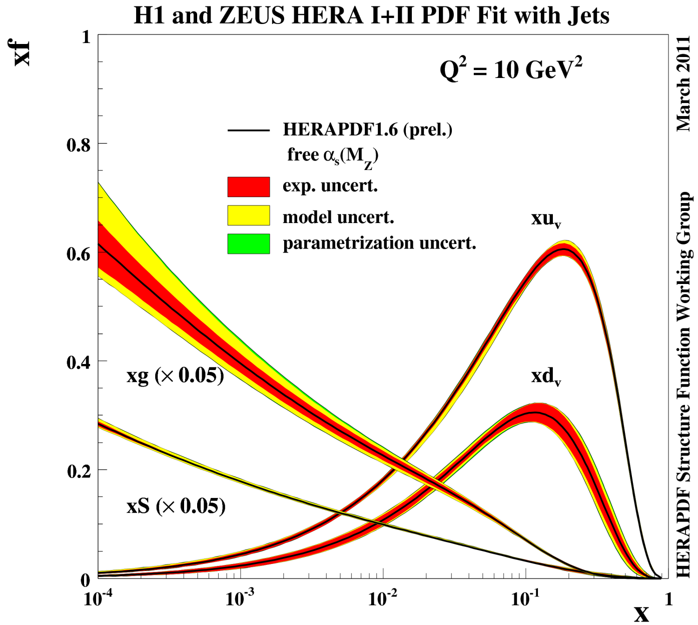


No jets, α_s free



With jets, α_s free



- ***Due to gluon – α_s correlation, freeing α_s lead to increase of gluon uncertainty***
- ***Jets bring gluon pdf back under control and allow α_s fit with reasonable precision***

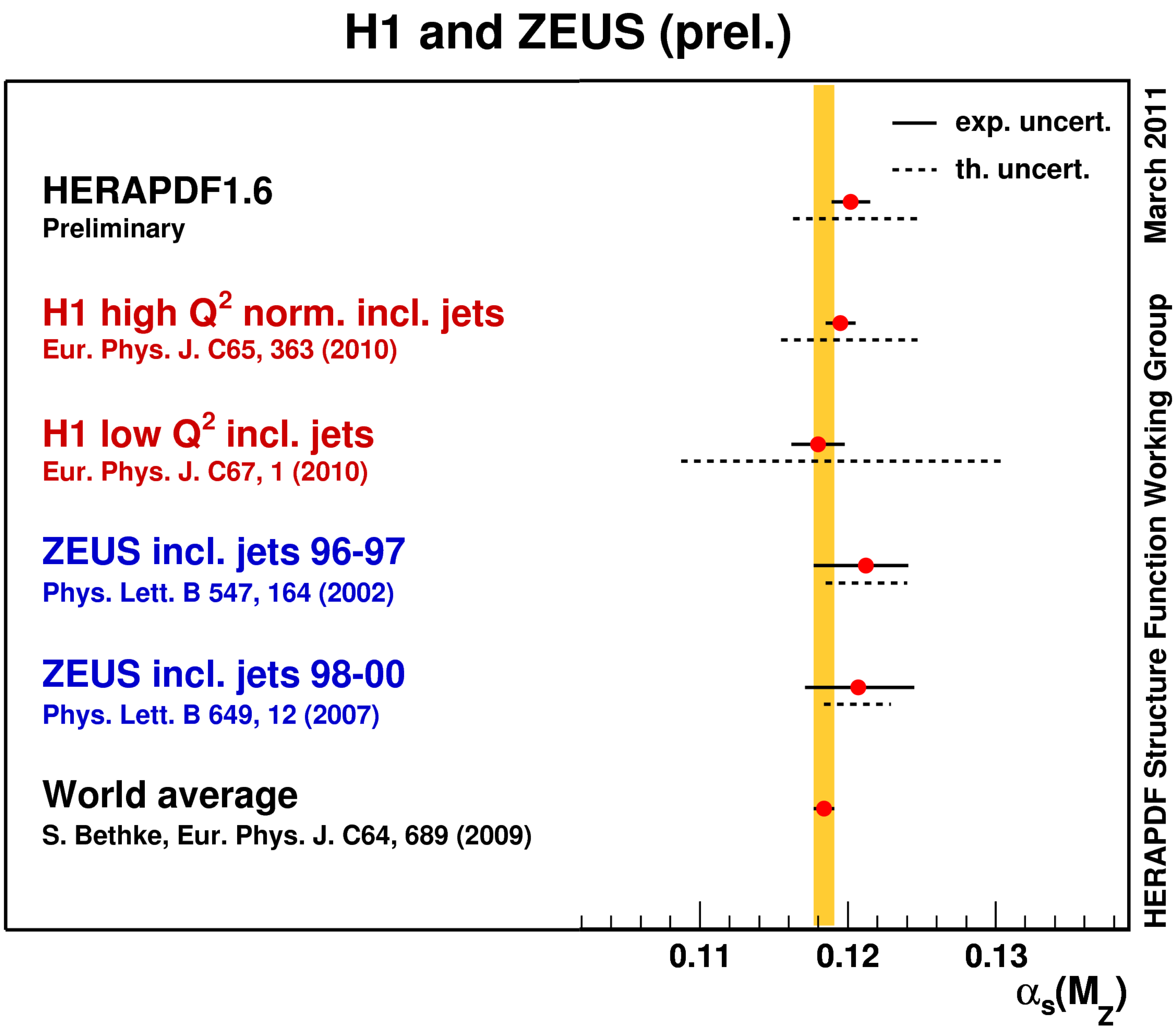
Fitted $\alpha_s(M_Z)$ value

Strong coupling constant obtained from the HERAPDF1.6 fit:

$$\alpha_s = 0.1202 \pm 0.0013(exp) \pm 0.0007(mod/par) \pm 0.0012(hadr) {}^{+0.0045}_{-0.0036}(scale)$$

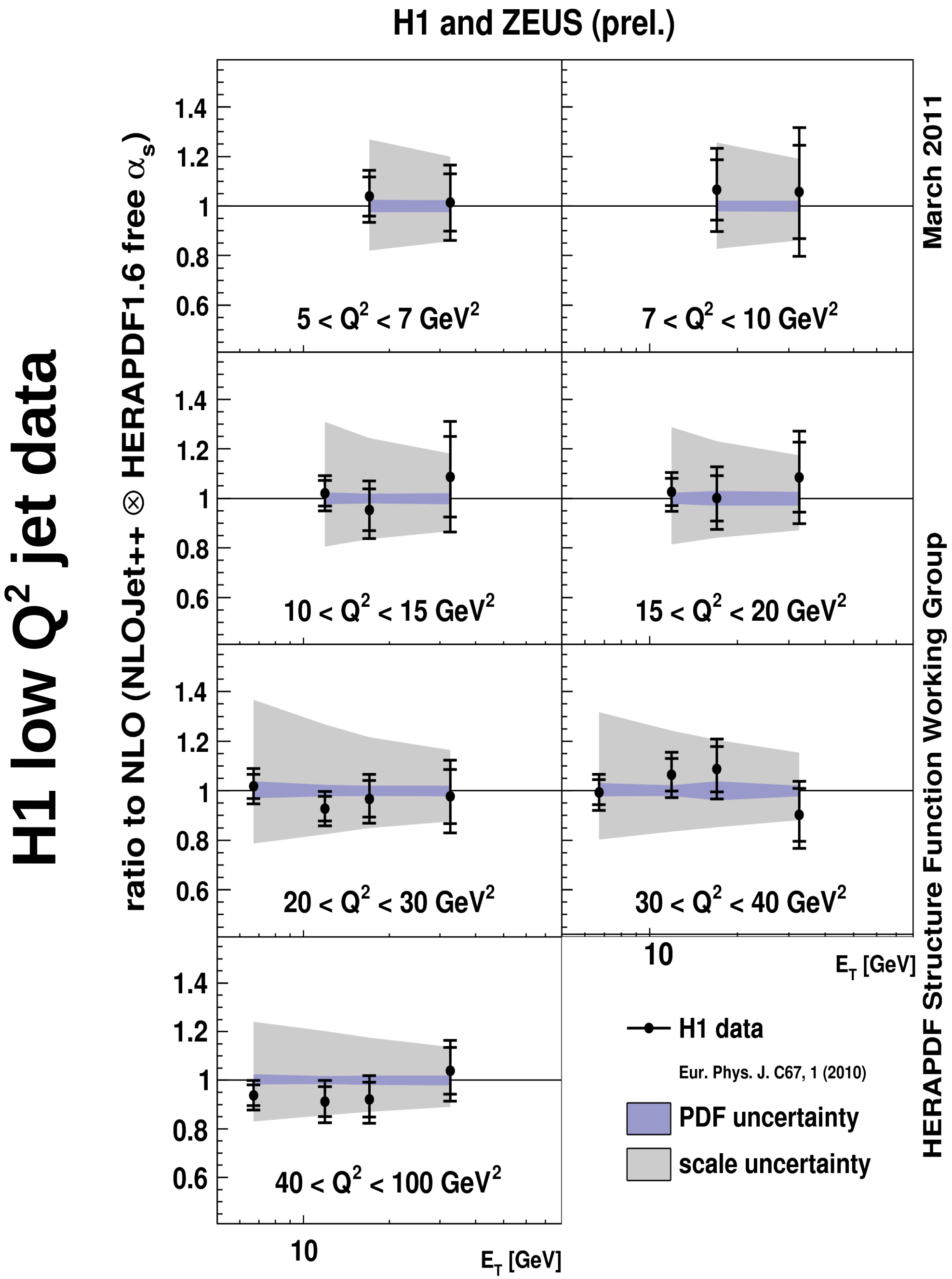
- ***Small experimental uncertainty***
- ***Model and parametrization uncertainty evaluated like for HERAPDF1.5***
- ***Hadronisation uncertainty significant***
- ***Largest uncertainty coming from scale variation***
  - ***Factorization scale multiplied by arbitrary factor of 2 and 0.5)***

Comparison of fitted $\alpha_s(M_Z)$



- *Fitted α_s ~ average between four used measurements*
- *PDF uncertainty part of experimental unc. for HERAPF1.6*
- *All results consistent with the world average*

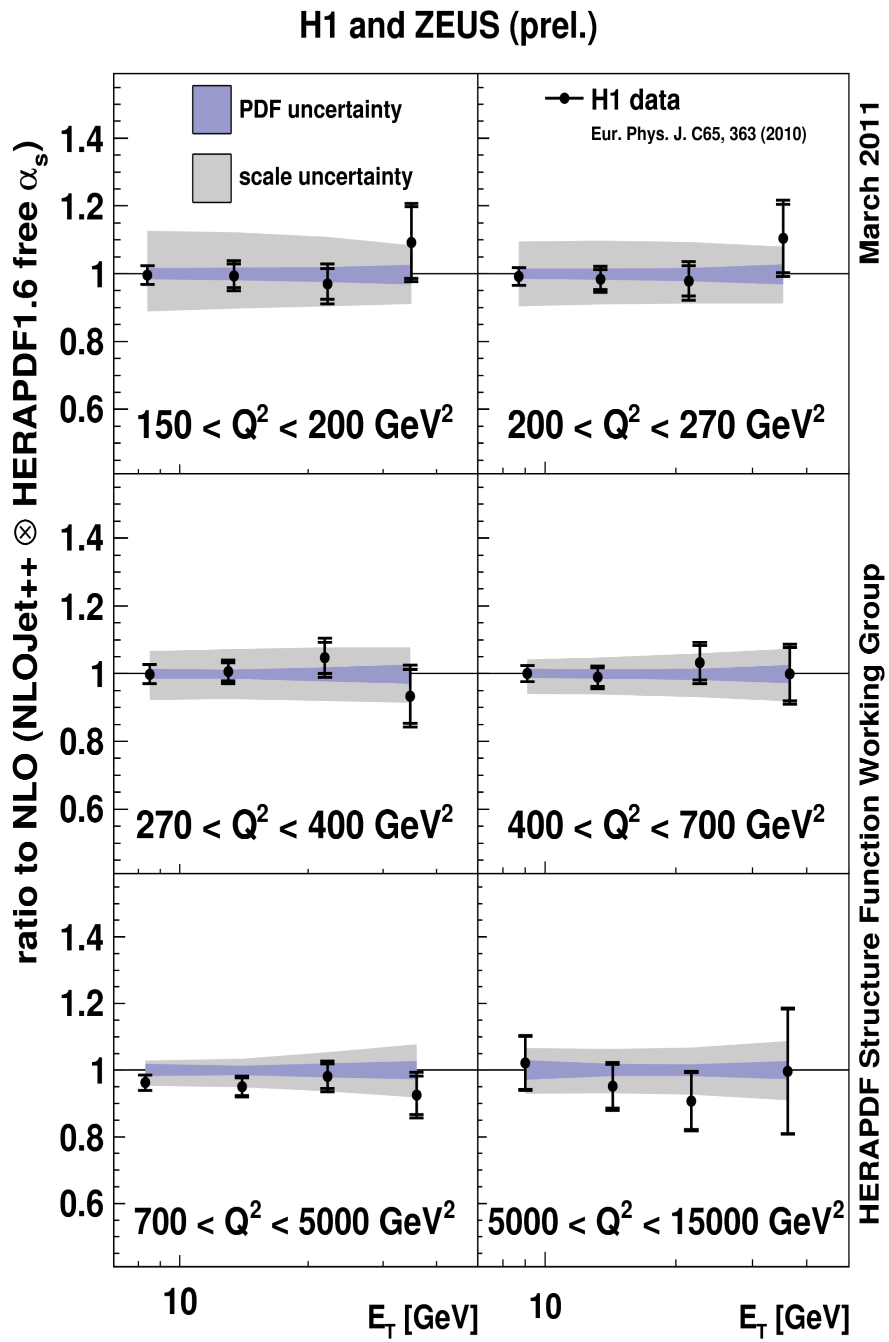
Data description



- ***Dominant uncertainty coming from factorisation scale variation***
- ***Higher order corrections less significant for increasing Q^2 and P_T***
- ***Fit well describes the measurement within uncertainties***

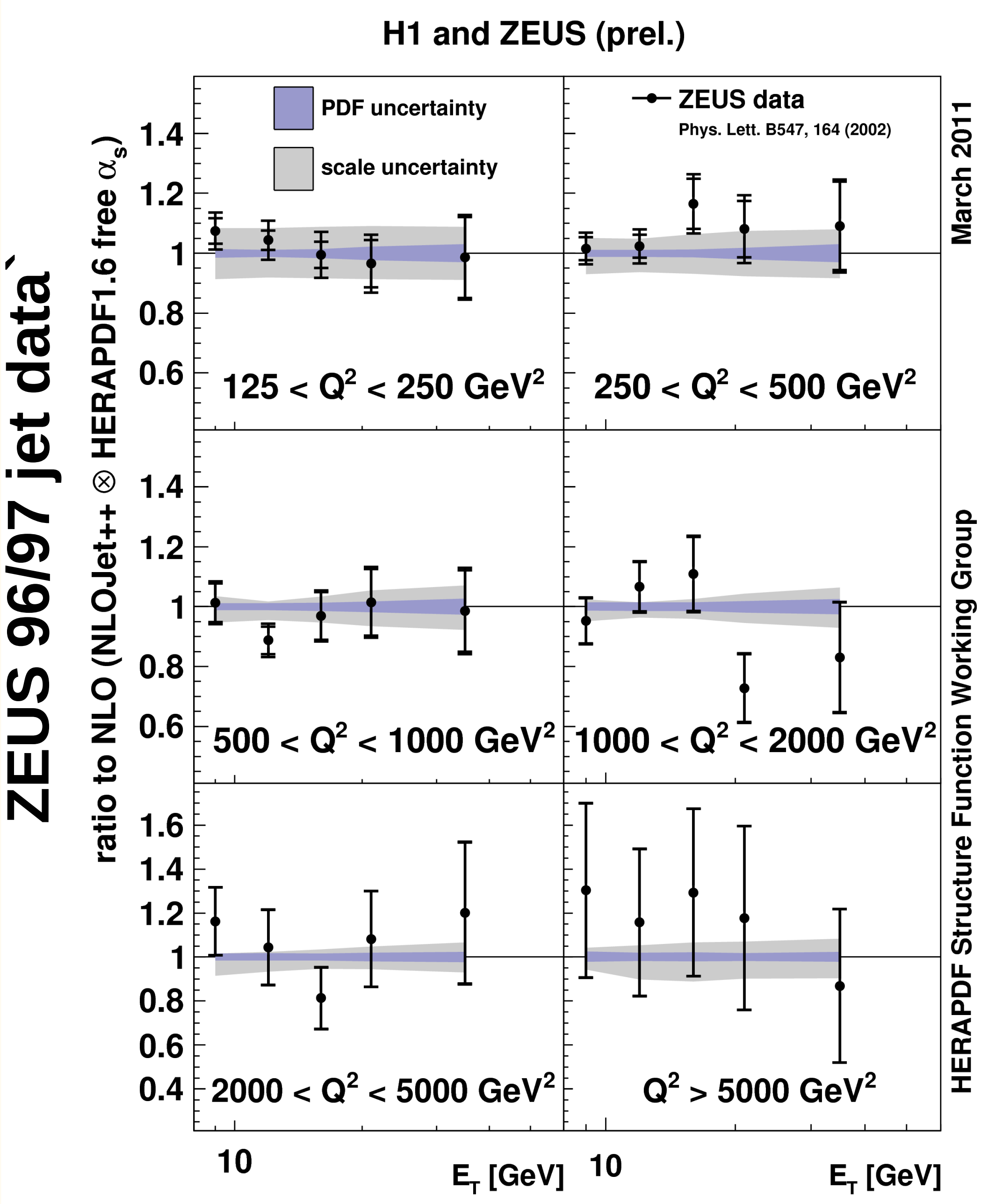
Data description

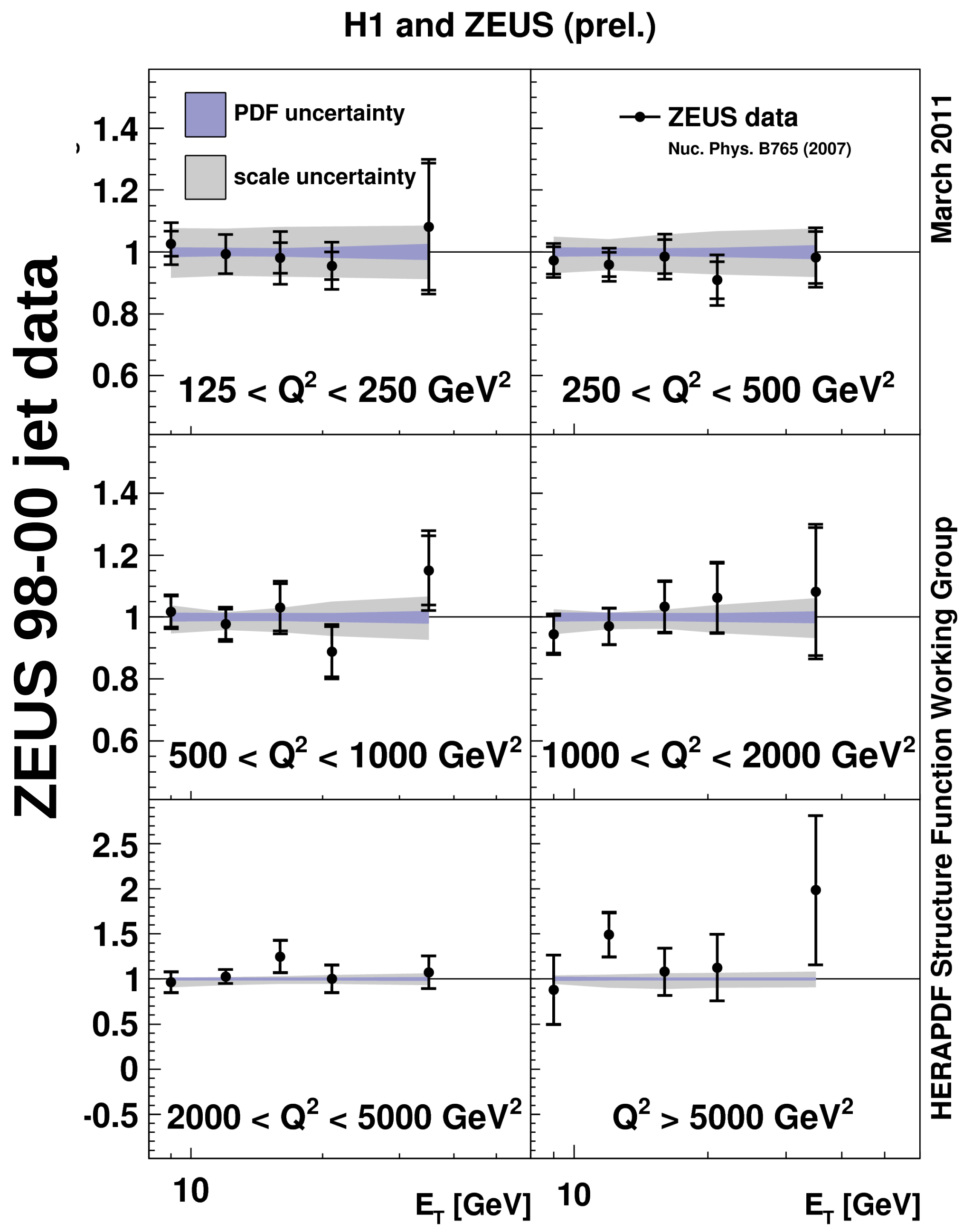
H1 high Q^2 jet data



- *Small experimental error due to high HERAI+II statistics and normalisation*
- *Smaller uncertainty coming from factorisation scale variation (still dominant)*
- *Fit well describes the measure-ment*

Data description





Summary

- ***Simultaneous PDF and α_s fit performed using HERA jet data (HERAPDF1.6)***

- ***Precision of α_s determination comparable to individual measurements and internally consistent***

- ***Experimentally HERA data provide one of the world bests α_s measurements***

- ***NNLO calculation needed to take advantage of very precise data***

Backup: Parametrization

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

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 (HERAPDF1.5f, HERAPDF1.6)

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