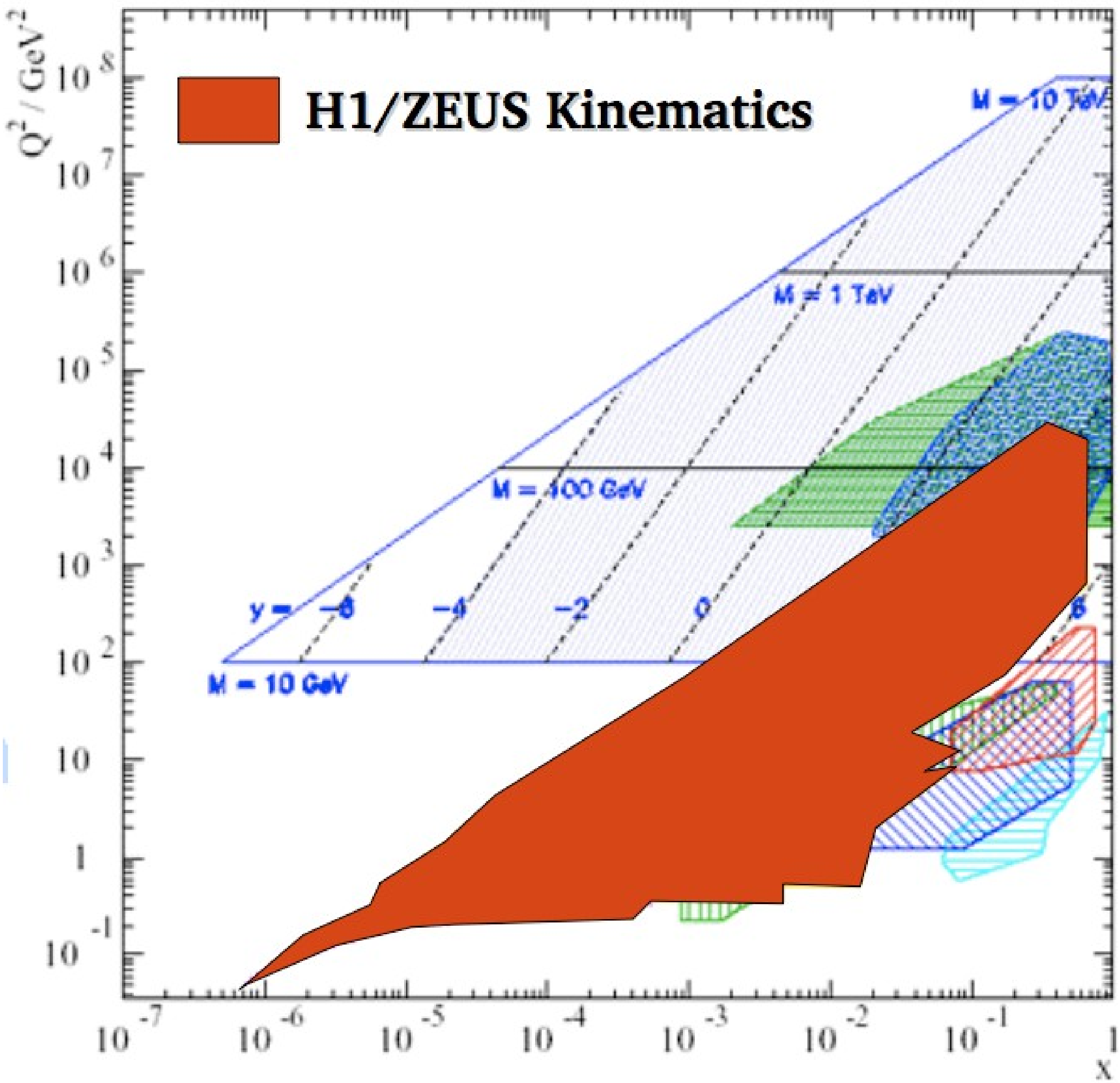
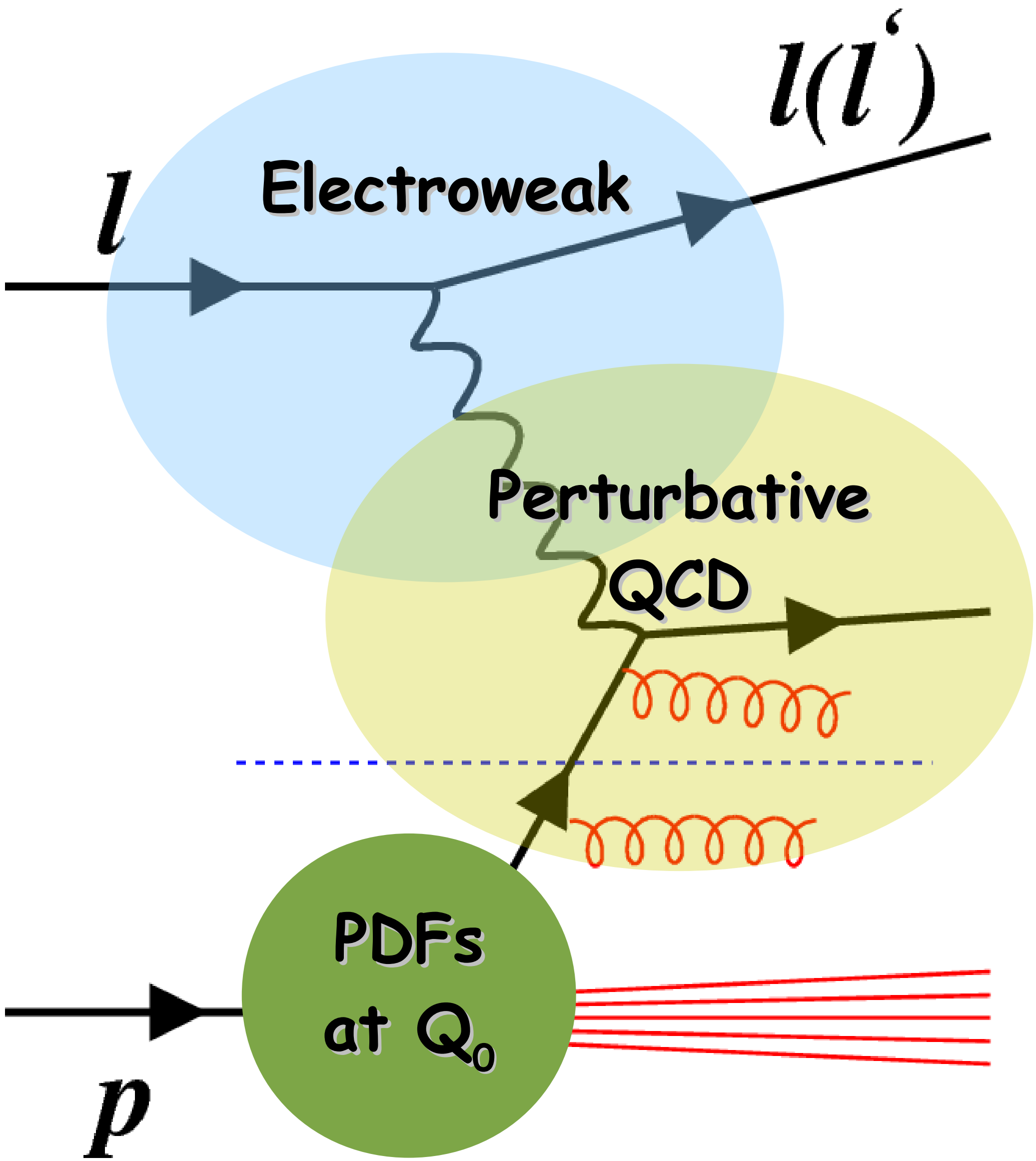
HERAPDF fits

K. Wichmann for H1 and ZEUS Collaborations

Inclusive measurements from HERA are core of every parton density extraction



Deep Inelastic Scattering @ HERA



- Fix pQCD & PDFs
  ! Test Electroweak
- Fix Electroweak
  ! Test pQCD & PDFs

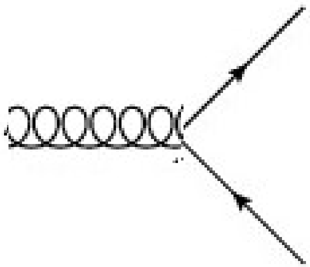
One example for each

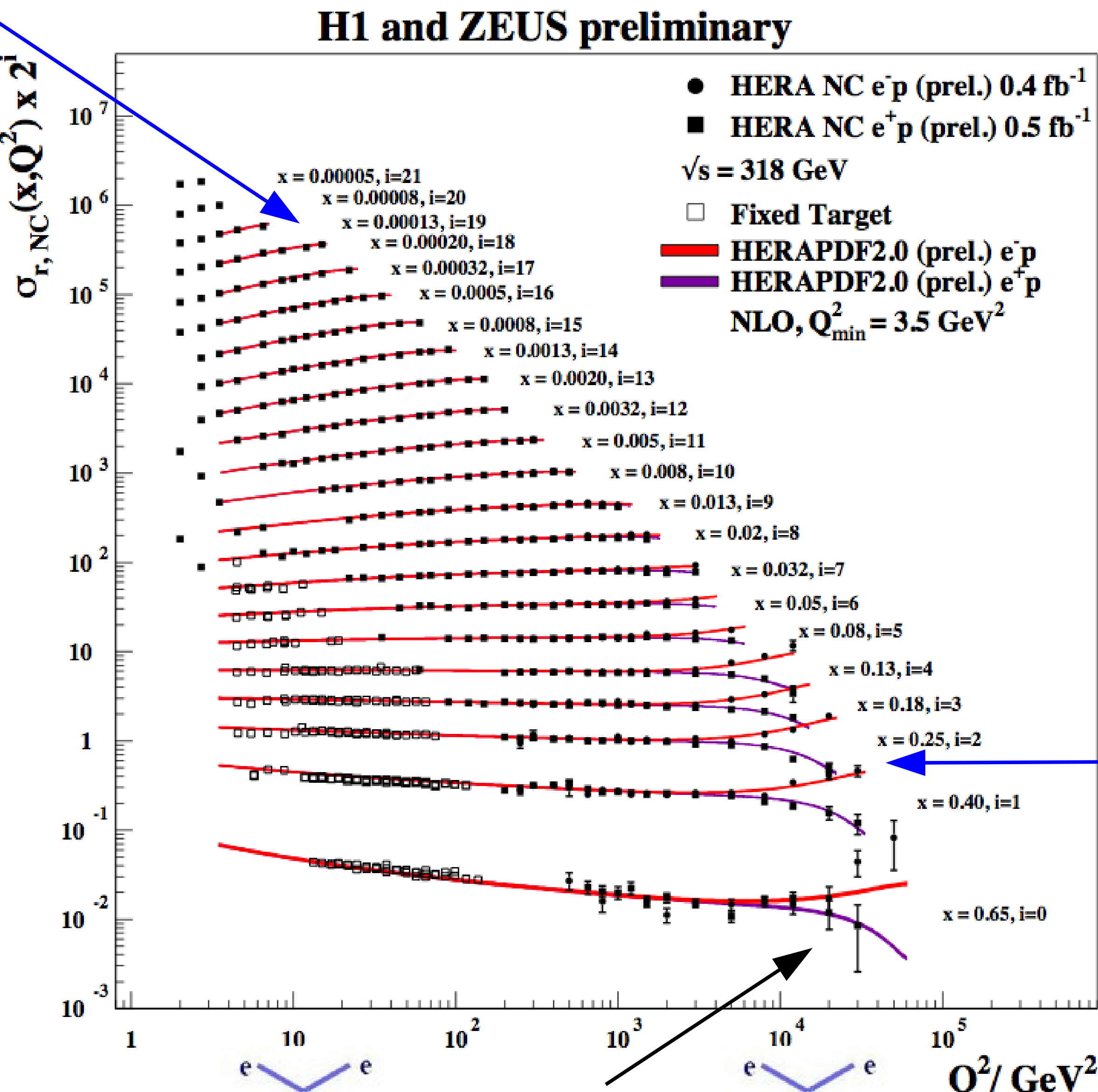
- Fix Electroweak & pQCD
  ! Determine PDFs

Focus of this talk

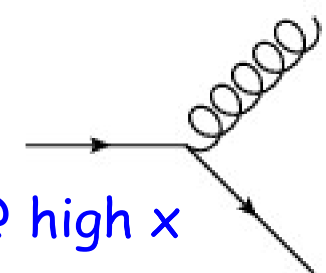
QCD scaling and EW effects beautifully seen

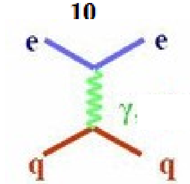
@ low x



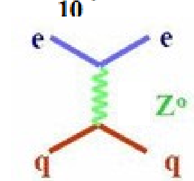


@ high x





@ high Q²



K. Wichmann, 04.07.14, ICHEP14, HERAPDF fits of parton densities

1 fb^{-1} HERA data – exclusively! - used as input to global QCD fit HERAPDF2.0 (prel.)

- Parton densities parametrised @ Q^2 = 1.9 GeV^2

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

$$xg(x), xu_v(x), xd_v(x), x\bar{U}(x), x\bar{D}(x)$$

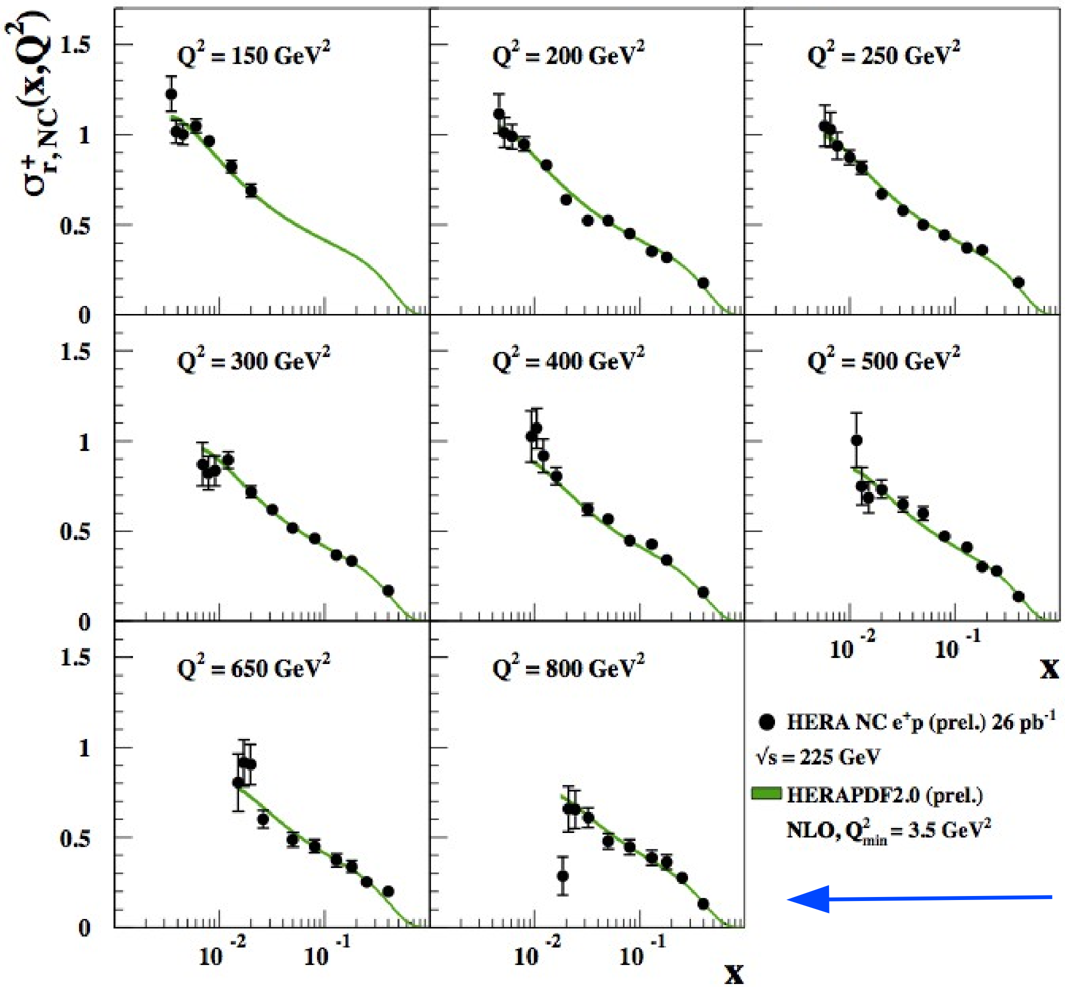
- DGLAP evolution
- 15 parameters determined in paramerisation scan
- Heavy quarks from Roberts-Thorne Variable Flavor Number Scheme

Where does the information on parton distributions come from?

By a small sample we may judge of the whole piece
Miguel de Cervantes, "Don Quixote"

Neutral Current

$$\frac{d^2\sigma^{\pm}_{NC}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+F_2 \mp Y_-xF_3 - y^2F_L\right]$$



Proton structure functions

$$F_2 = x\sum e_q^2[q(x) + \bar{q}(x)]$$

- Dominant
- Sensitive to quarks

$$xF_3 = x\sum 2e_q a_q[q(x) - \bar{q}(x)]$$

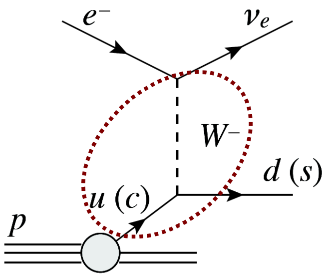
- Sensitive to valence distributions
- Essential at high Q^2

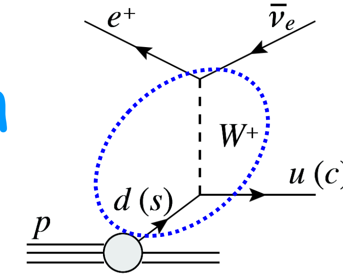
$$F_L \sim \alpha_S\, x\, g$$

- Sensitive to gluon
- Essential at high y

- NC and CC available for e^+ and e^-
- NCe^+p available for $\sqrt{s}$ of 225, 251, 300 and 318 GeV

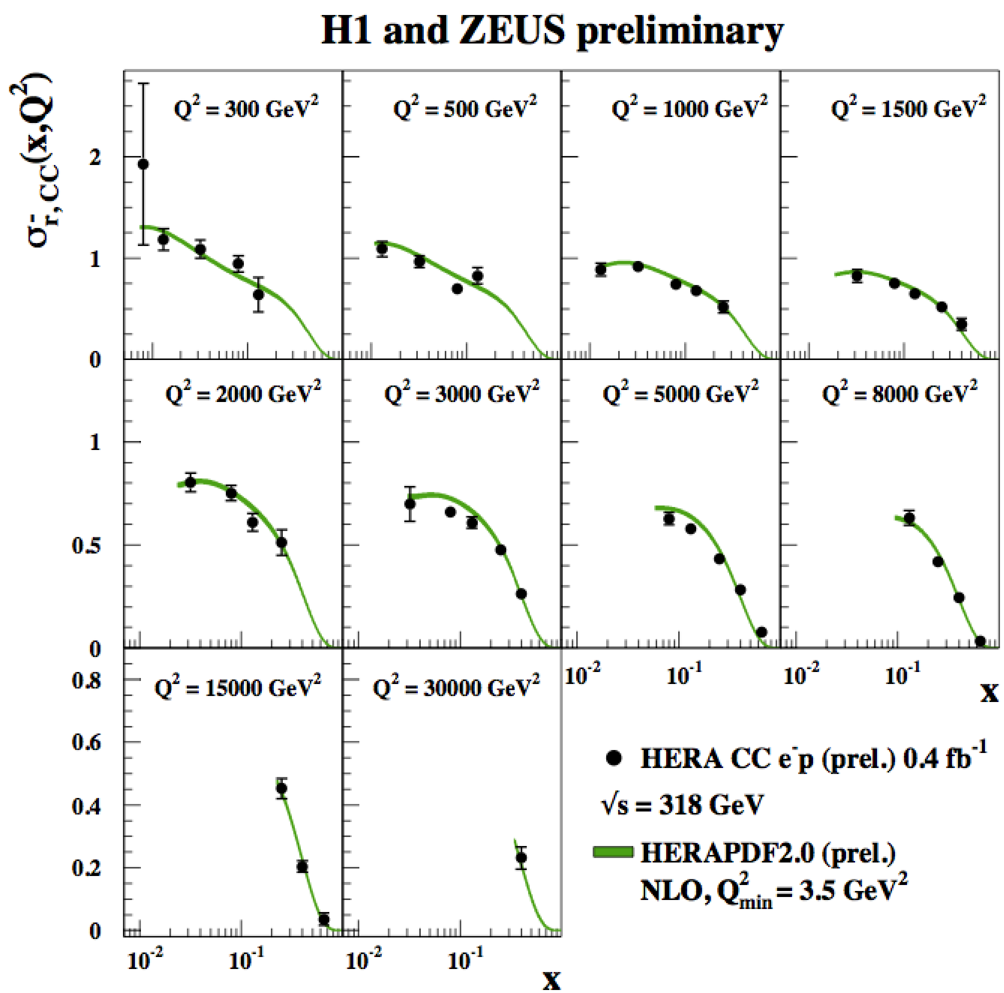
Charge Current: flavor decomposition

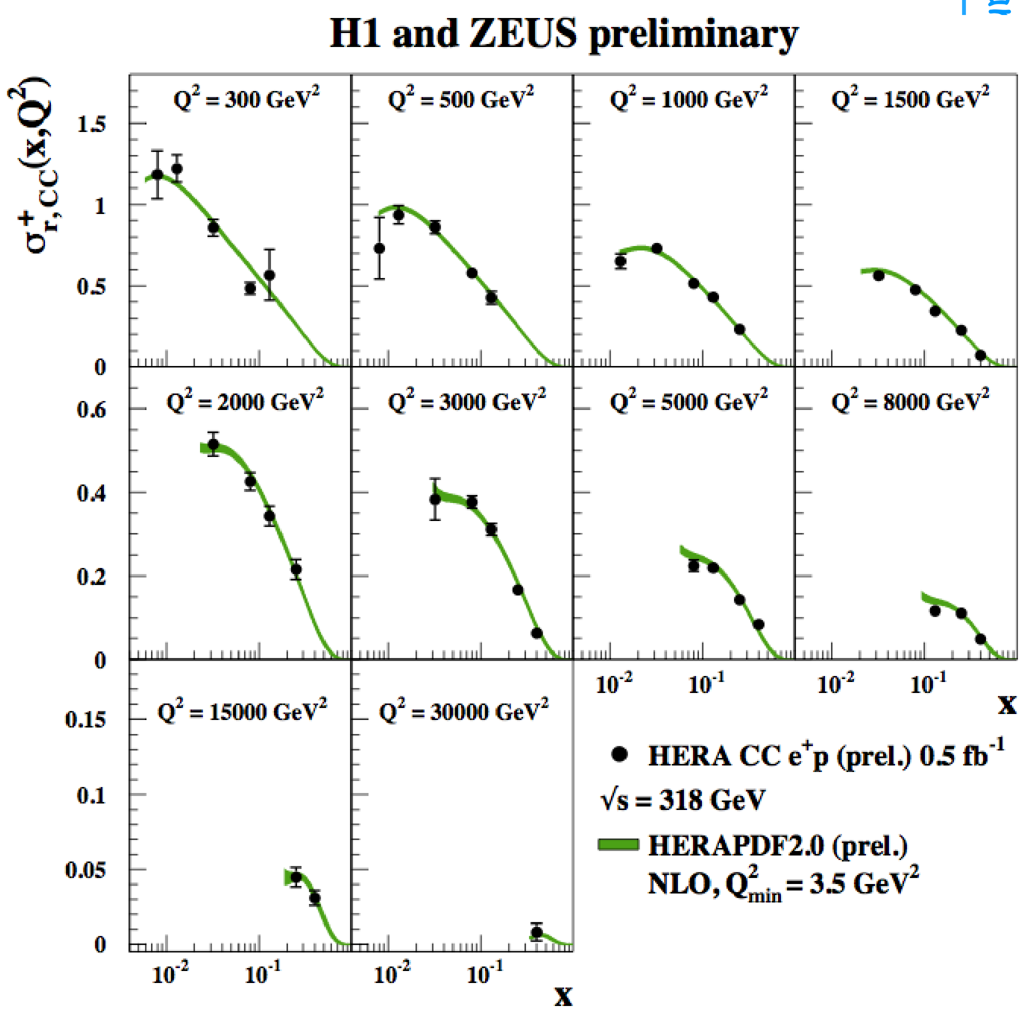




$$\sigma^-_{CC} \sim x[u + c] + x(1 - y)^2[\bar{d} + \bar{s}]$$

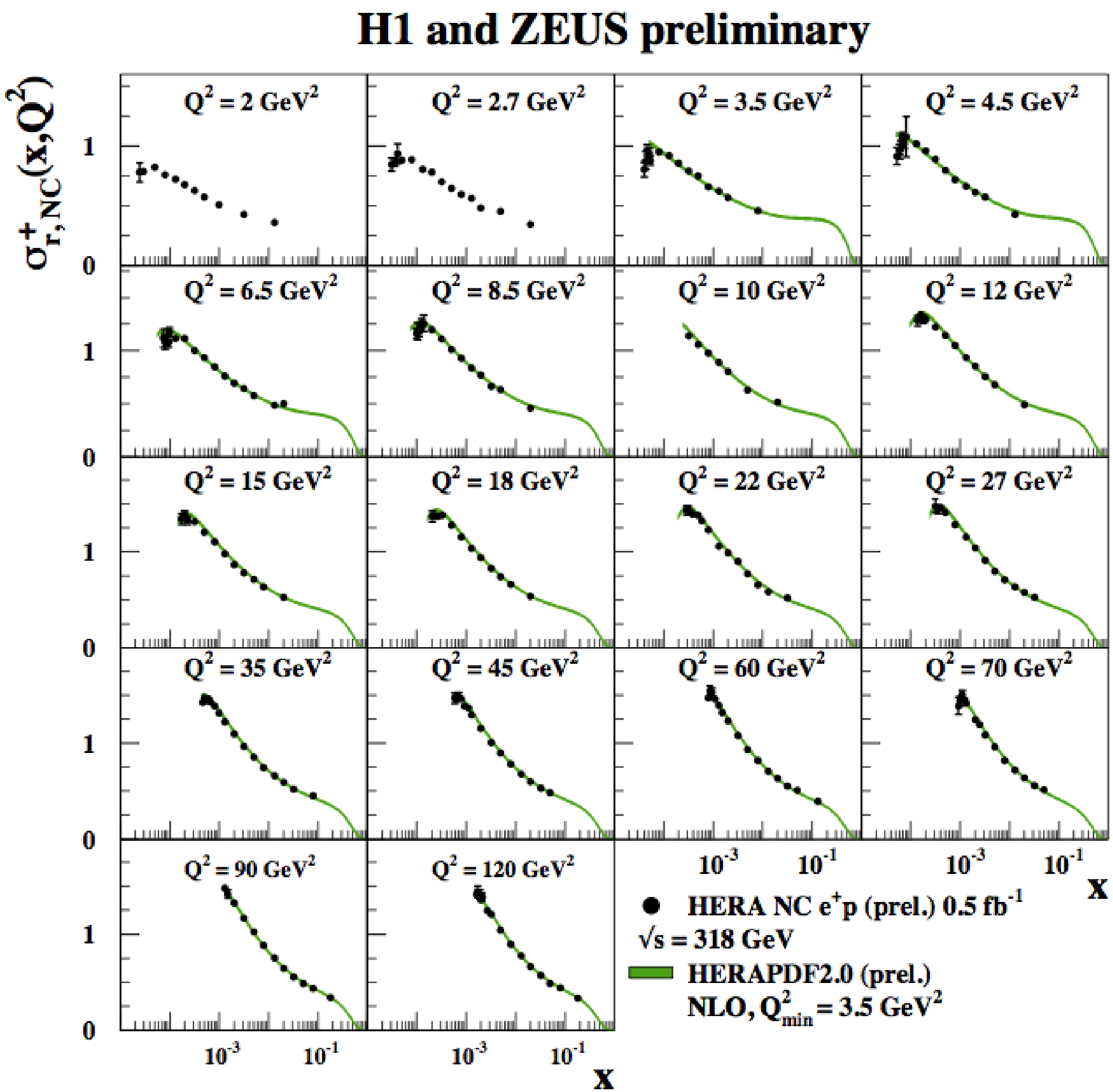
$$\sigma^+_{CC} \sim x[\bar{u} + \bar{c}] + x(1 - y)^2[d + s]$$





CC data used to separate up/down distributions

HERAPDF2.0 (prel.)



- NLO fit for Q^2_{min} = 3.5 GeV^2

  χ^2/dof = 1386/1130

- Additional fit performed with Q^2_{min} = 10 GeV^2

  χ^2/dof = 1156/1003

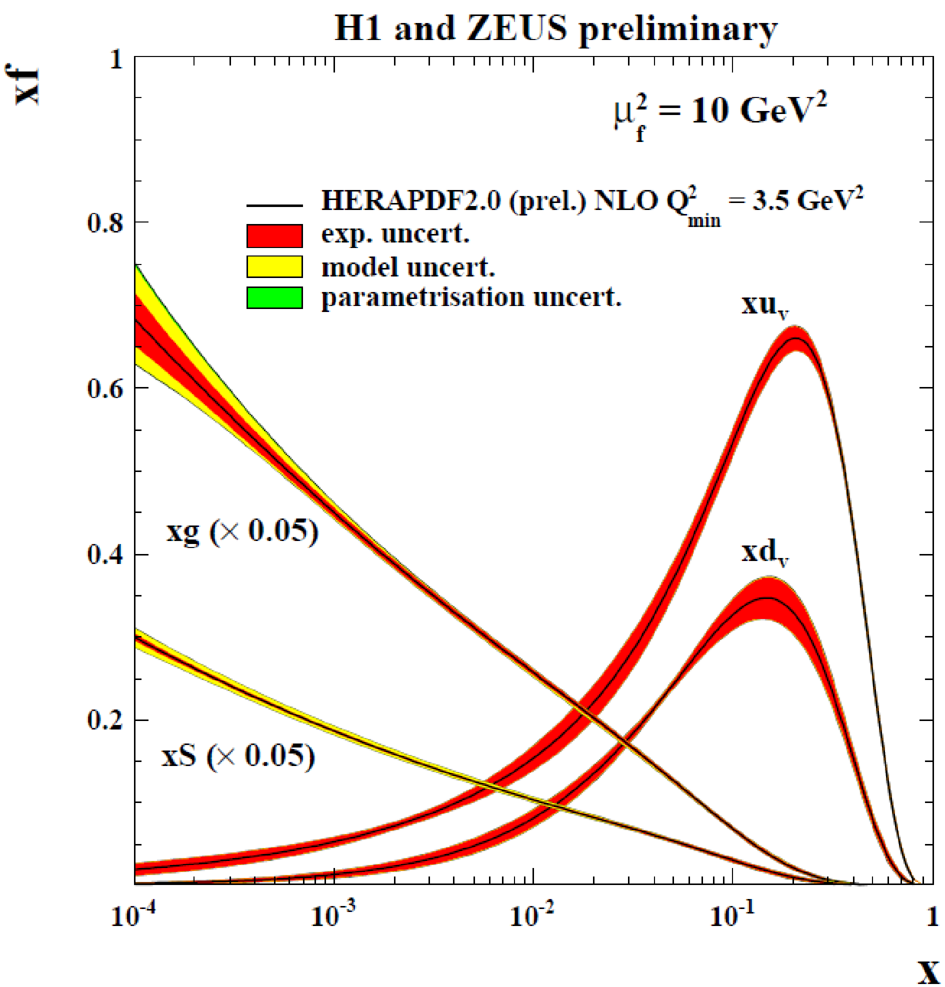
Situation somewhat improved

- **Similar results for NNLO**

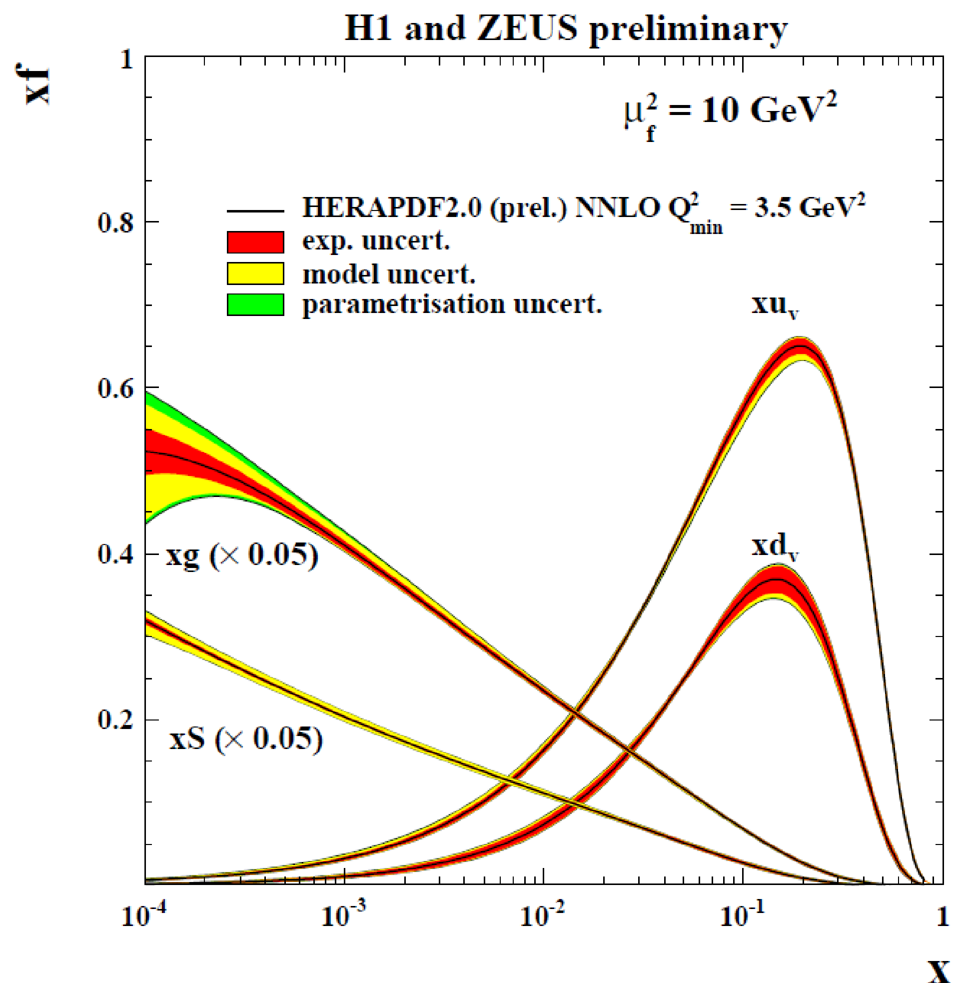
Reasonable description of NC, CC and low energy data for NLO and NNLO

NLO & NNLO parton densities

NLO



NNLO



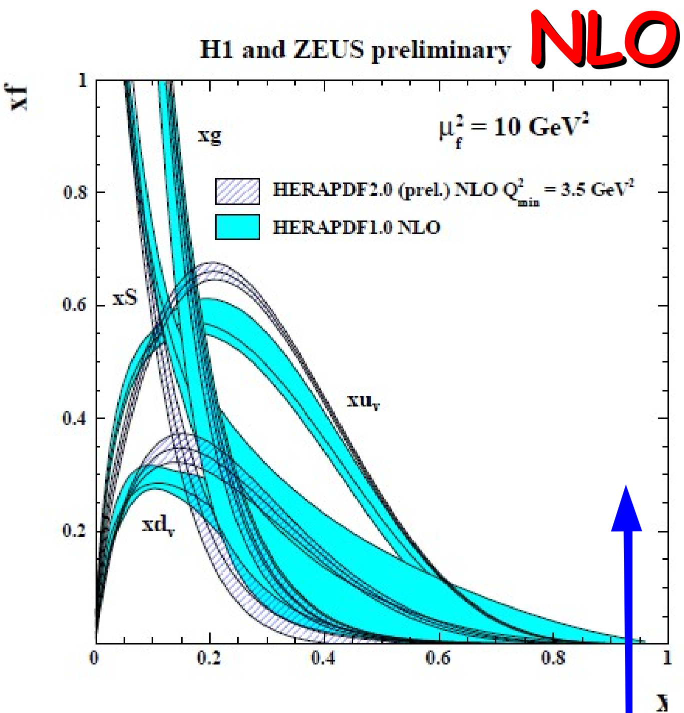
HERAPDF2.0 (prel.) extracted

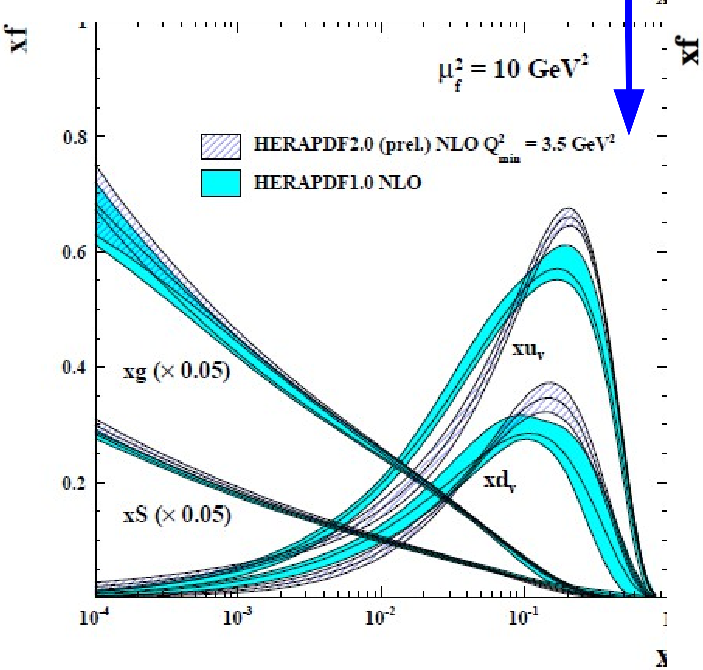
with experimental, model and parametrization uncertainties

Comparisons are odious

Miguel de Cervantes, “Don Quixote”

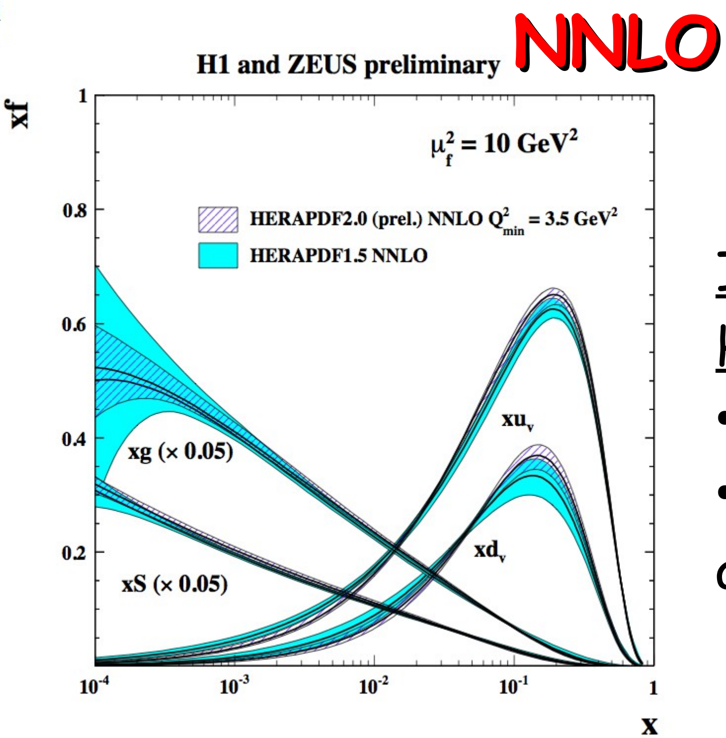
Comparison to HERAPDF1.0 and HERAPDF1.5





<u>In comparison to HERAPDF1.0 @ NLO</u>

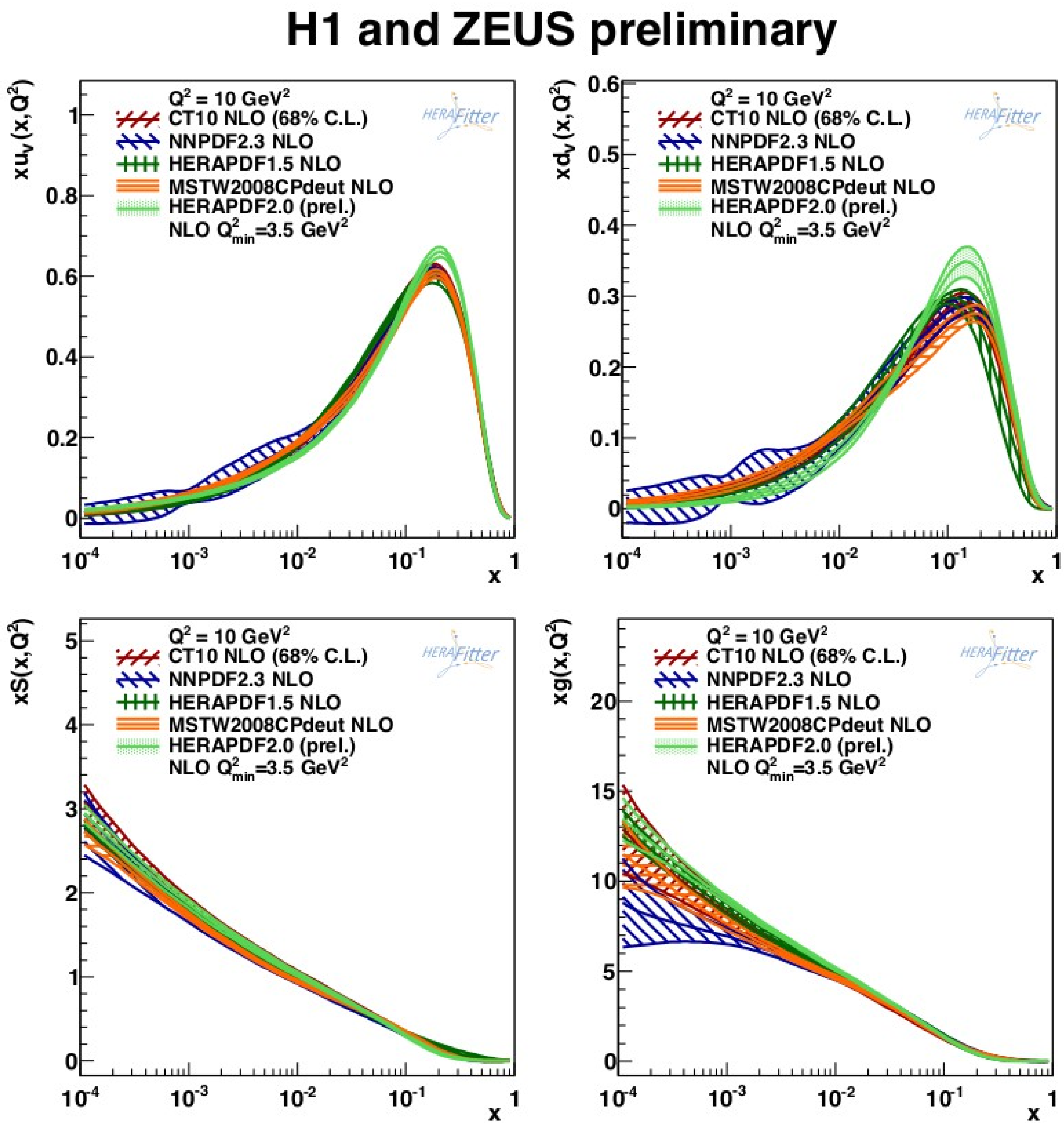
- Considerable decrease in uncertainty
  - Particularly in high-x sea
- Valence changed due to more high-x data
- High-x sea becomes softer



<u>In comparison to HERAPDF1.5 @ NNLO</u>

- Valence quarks similar
- Low-x gluon more accuarte

HERAPDF2.0 (prel.) versus other VFNS PDF sets

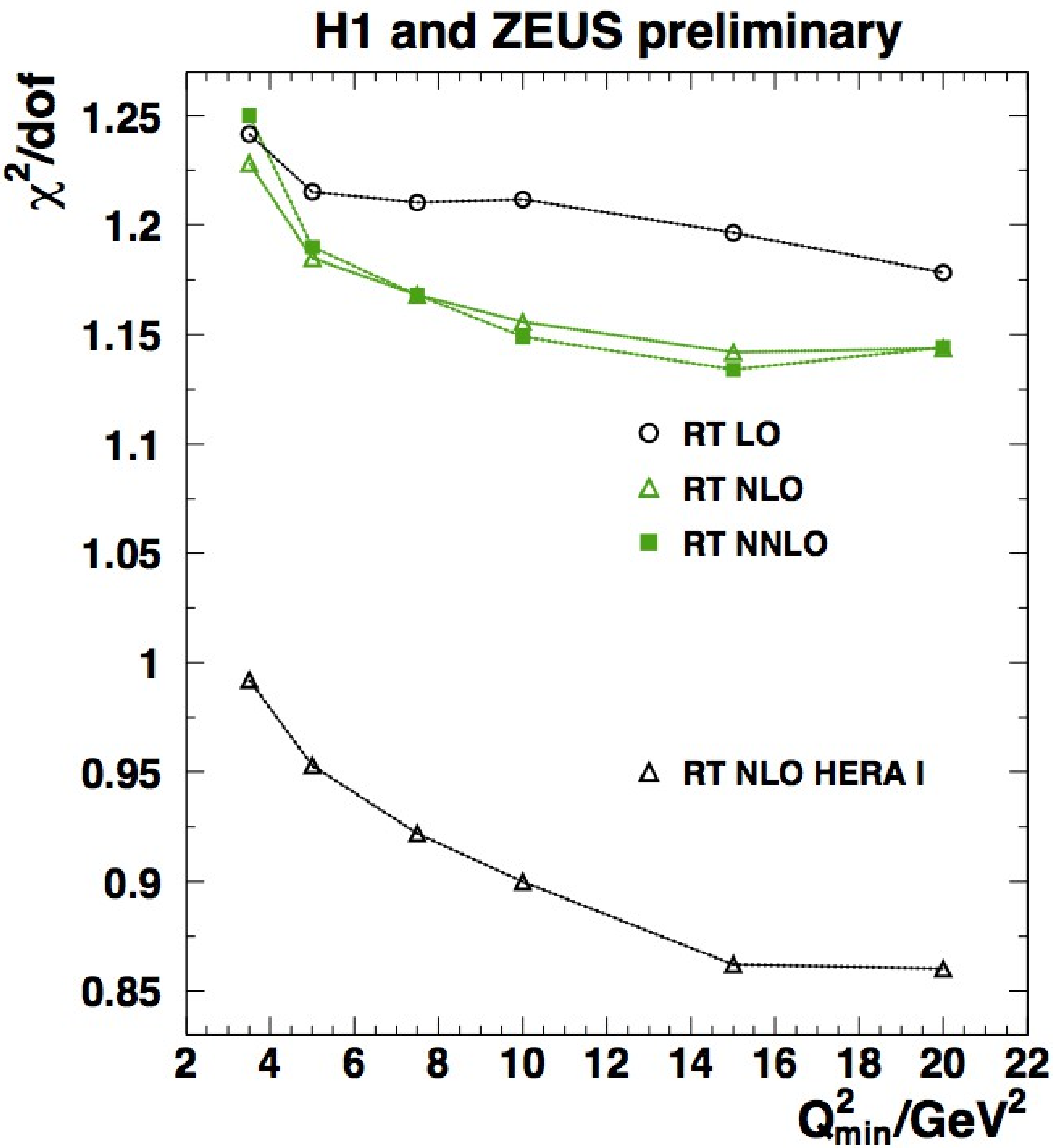


- Difference for valence quarks

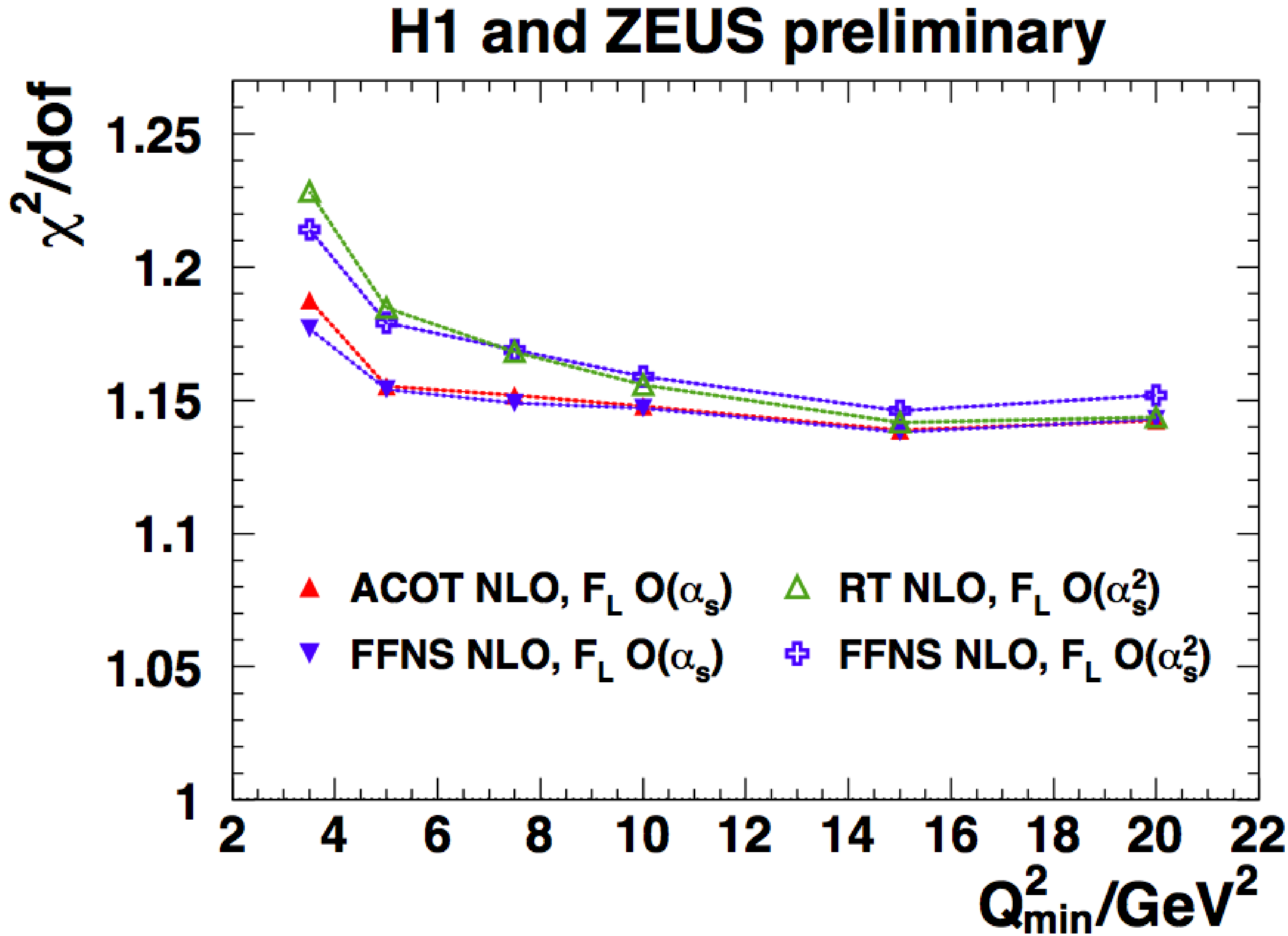
HERAPDF - the only group to get d valence from proton in CCe+p and not from neutron by assuming that u in neutron = d in proton

Studies of Q^2_{min} cut

Q^2_{min} cut



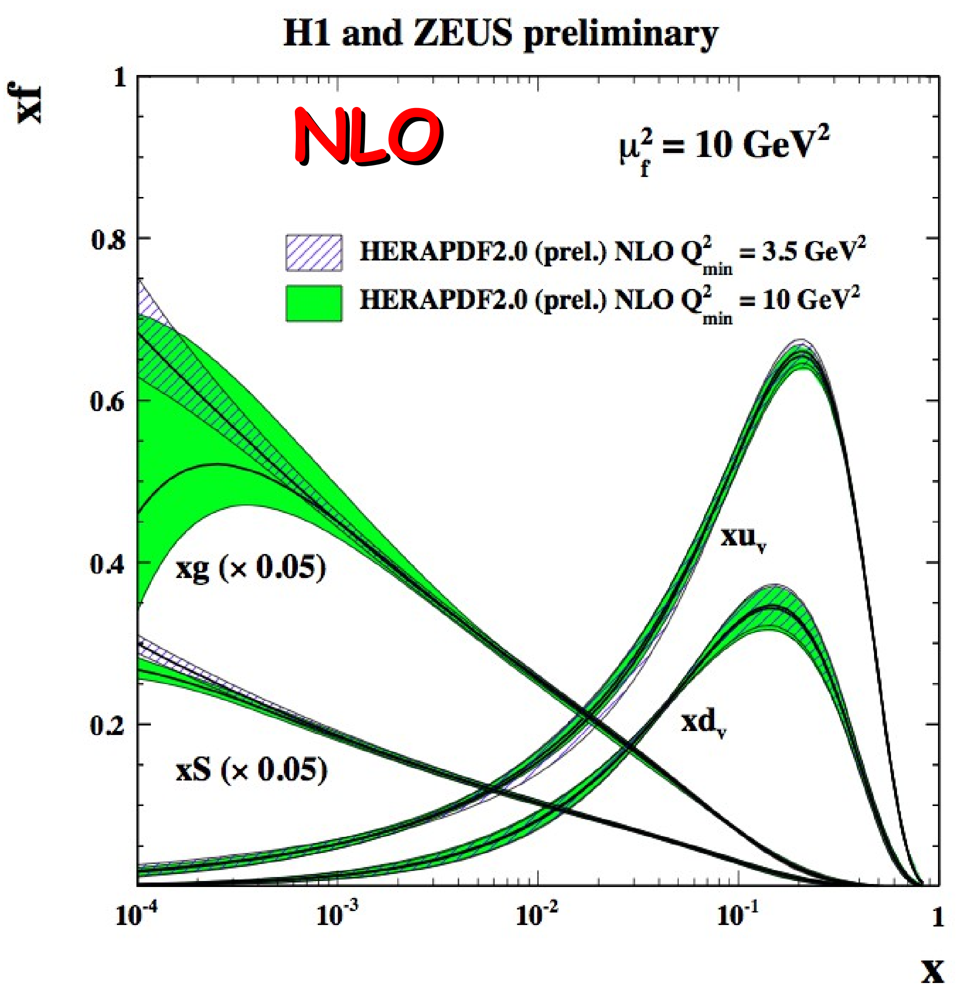
- Dependence of chi2/dof on Q^2_{min} cut
  - Drop of chi2 with Q^2_{min} cut
  - Saturation around 10 GeV^2
- Significant improvement of NLO compared to LO
- Marginal to no improvement of NNLO compared to NLO
- NLO behavior similar in HERAI and HERAI+II

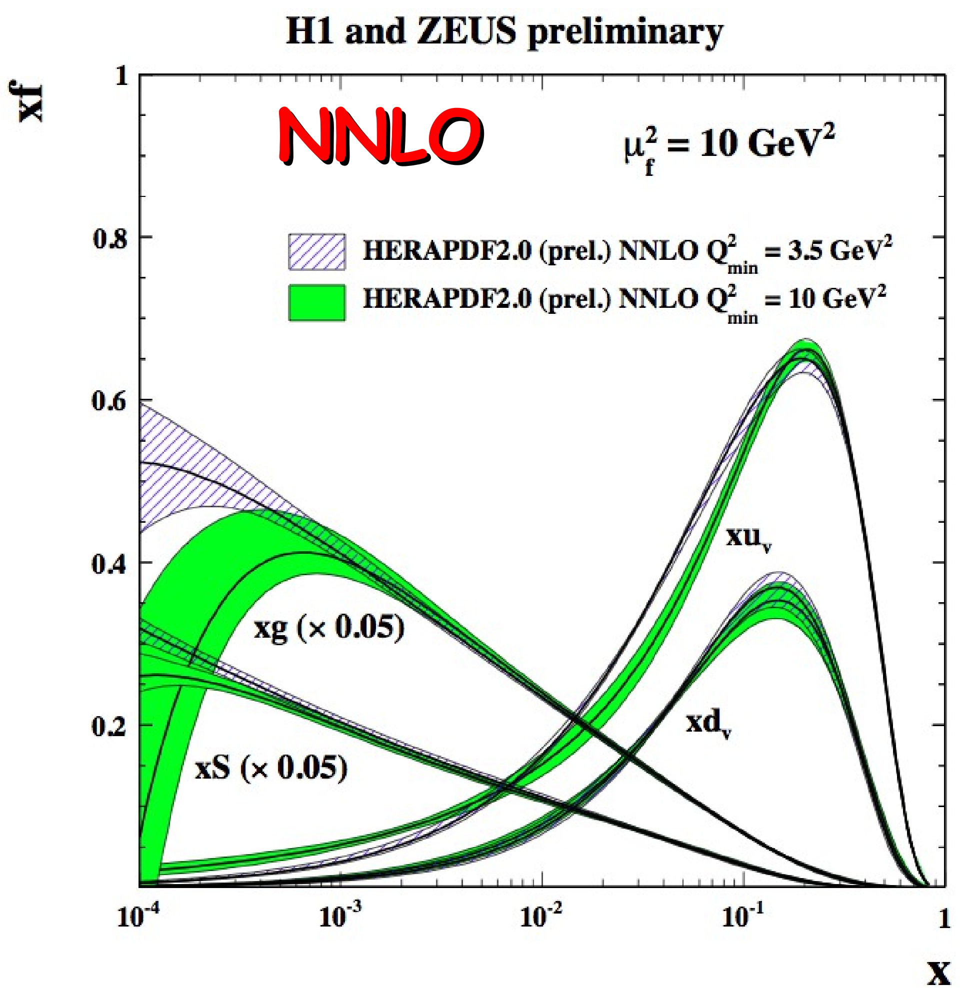


- Treating F_L to order α_s – the same order as F_2 – yields better χ^2 than treating F_L to order $\alpha_s{}^2$ – the same number of loops (1 loop)
- Almost independent of heavy flavor scheme

HERAPDF2.0 with Q^2_{min} = 3.5 GeV² and 10 GeV²

- At low-x gluon and sea
  - greater uncertainty for Q^2_{min} = 10 GeV² & small shift of shape
- At large x gluon, sea and valence similar

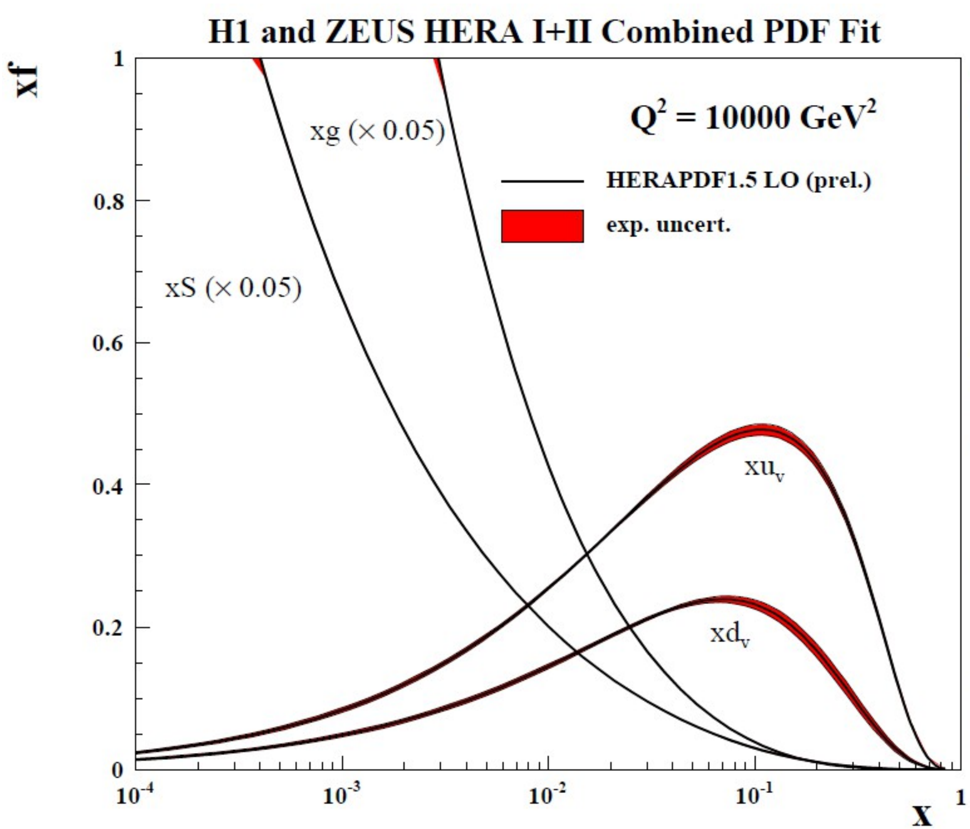


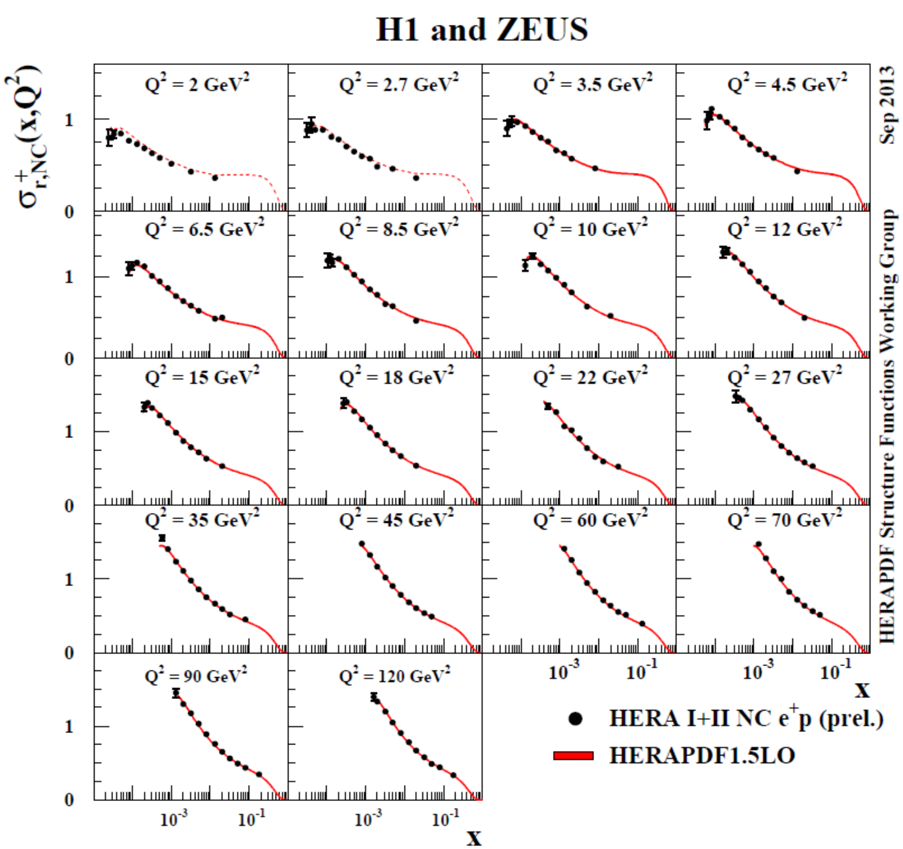


HERAPDF1.5LO (prel.)

HERAPDF1.5LO (prel.)

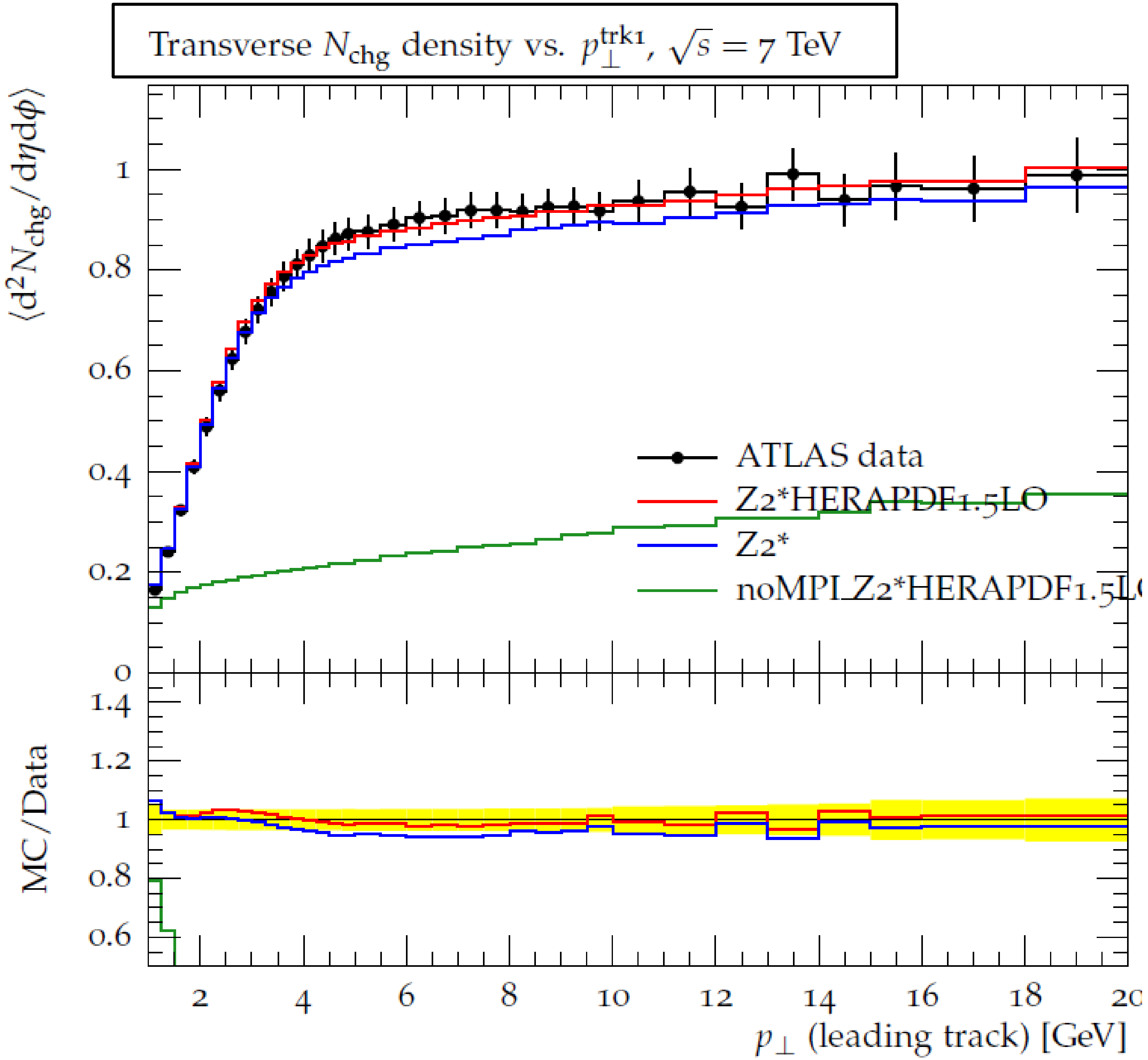
- Parton densities @LO are essential for proper simulation of parton showers and underlying event properties in LO+PS Monte Carlo event generators
- HERAPDF1.5 LO set based on HERAPDF1.5 NLO PDF settings
- Includes experimental uncertainties





Available in LHAPDF library

Example use of HERAPDF1.5LO in tuning



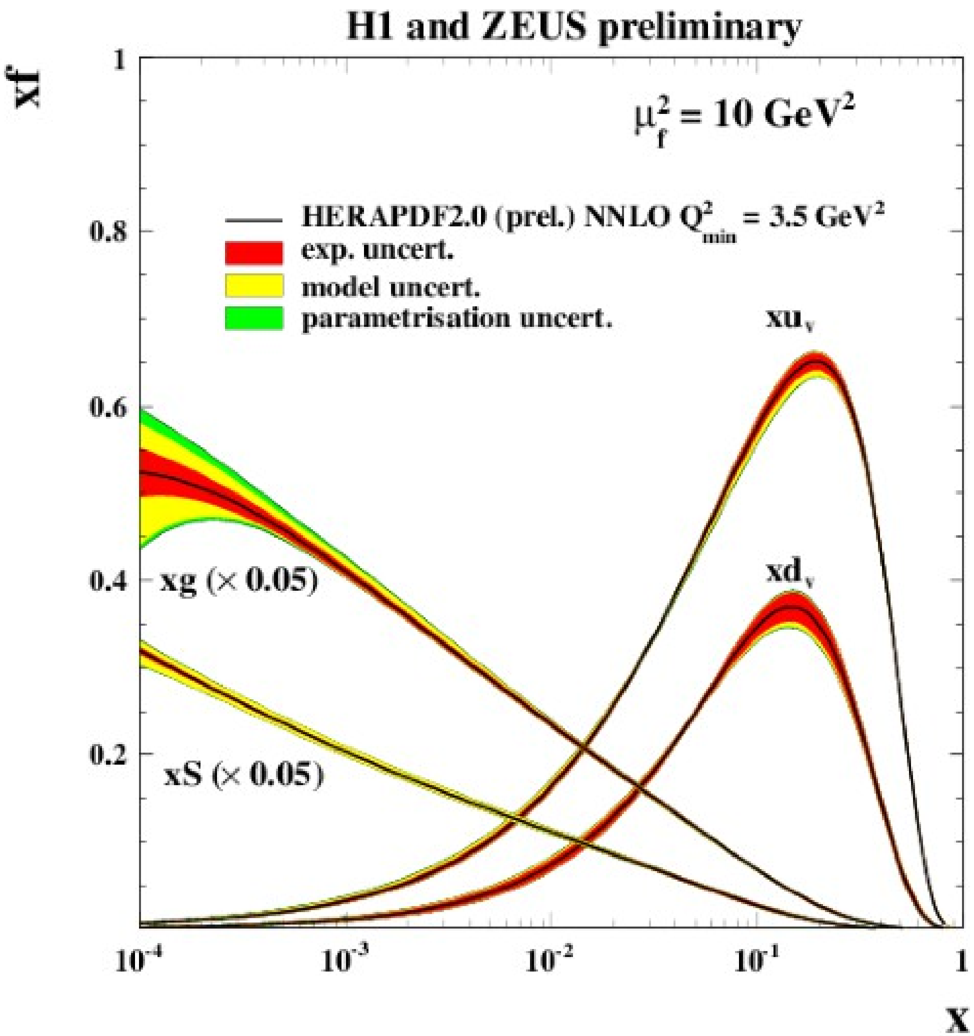
Summary

- HERA provides a clean determination of proton's PDFs based solely on ep collider data
  - HERAPDF1.5LO (prel.) with experimental uncertainties
  - HERAPDF2.0 (prel.) at NLO and NNLO with full uncertainties
- New preliminary combined HERA I+II+low energy measurements improves precision of PDFs
- Q^2 dependence of fit observed for HERAPDF2.0 (prel.) and two sets, Q^2 >3.5 GeV^2 and Q^2>10 GeV^2, provided

"I do not insist," answered Don Quixote, "that this is a full adventure, but it is the beginning of one, for this is the way adventures begin."

Backup

HERAPDF2.0 (prel.) uncertainties



- **Experimental uncertainties:**
  - Hessian method used: full second-derivative matrix calculated
  - Conventional $\Delta\chi^2 = 1$ => 68% CL

- **Model uncertainties:**

Variation	Standard Value	Lower Limit	Upper Limit
f_s	0.4	0.3	0.5
M_c^{opt}(NLO) [GeV]	1.47	1.41	1.53
M_c^{opt} (NNLO) [GeV]	1.44	1.38	1.50
M_b [GeV]	4.75	4.5	5.0
Q^2_{min} [GeV^2]	10.0	7.5	12.5
Q^2_{min} [GeV^2]	3.5	2.5	5.0
Q^2_0 [GeV^2]	1.9	1.6	2.2

- **Parametrisation uncertainties:**
  - Starting scale Q_0^2 variation.

HERAPDF2.0 (prel.)

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

Data for parton distributions: preLHC