Inclusion of the Low Energy and High-Q^2 combined data in HERAPDF fits

Voica Radescu
(Physikalisches Institut Heidelberg)

on behalf of the H1 and ZEUS Collaborations

QCD at the LHC workshop
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ECT, Trento

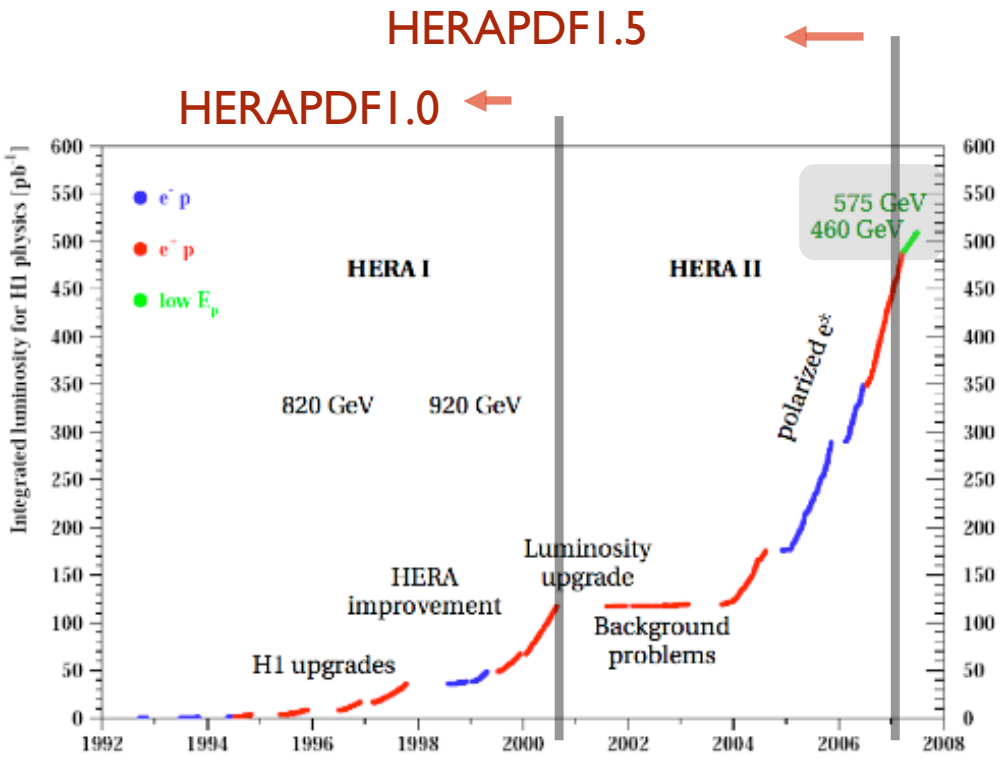
Outline:

- Introduction
- QCD fits including:
  - Low Energy Data
  - HERA II data
- Results and Comparisons
- Summary

Introduction

New preliminary data from HERA II is included in the HERA fits:

- Combined HERA II Low Energy Data
  - Accurate measurement in $Q^2 \geq 2.5\ GeV^2$ range, sensitive to structure function F_L:
    - Investigate the low Q^2 region;
    - Test sensitivity to different heavy flavour treatments;
- Combined HERA I+high Q^2 HERA II Data
  - Accurate measurements in high Q^2 region:
    - Sensitive to the valence distributions.



QCD Analysis Framework

- Data Sets:
  - HERA I combined data (same as used for HERAPDF1.0 [JHEP01 (2010) 109])
    - NC e^-, CC e^-, CC e^+ (Q^2>100 GeV^2)
    - NC e^+ (Q^2>0.045 GeV^2)
  - Combined HERA II Low Energy Data Set of Ep=460, 575 GeV [prelim.]
    - Q^2>2.5 GeV^2
  - Combined HERA I+high Q^2 II Data [prelim.]

- QCD Fit settings: same settings as for HERAPDF1.0 [see S. Glazov presentation]

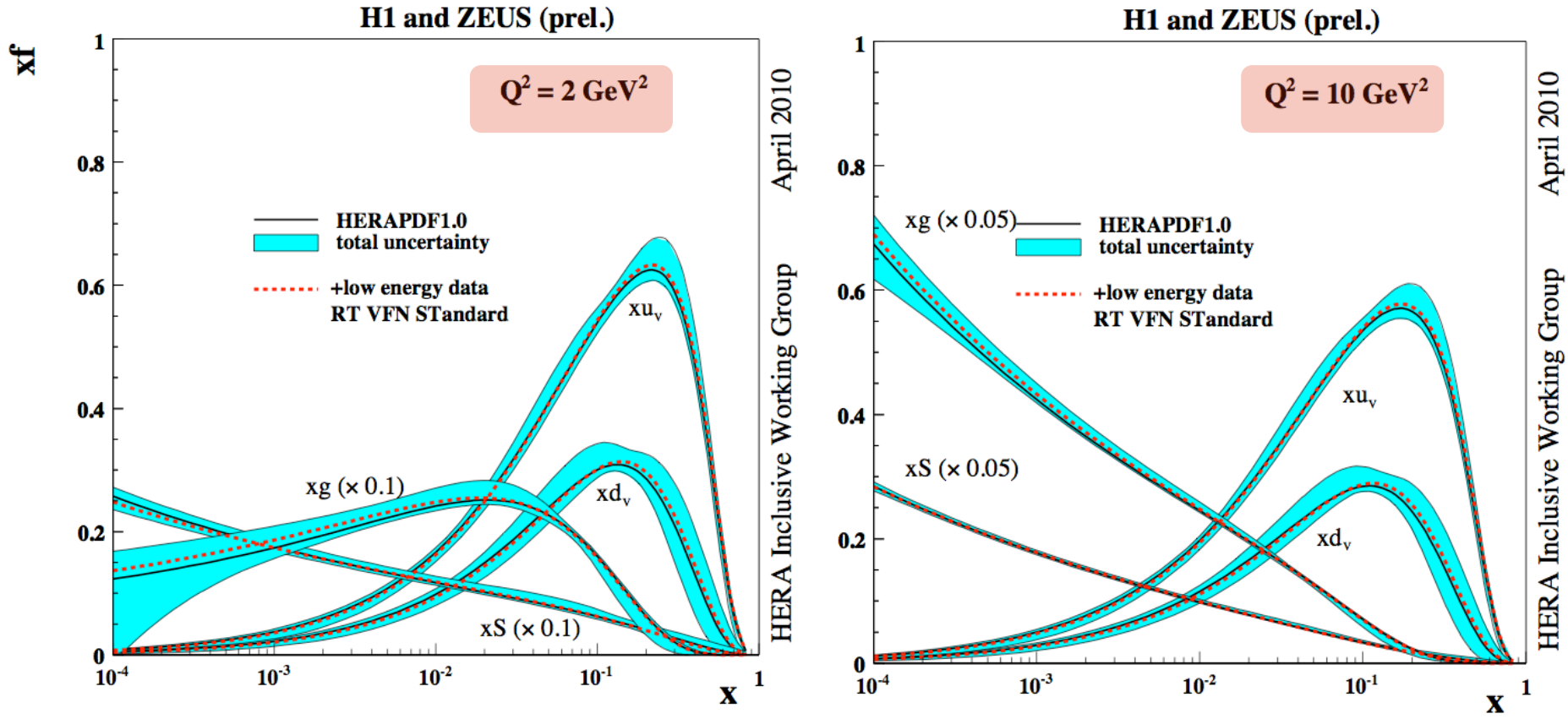
f_s	0.31
m_c [GeV]	1.4
m_b [GeV]	4.75
Q^2_{min} [GeV^2]	3.5
Q^2_0 [GeV^2]	1.9

→ cut variation

  - Fitted PDFs: $\mathbf{G}, \mathbf{u_{val}}, \mathbf{d_{val}}, \overline{\mathbf{U}} = \overline{\mathbf{u}}(+\overline{\mathbf{c}}), \overline{\mathbf{D}} = \overline{\mathbf{d}} + \overline{\mathbf{s}}(+\overline{\mathbf{b}})$
  - NLO (and NNLO) DGLAP evolution equations, RT-VFNS (as for MSTW08)
    - Other schemes were investigated as well: RT (optimal), ACOT (full and χ)

HERAPDF including Low Energy Data

HERAPDF including Low Energy data



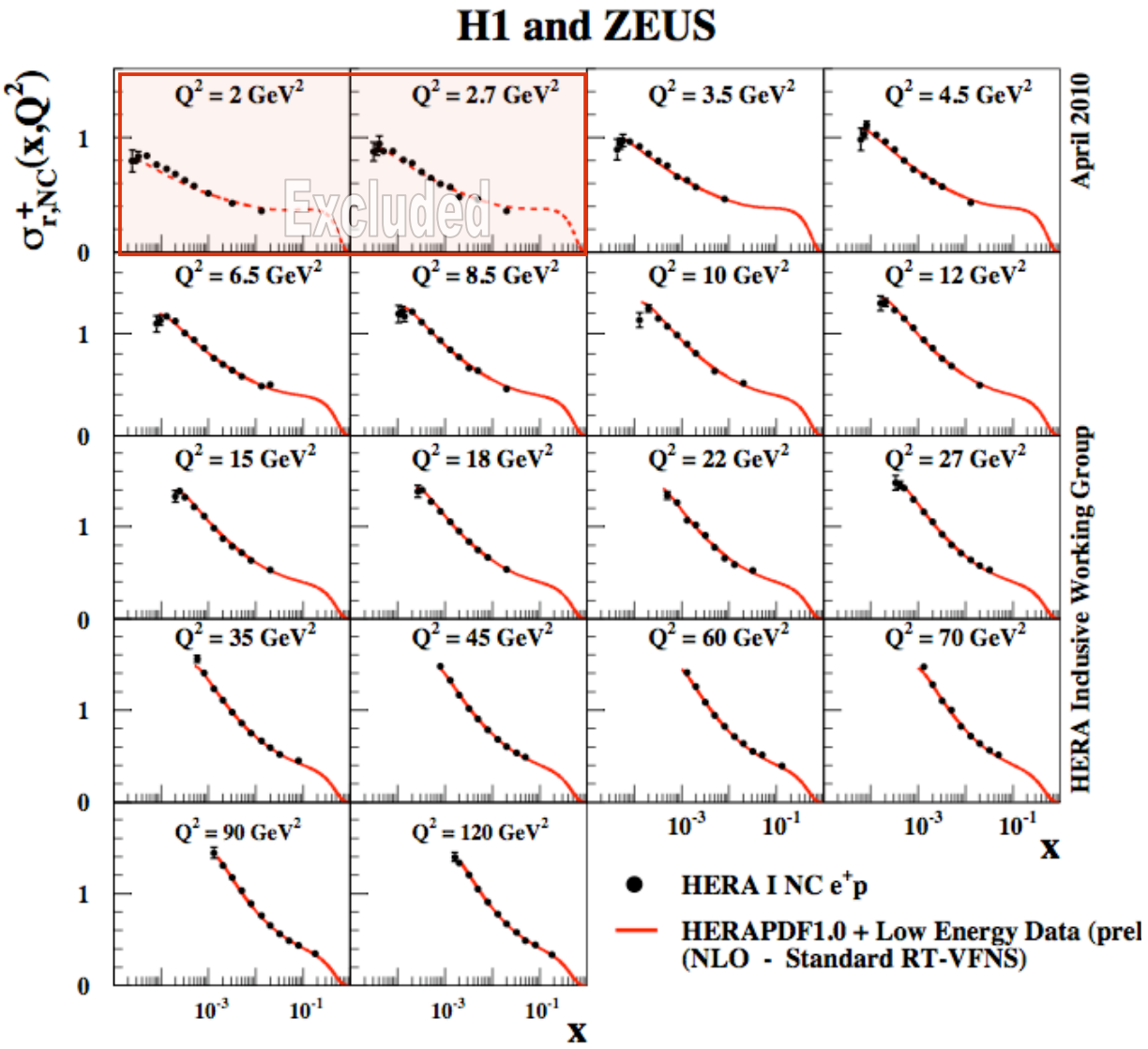
- PDFs from the new fit agree very well with HERAPDF1.0

Data sets	HERAPDF1.0	+ Low Energy Data
Total χ^2/dof	574/582	818/806

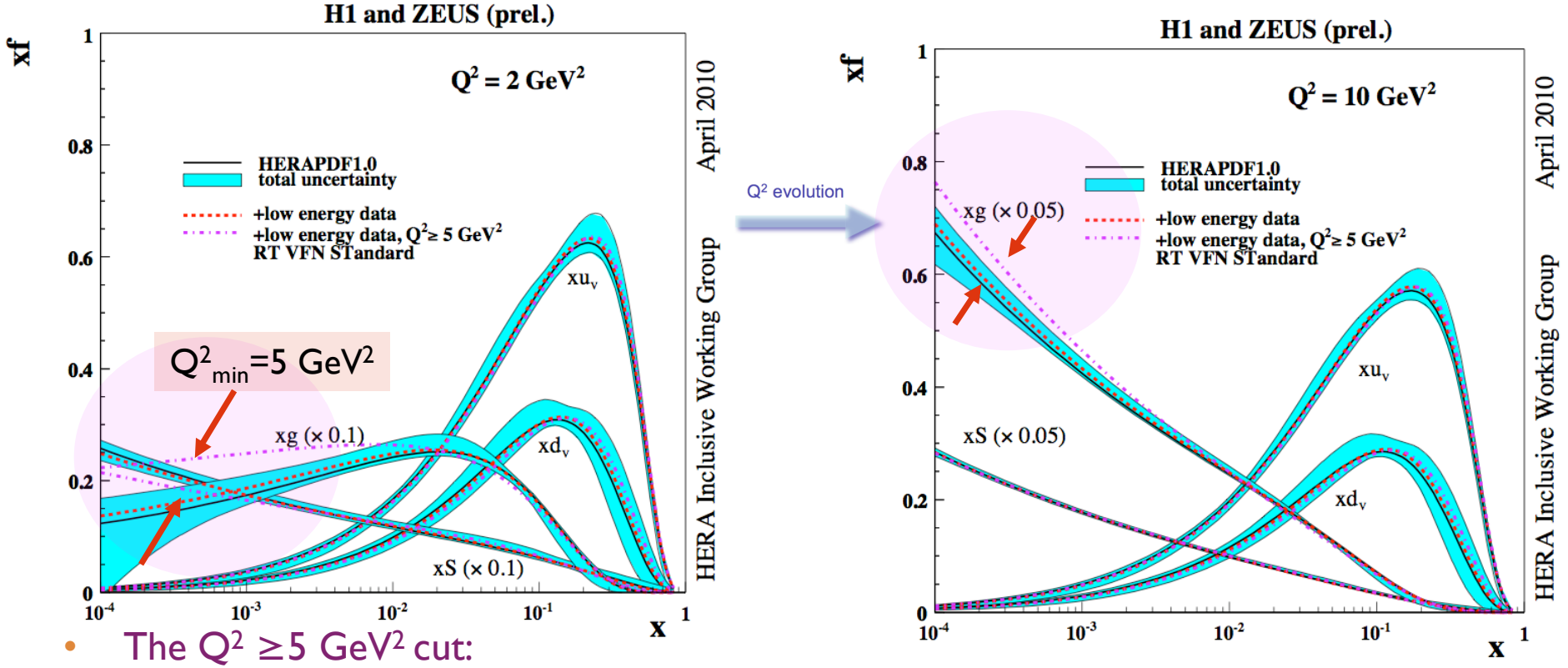
Comparison with Data

Line corresponds to the fit of HERA I and Low Energy data ($Q^2 \geq 3.5$ GeV^2 cut) using HERAPDF1.0 settings

- Turn over is observed for 920 GeV NC e^+p data at low x and Q^2 (high y $\rightarrow$ F_L sensitivity) which is not reproduced by the fit.



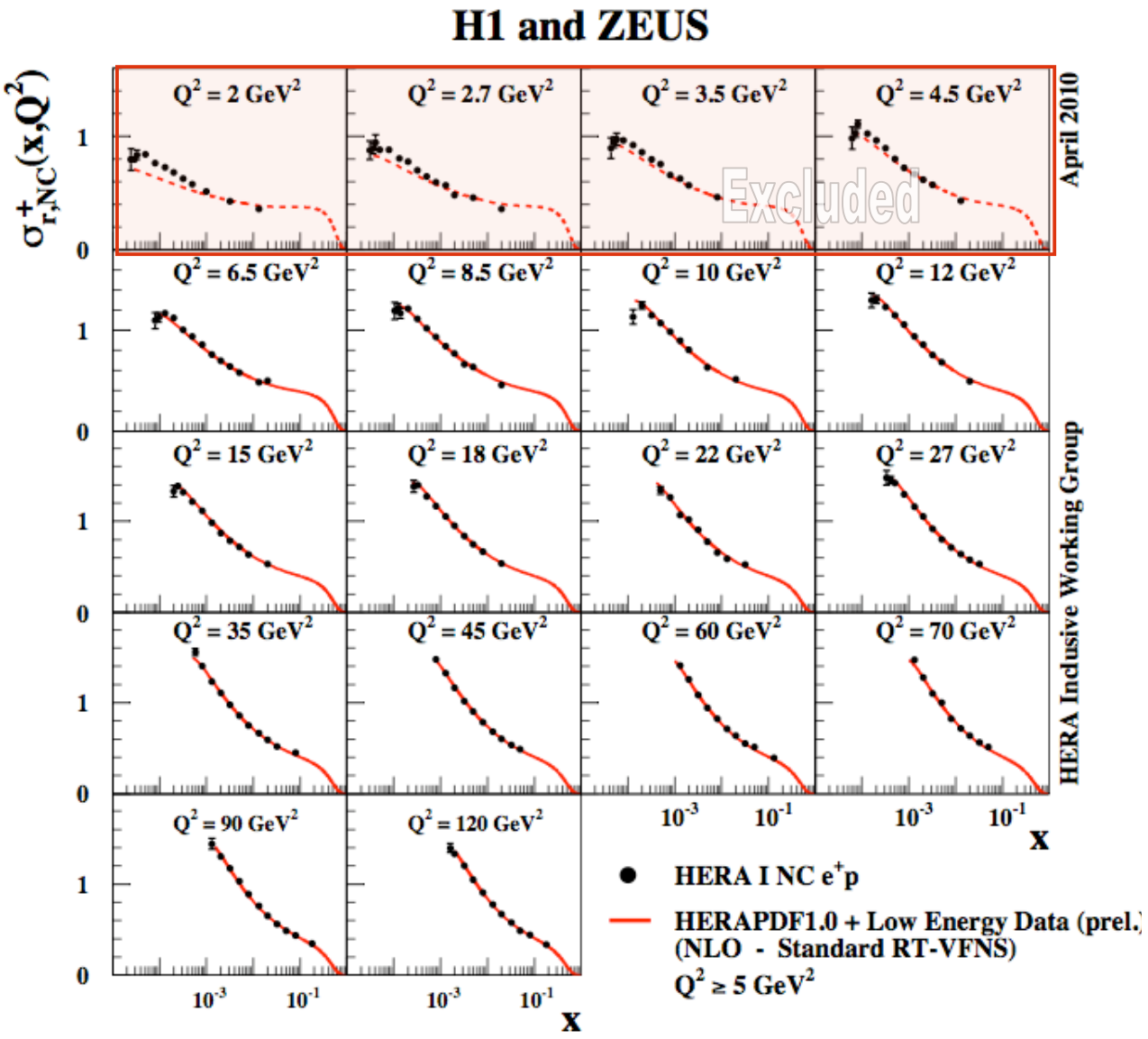
Kinematic Cut Dependence



- The $Q^2 \geq 5$ GeV^2 cut:
  - brings large improvement in χ^2 [818/806 → 698/771]
  - yields different shapes for gluon and sea PDFs.
- Compare Red (before Q^2 cut) with Magenta (after Q^2 cut):
  - Gluon is visibly enhanced and sea is reduced for $Q^2 \geq 5$ GeV^2 cut at the starting scale.
  - At the evolved scale sea is dynamically generated.
- Note: for HERAPDF1.0, the Q^2 cut variation is included in the model uncertainty.

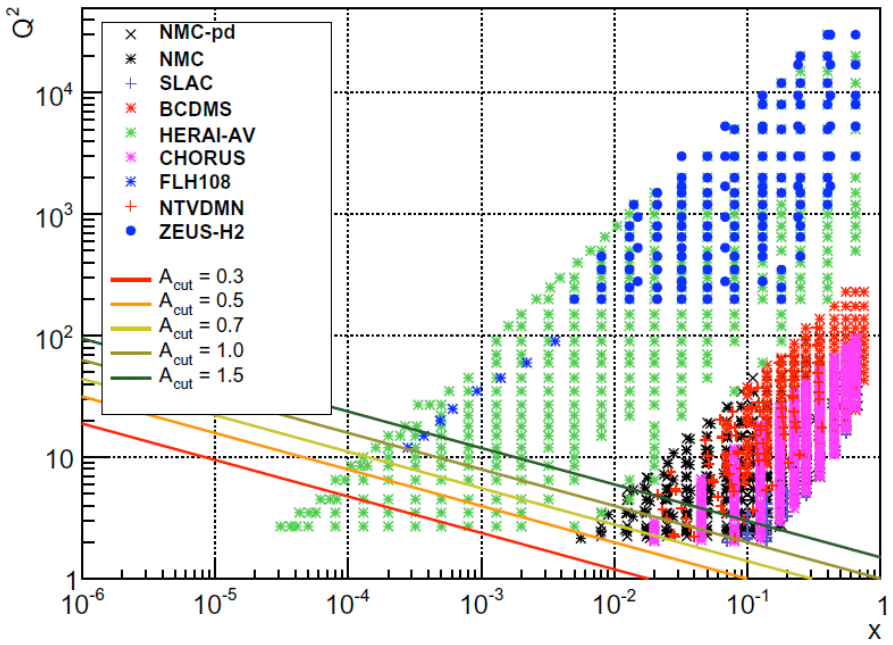
Comparison with Data, Fit with Q^2 cut

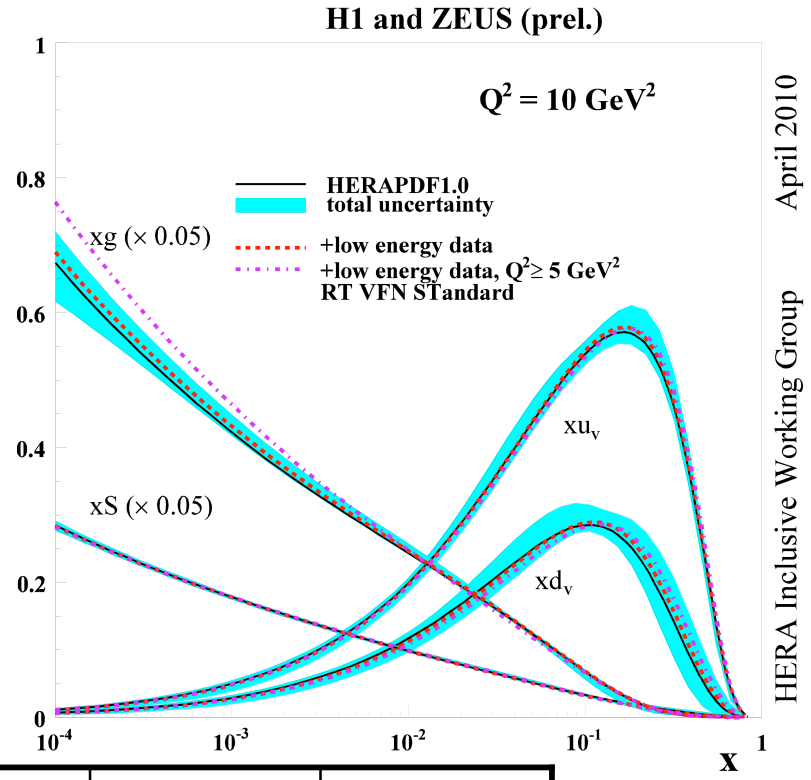
- Line corresponds to the fit of HERA I and Low Energy Data ($Q^2 \geq 5$ GeV^2 cut) using HERAPDF1.0 settings
  - Poor description in the region where data do NOT enter into the fit.



Further Kinematic Cut Tests

- Inspired by Fabrizio Caola's presentation at DIS2010 Workshop [http://indico.cern.ch/contributionDisplay.py?contribId=189&confId=86184]:
  - Use a different cut criterion: $Q^2 > Q_S(x)^2 = Ax^{-\lambda}$ with λ=0.3 and varying A





Cut	$Q^2>0.5x^{-0.3}$	$Q^2>5$	$X>5\cdot10^{-4}$	stnd cut
All χ^2/dof	683.4/760	698.3/771	598.2/686	818/806
Low Energy data χ^2/npts	0.86 (199)	0.82 (215)	0.79 (161)	1.04 (224)

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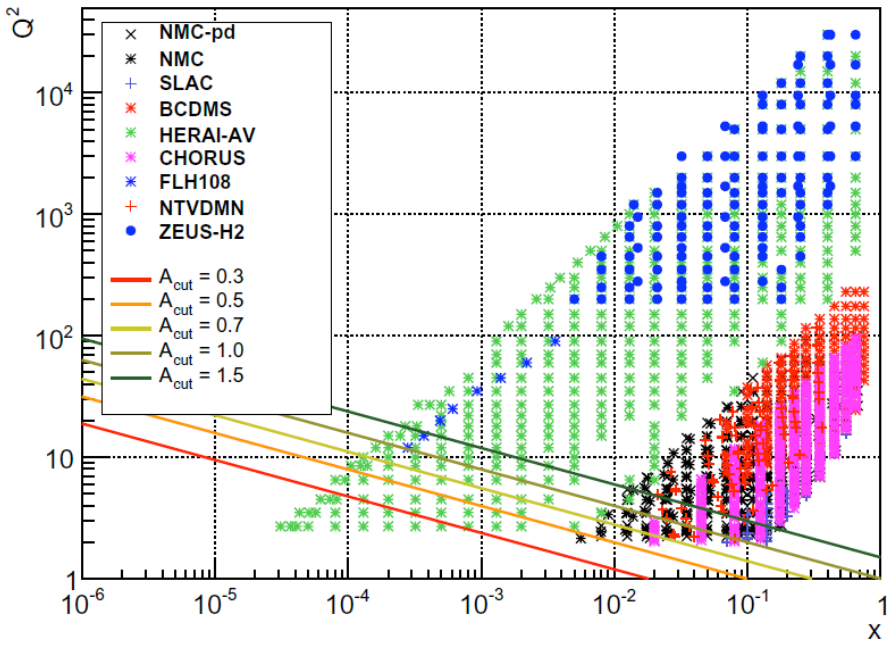

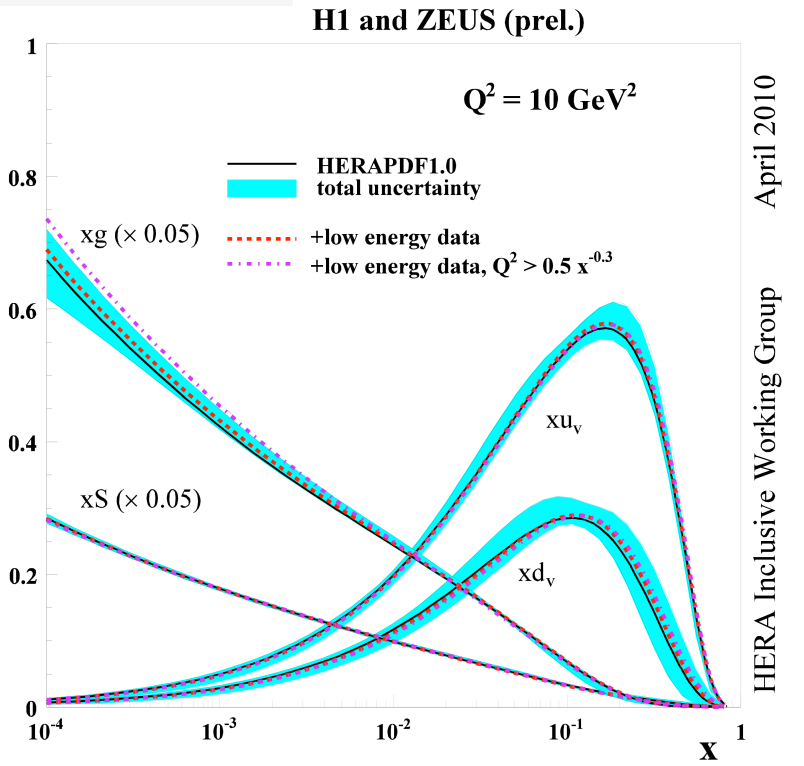

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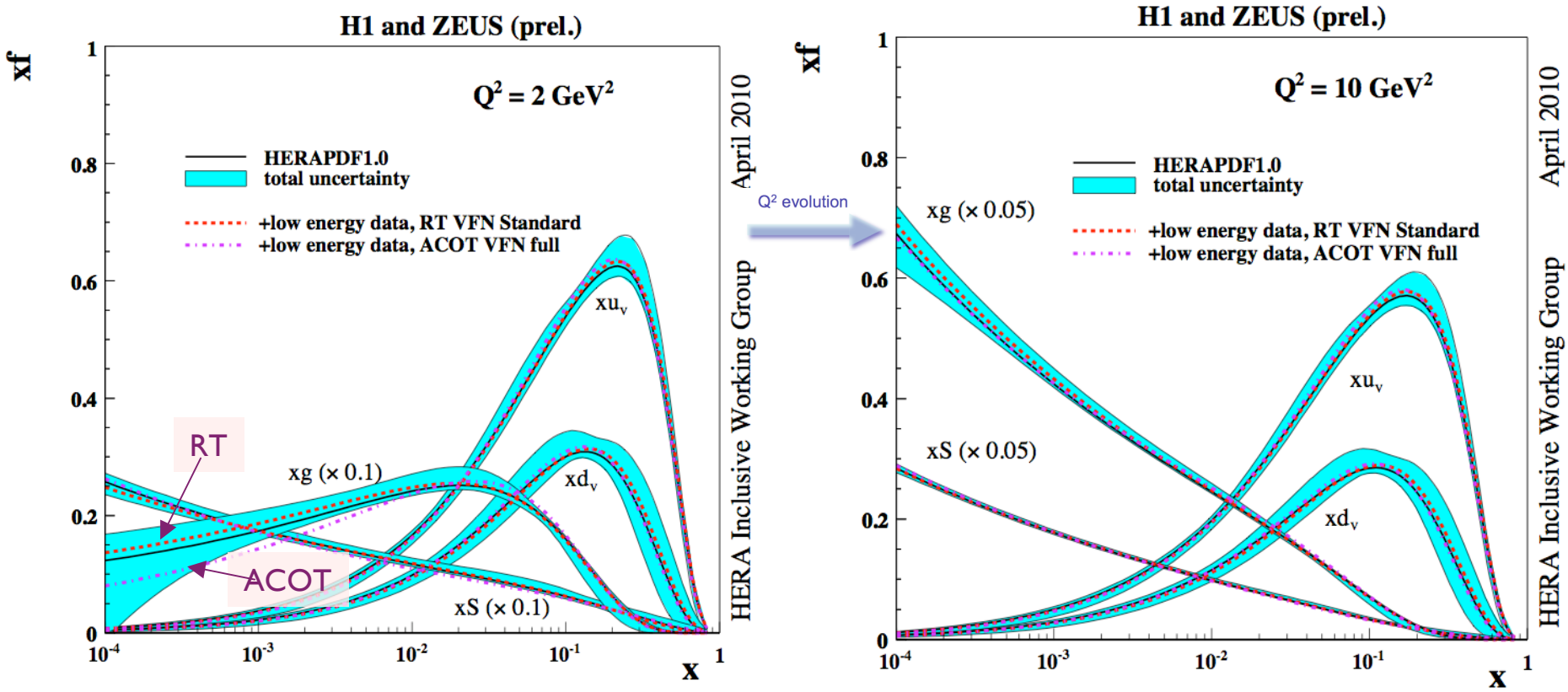
ACOT (Full) vs RT scheme

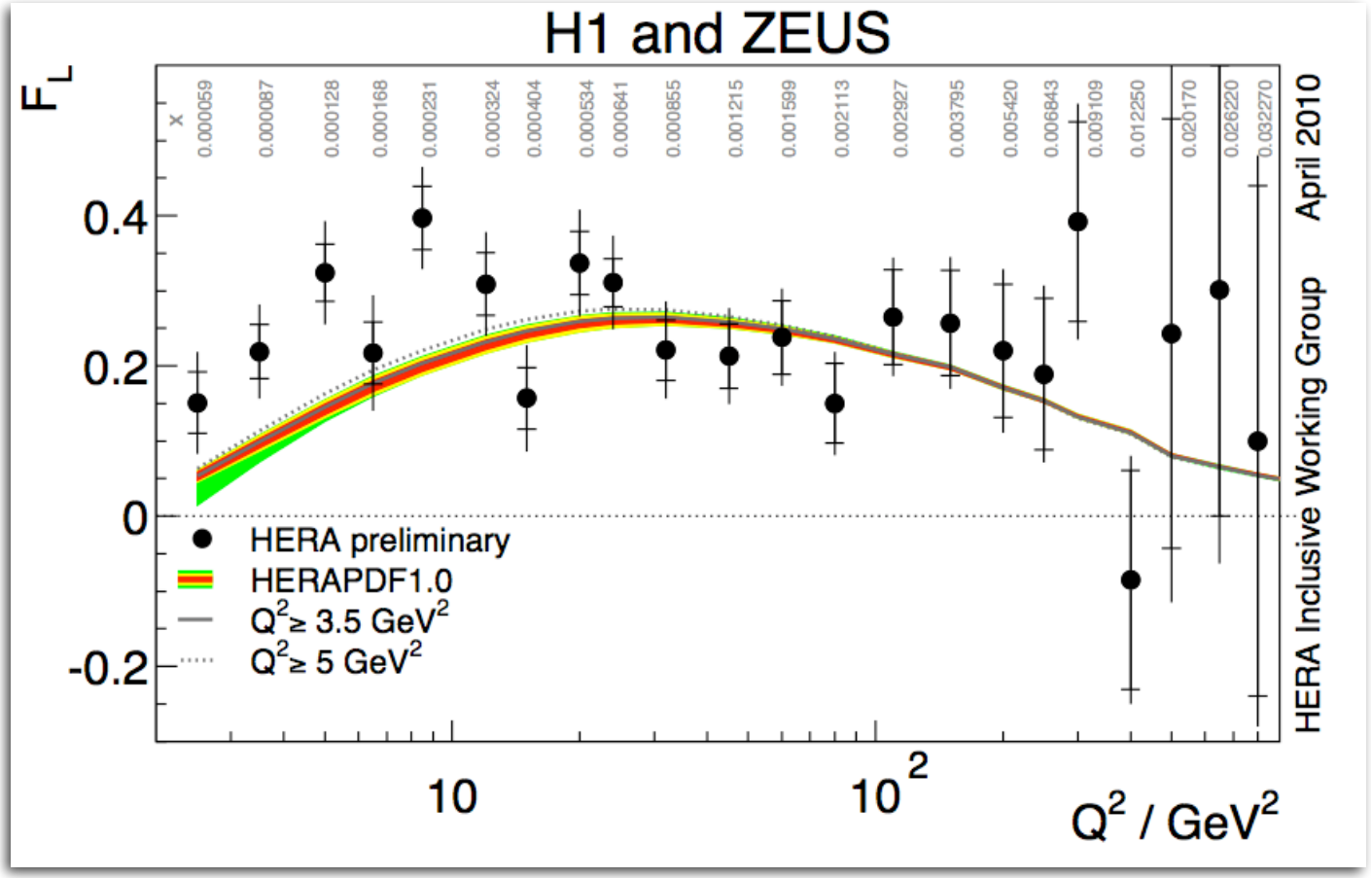


Compare fits to combined HERA I data including Low Energy Data using the ACOT (full) scheme to the RT standard scheme (VFNS):

- 30 Units improvement in χ^2 when using ACOT scheme!
- Large differences in the gluon at the starting scale, which are reduced at evolved Q^2

HERA F_L data vs F_L predictions

The lines are F_L predictions using combined HERA I and low energy data.



Q^2 cut does not bring improvement in F_L prediction.

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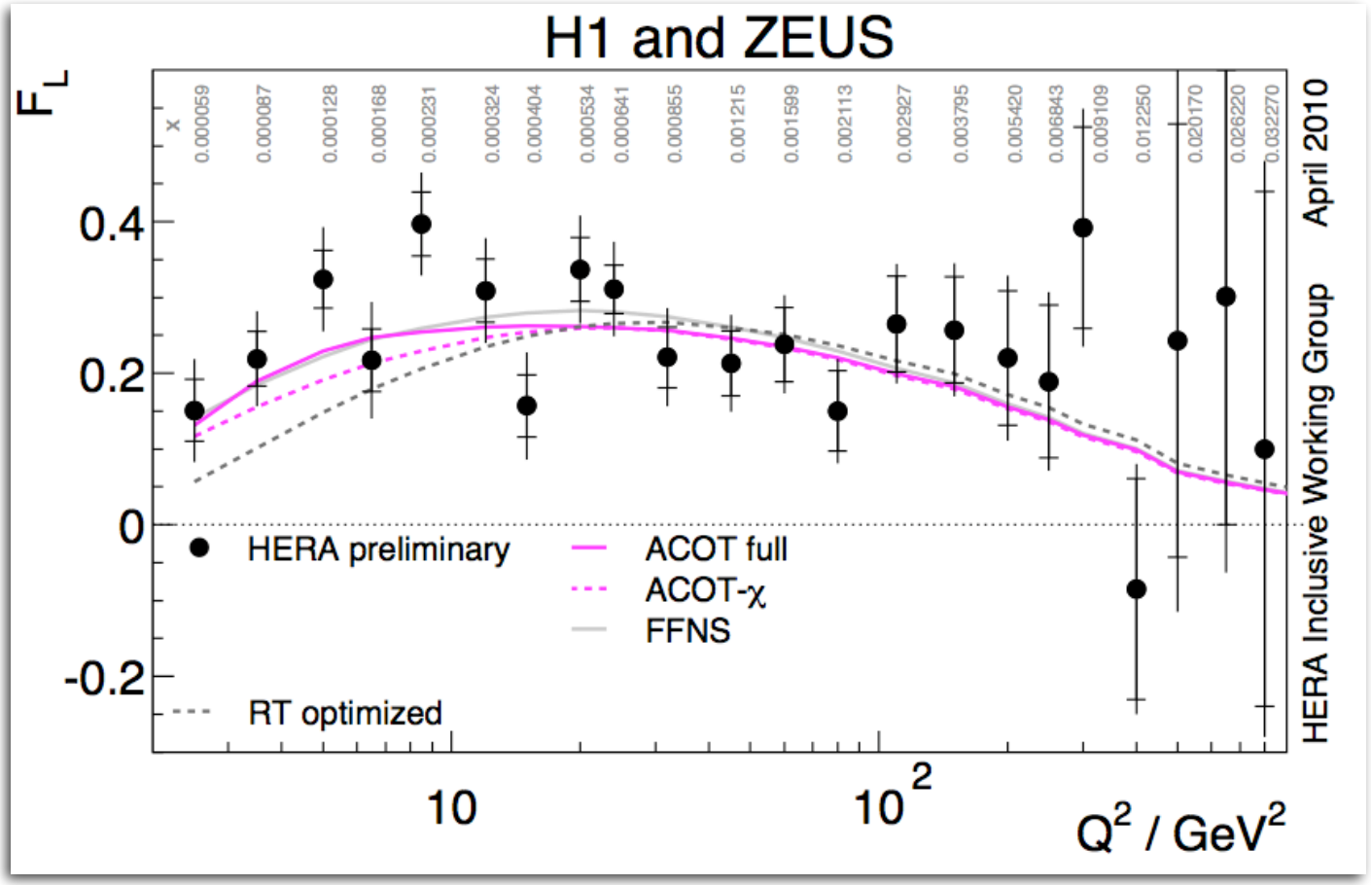
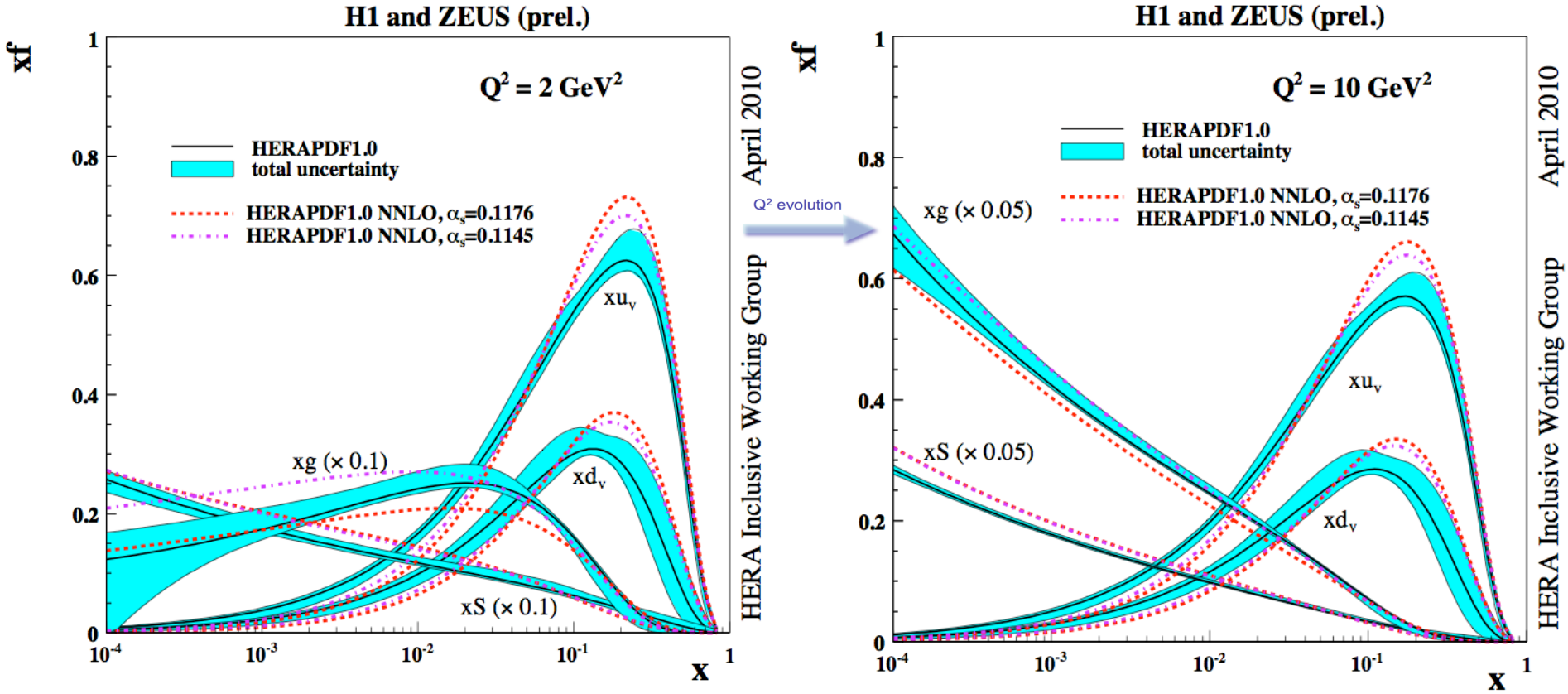


Various Heavy Flavour schemes: best ACOT(full) and FFNS

HERAPDF fits at NNLO

- Fits performed to HERA I data (as used for HERAPDF1.0) at NNLO using RT-VFNS:
  - $\alpha_S(Mz)$ at NNLO = 0.1176 and $\alpha_S(Mz)$ at NNLO = 0.1145

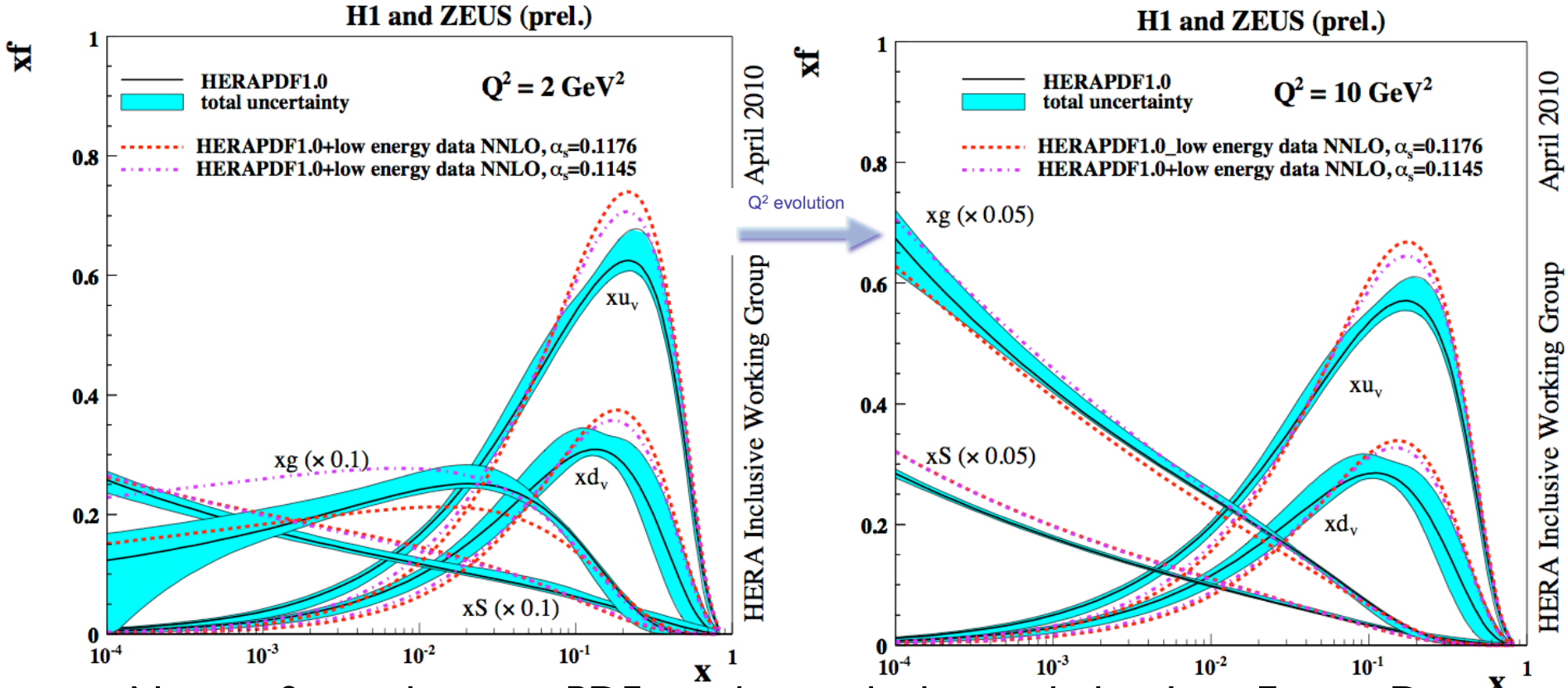


- Using the same settings as for HERAPDF1.0 NNLO fit does not improve fit results.

scheme	NNLO $\alpha_S(Mz)$=0.1145	NNLO $\alpha_S(Mz)$=0.1176	NLO $\alpha_S(Mz)$=0.1176
All χ^2/dof	623.7/582	638.3/582	574.4/582

NNLO HERAPDF fits including Low Energy Data

$\alpha_S(Mz)$ at NNLO = 0.1176 and $\alpha_S(Mz)$ at NNLO = 0.1145

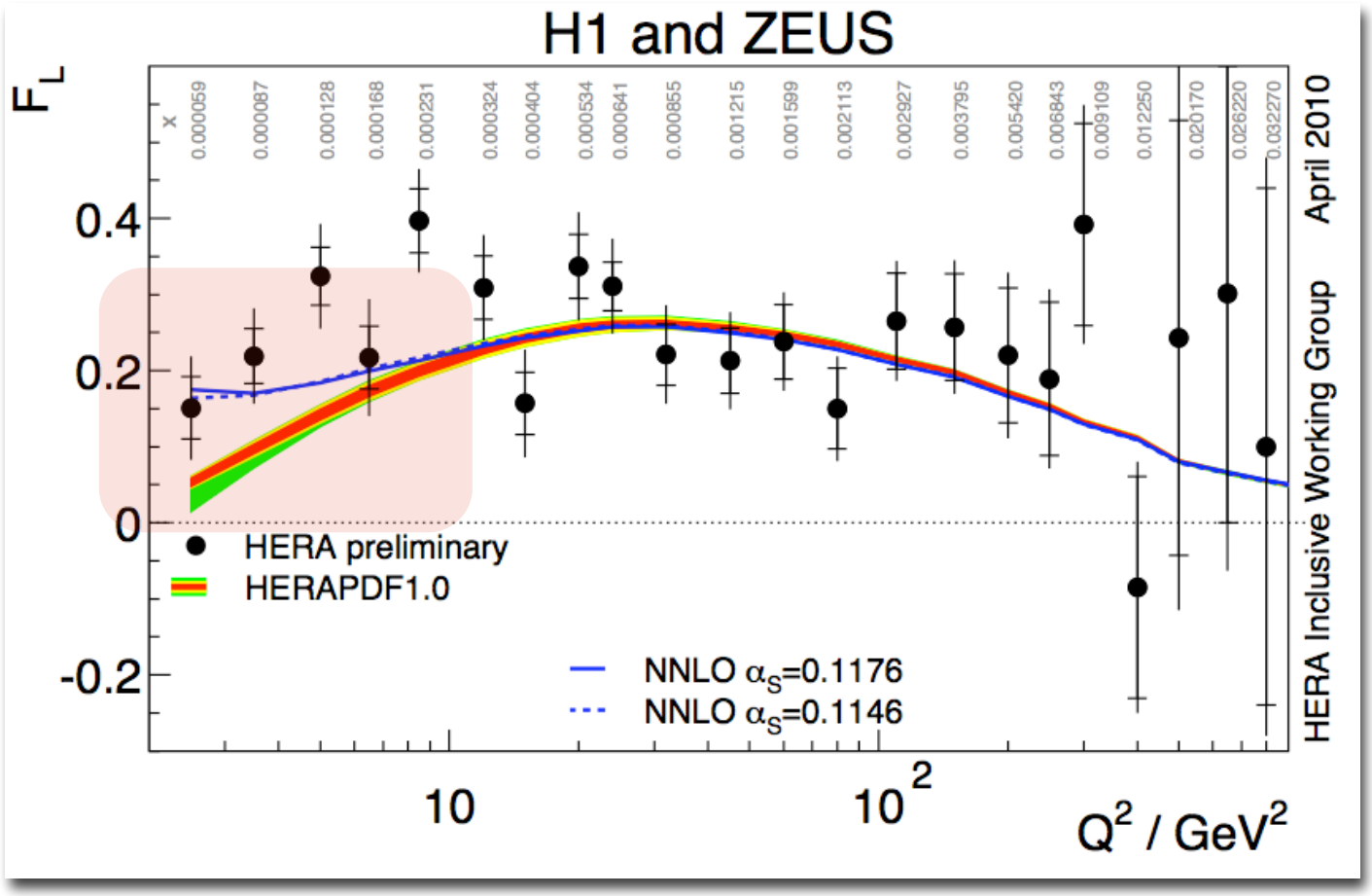


- No significant change in PDFs is observed when including Low Energy Data.

scheme	NNLO	NNLO	NLO
All χ^2/dof	911.5/806	893.2/806	818/806

HERA F_L data vs NNLO F_L predictions

The lines are F_L predictions using combined HERA I and low energy data.



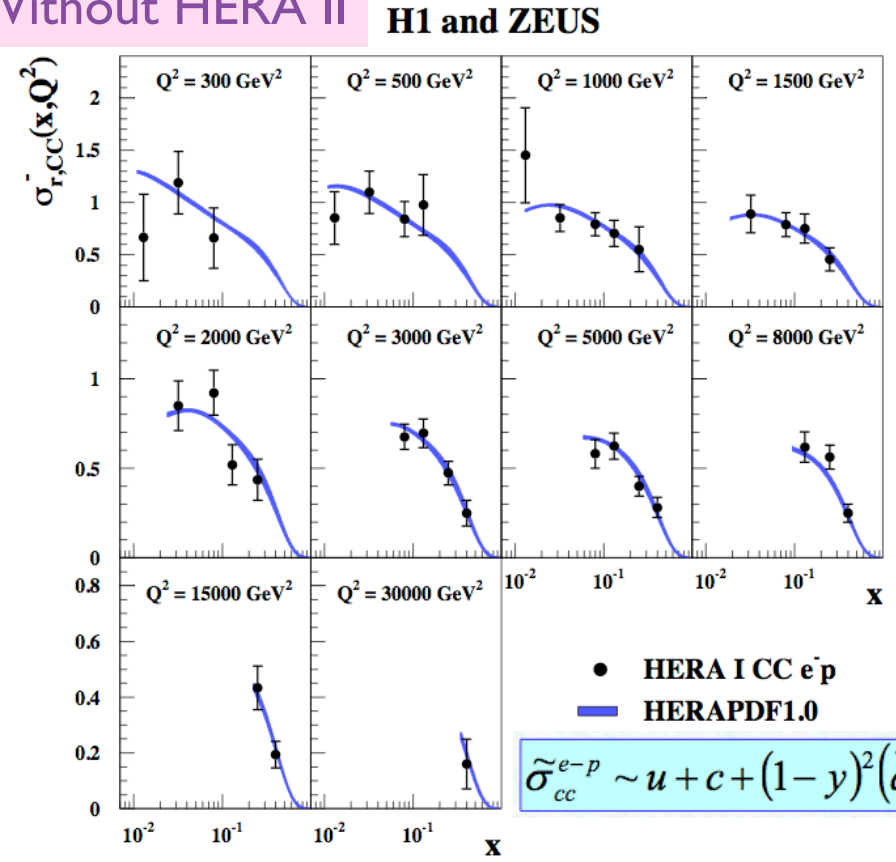
NNLO (RT) prediction yields interesting behaviour at low Q^2

HERA Fits to the Combined HERA I and II Inclusive data

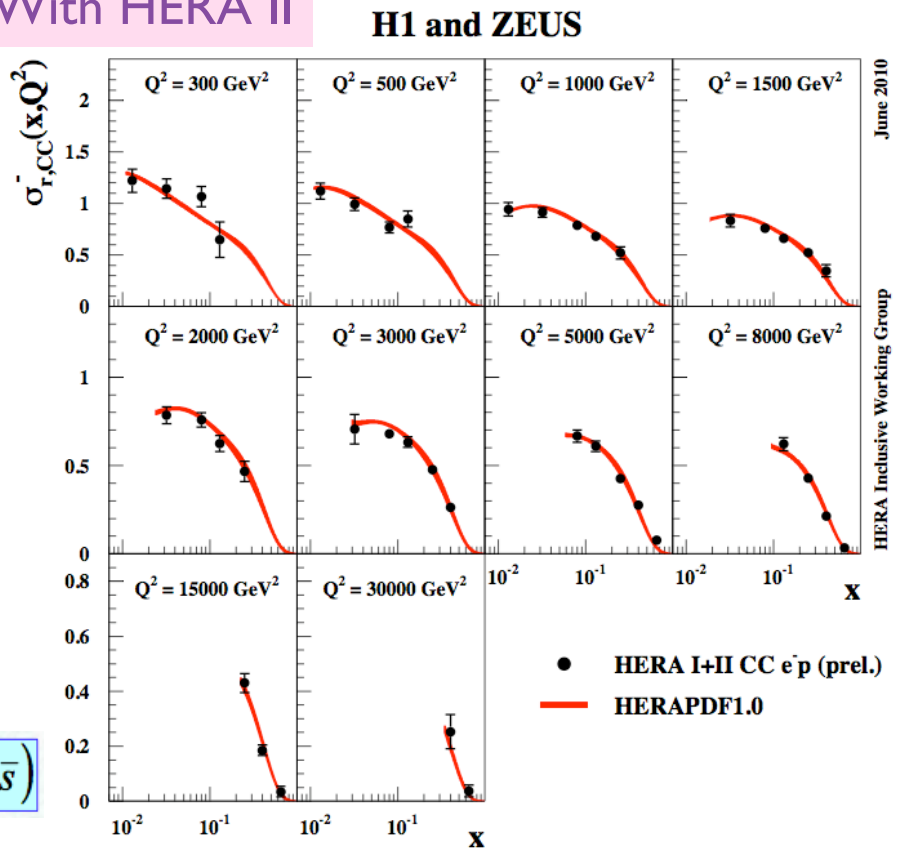
Combined HERA I and II Inclusive data

- New HERA II preliminary data available!
  - More precise measurements in the high Q^2 and high x regions (especially NC e^-p and CC $e^{\pm}p$)
  - ➔ could constrain better PDFs at high x

Without HERA II



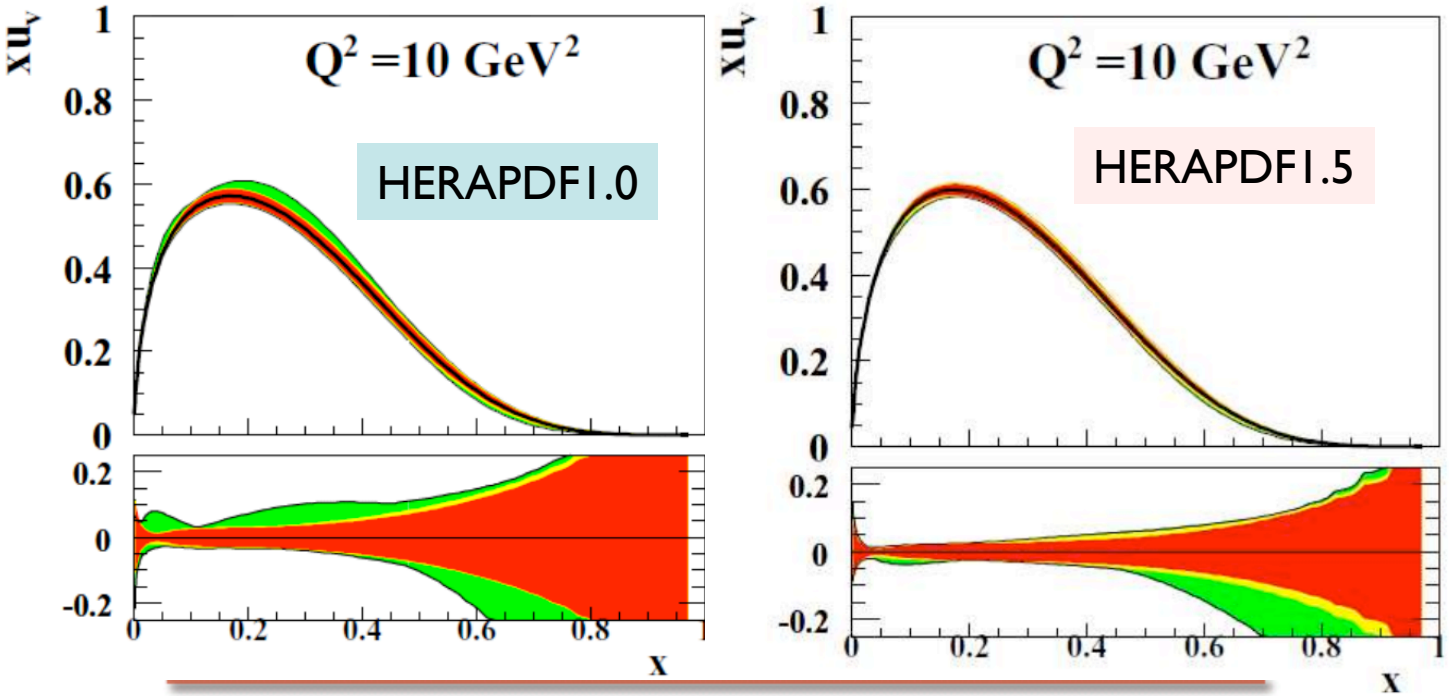
With HERA II



Much more precise CC measurements after including new high Q^2 HERA II set!

Fits to New Combined HERA data: HERAPDF1.5

- Propagate new data through QCD fit analysis to produce a new set of HERAPDFs: HERAPDF1.5
  - For preliminary studies use same settings as for HERAPDF1.0
  - Parametrisation uncertainty will be further investigated for final release.



⇒Experimental uncertainty reduced
⇒Parametrisation uncertainty reduced

- "HERAPDF1.0"

SET	Data	points	RT	ACOT
TOT	χ^2	582(dof)	574	560

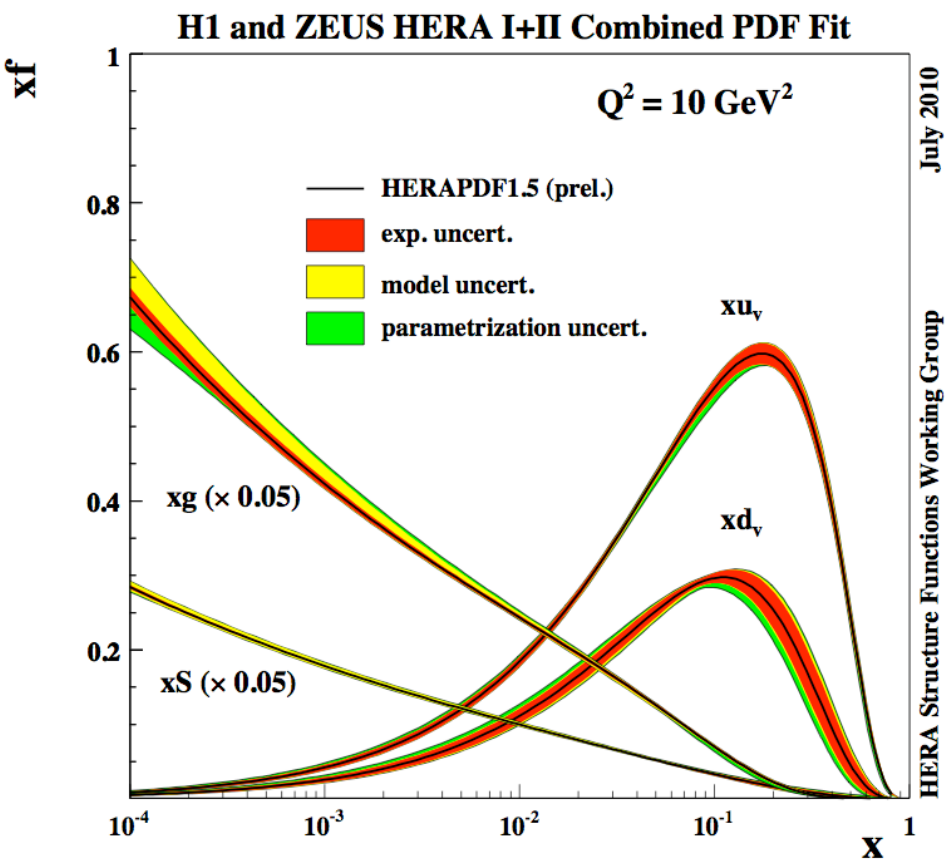
- "HERAPDF1.5"

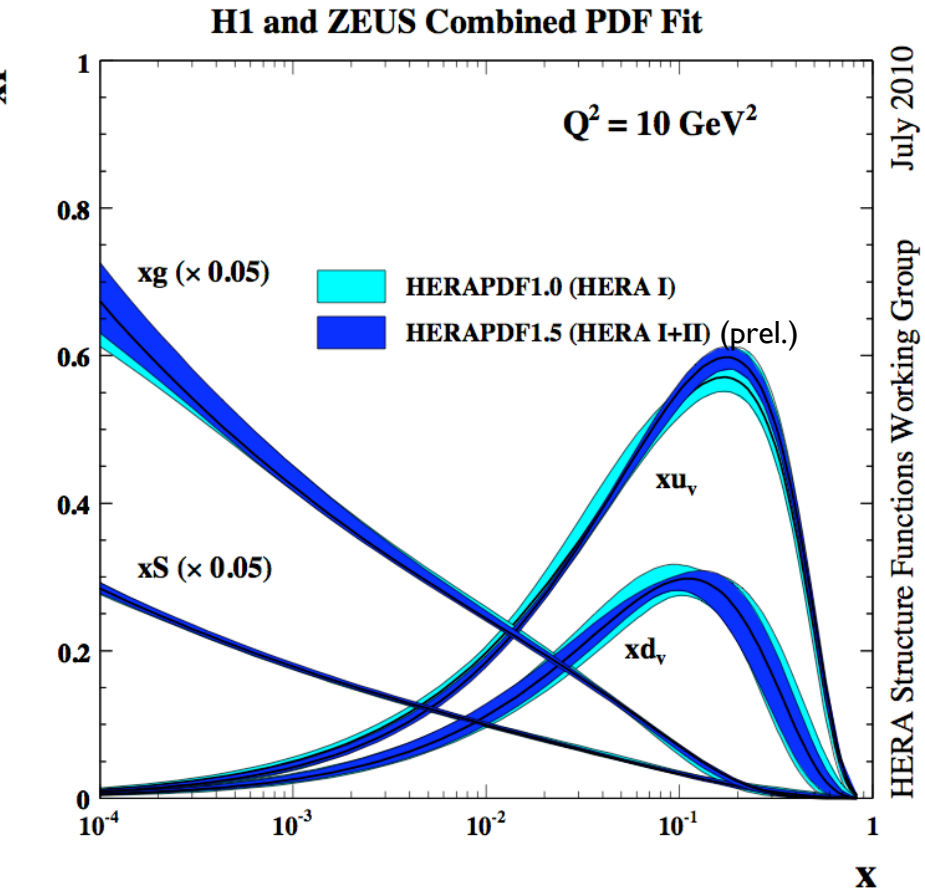
SET	Data	points	RT	ACOT
TOT	χ^2	664(dof)	761.8	754.6

The χ^2 increased due to the precision of data (especially CC)

HERAPDF1.5 vs HERAPDF1.0

- xg, xu_v, xd_v, xSea (xSea=$x\overline{U}+x\overline{D}$) at the scale Q_0^2=10 GeV^2





- Inclusion of the HERA II data reduces the uncertainties on PDFs in the high x region especially visible on the valence distributions!
  - See HERAPDF1.5(prel) vs HERAPDF1.0

HERAPDF1.5 vs HERAPDF1.0

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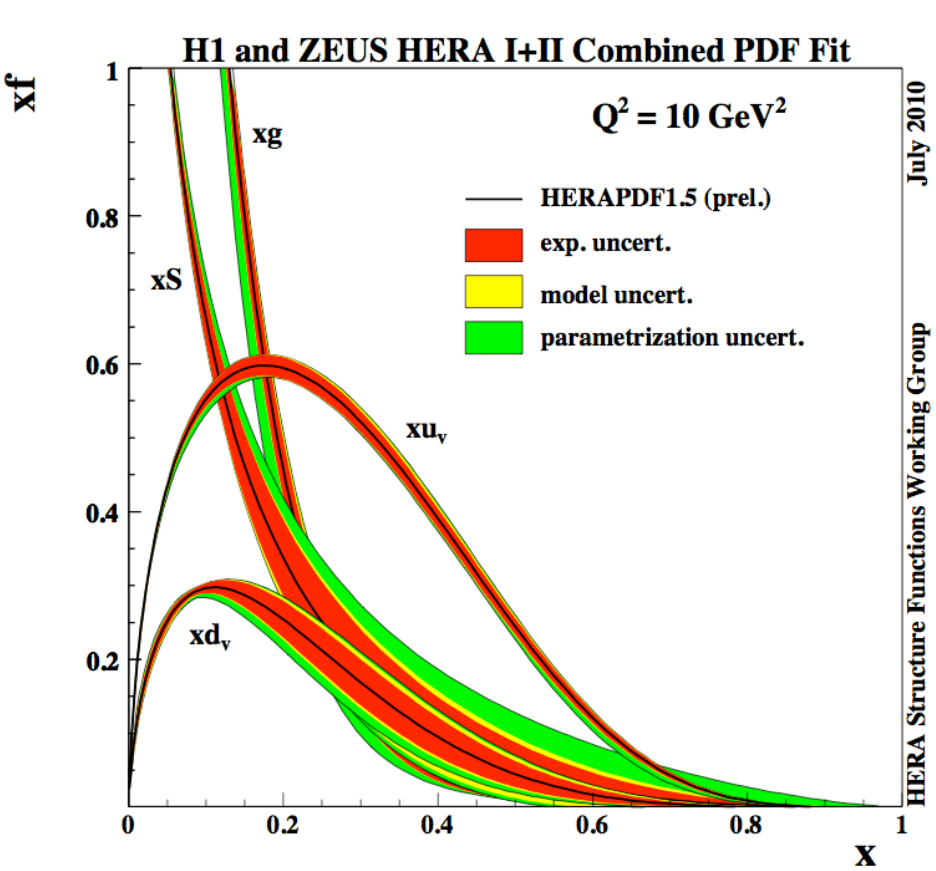
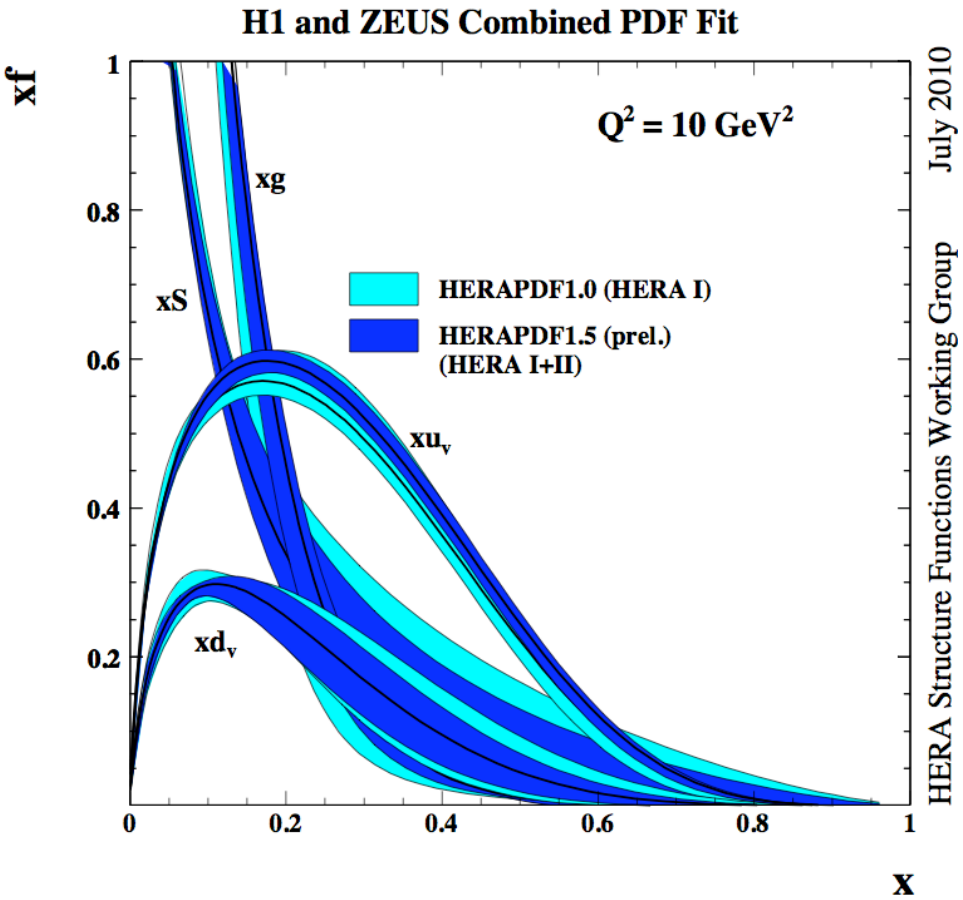
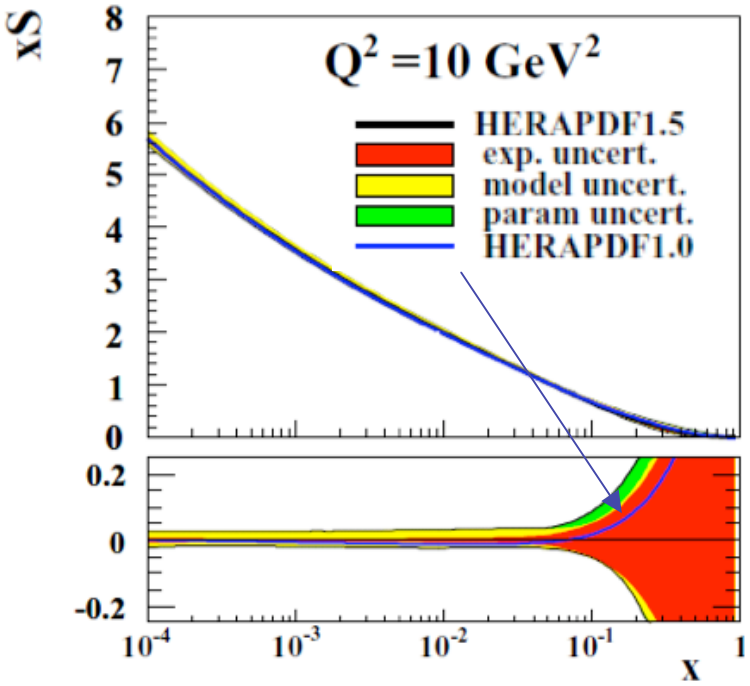
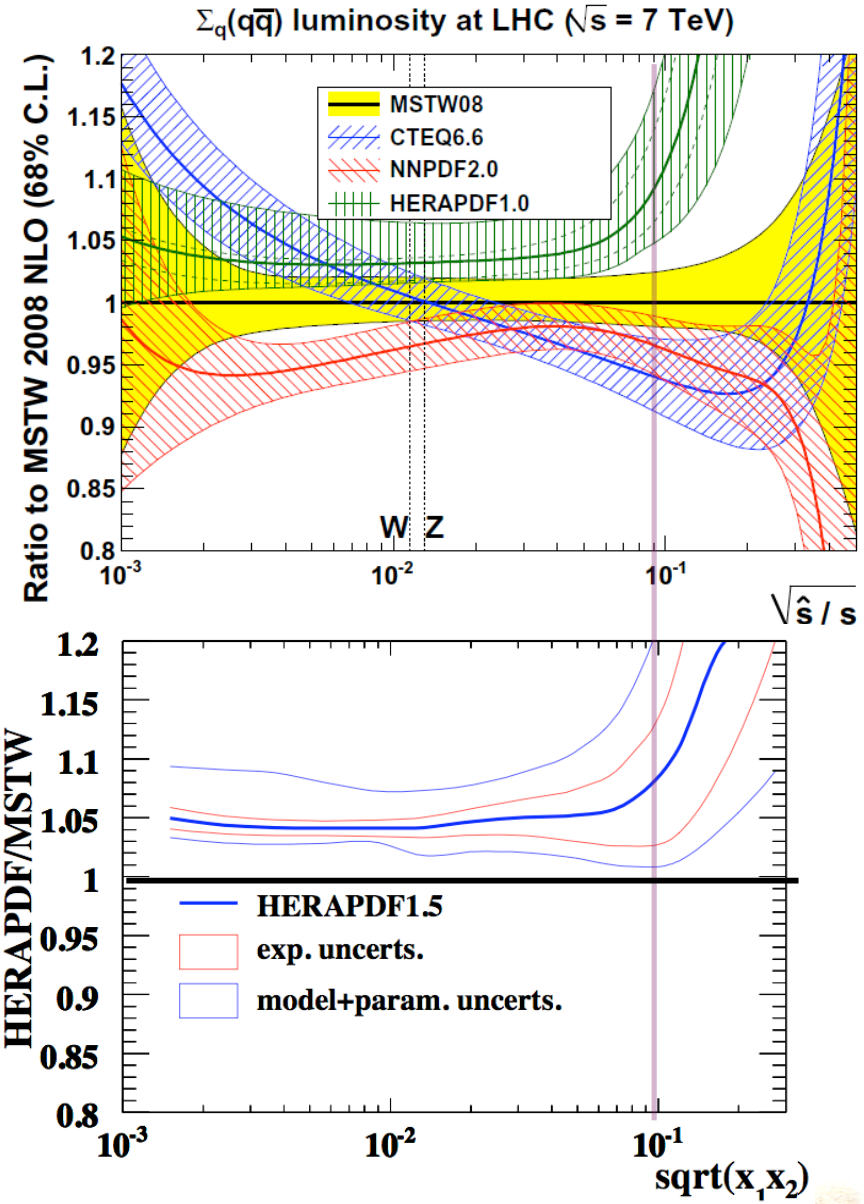




- Inclusion of the HERA II data reduces the uncertainties on PDFs in the high x region especially visible on the valence distributions!
  - See HERAPDF1.5(prel) vs HERAPDF1.0

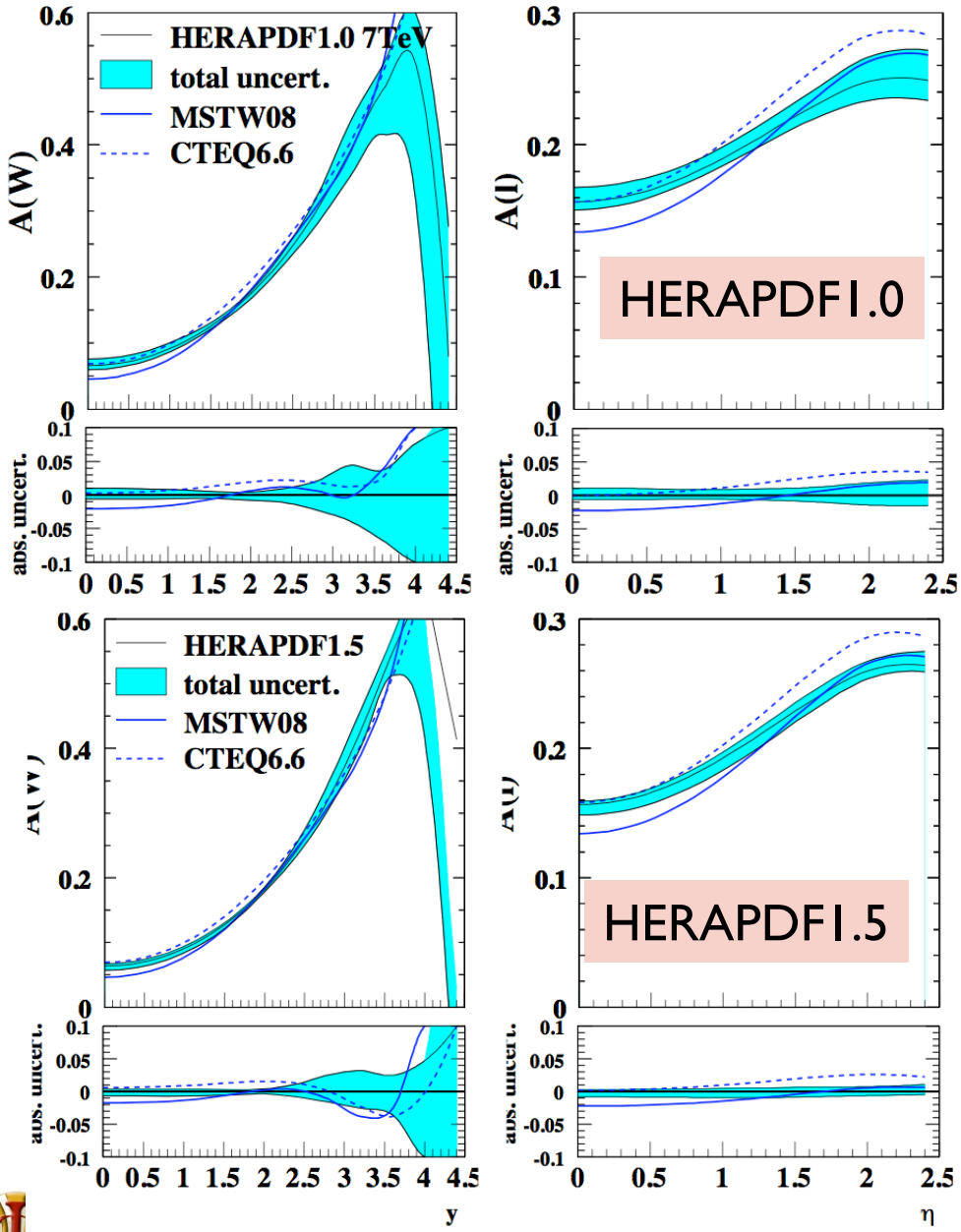
Impact on the LHC





- HERAPDF1.0 is high at the large scale because Sea is hard at high x
- HERAPDF1.5 has a softer Sea, hence better agreement with MSTW08

LHC predictions for W and lepton asymmtries



- The uncertainties are reduced for the predictions using HERAPDF1.5 as compared to HERAPDF1.0 showing the impact of the new precise measurements from HERA II.

Summary

- New preliminary low energy data have been included in the HERAPDF QCD fits:
  - New fits are in agreement with HERAPDF1.0
    - Observe large sensitivity to kinematic cut at low Q^2 and low x.
    - Different schemes in the fit yield interestingly different F_L prediction.

- HERAPDF fits at NNLO (RT-VFNS) were presented

- New preliminary measurements from HERA II are available in the HERA QCD analyses:
  - Precise new measurements of high Q2 with constraining power in the high x region
    HERAPDF1.5
  - Provides more precise predictions for LHC than HERAPDF1.0
  - Provides good predictions for the W and lepton asymmetries measured at Tevatron
    - [see M. Cooper-Sarkar's presentation]

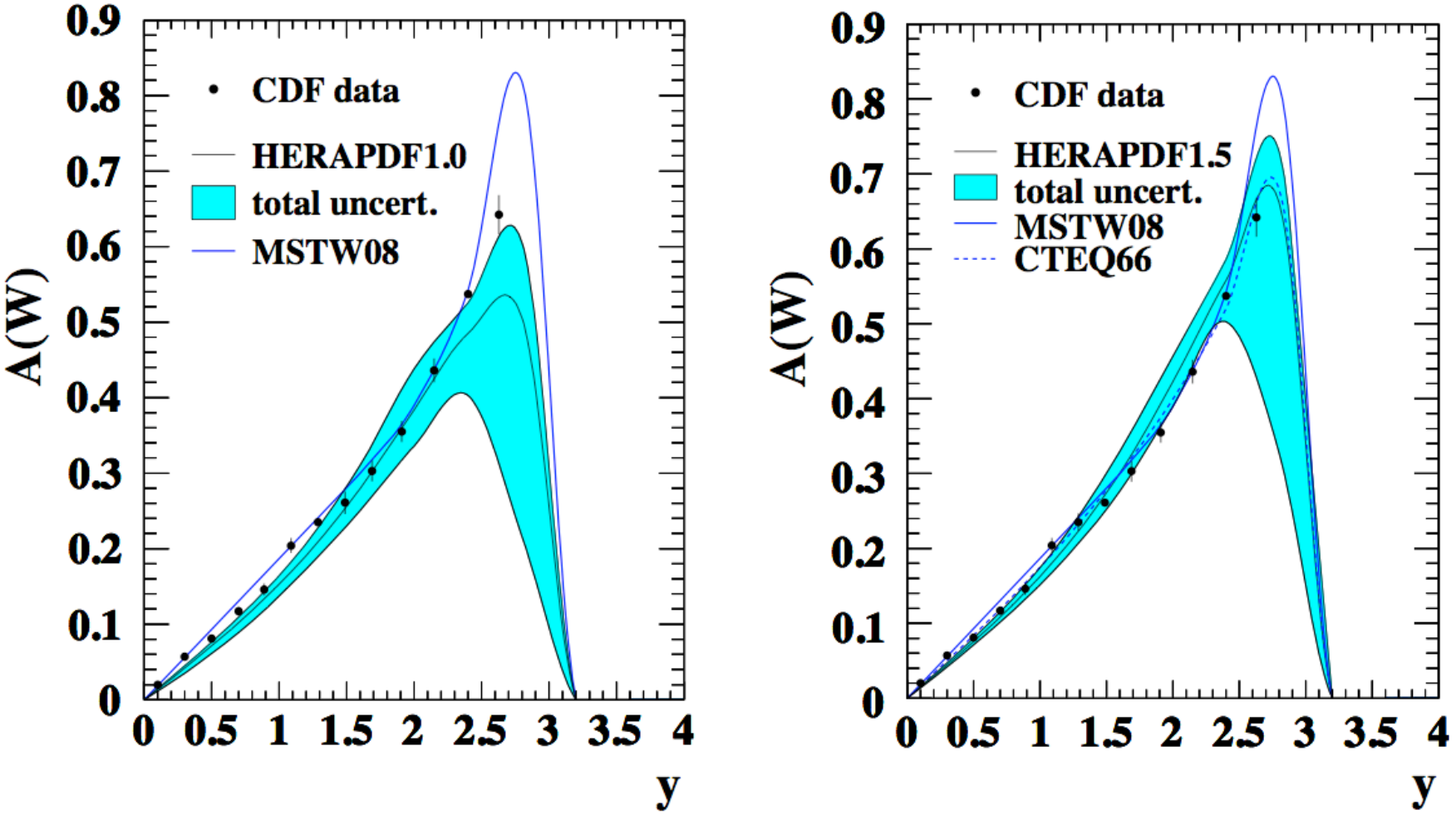
- LHAPDF grid files for HERAPDF1.5 with the full uncertainties can be found at:

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

H1-ZEUS combined results

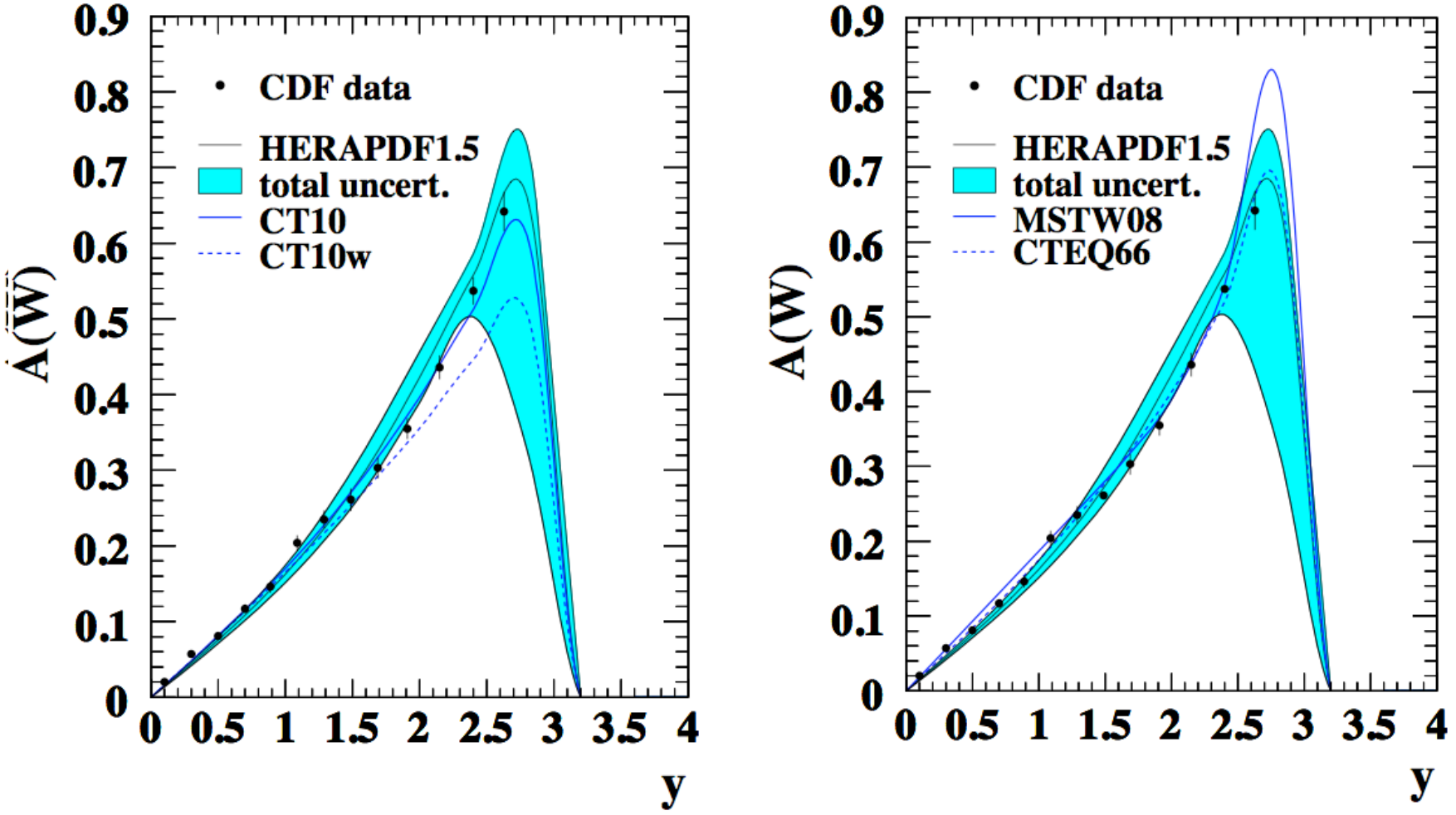
https://www.desy.de/h1zeus/combined_results/index.php

Comparison to Tevatron W asymmetry



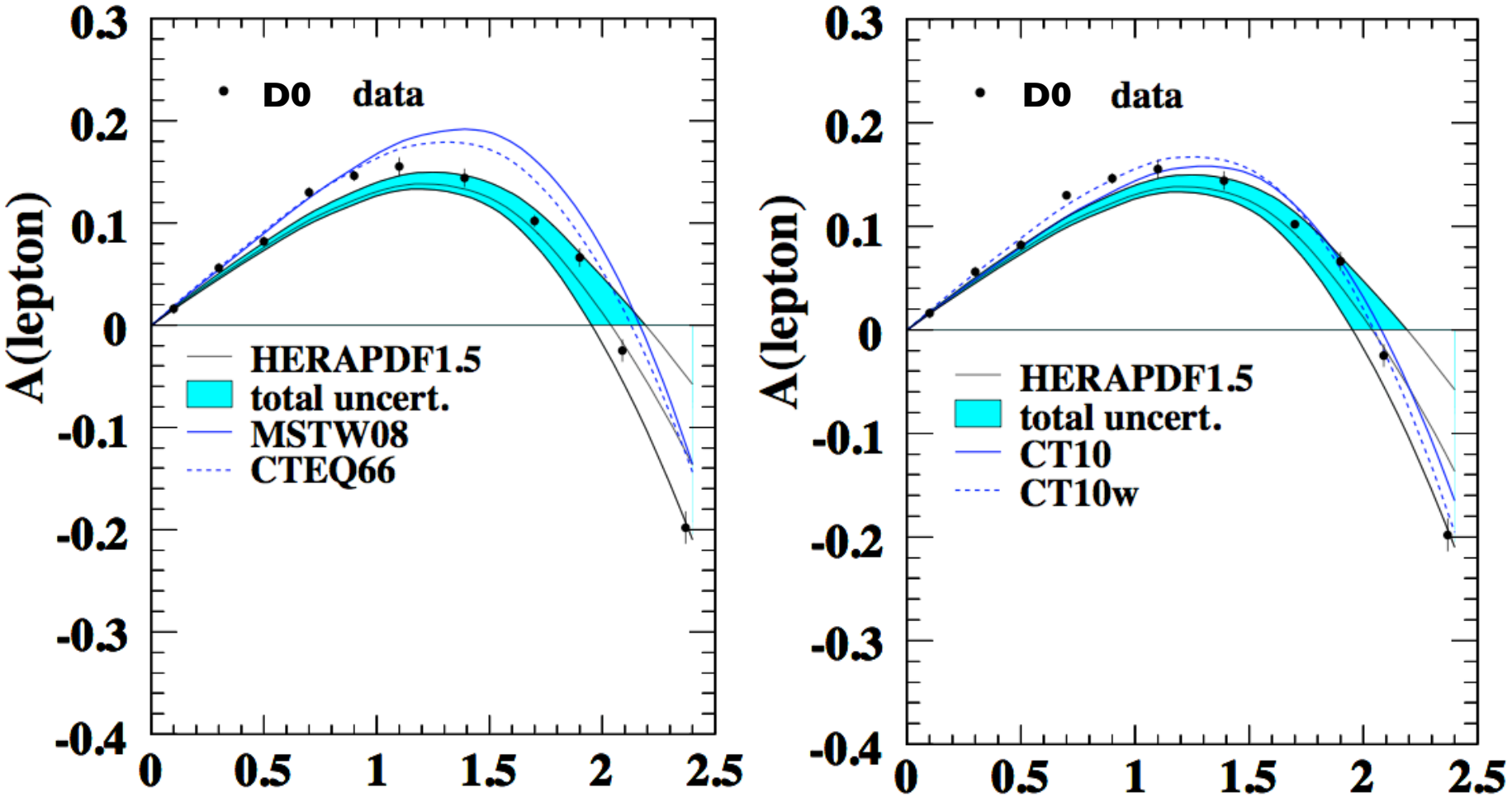
- HERAPDF1.5 results in a better agreement than HERAPDF1.0 with the CDF data for the W asymmetry, even if this data is not included in the HERA fits.

Comparison to Tevatron CDF W asymmetry



- HERAPDF1.5 compared to Global PDF sets

D0 Lepton Asymmetry

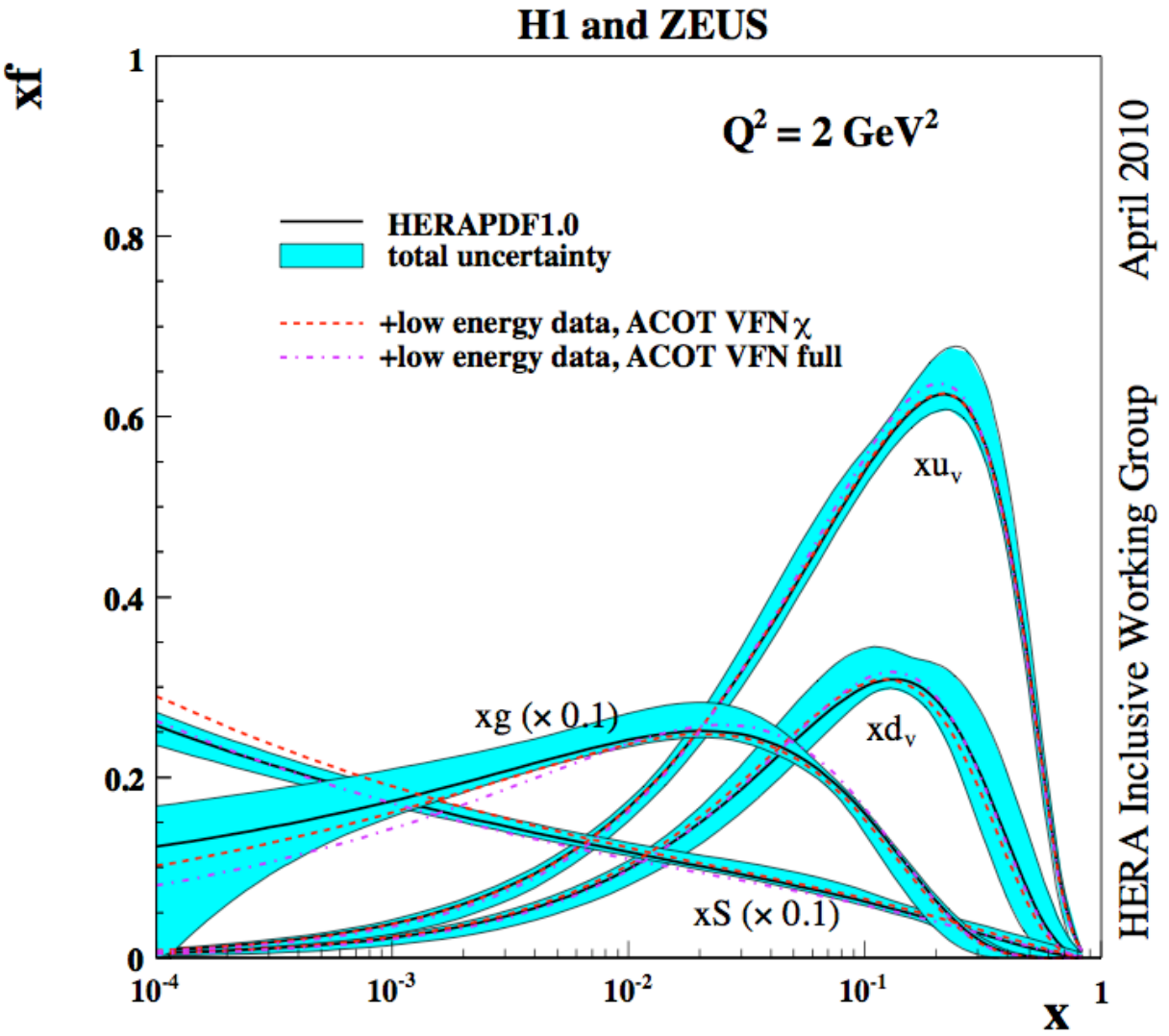


- HERAPDF1.5 provides a reasonable agreement even with the D0 lepton asymmetry, for which the global fits have difficulties.

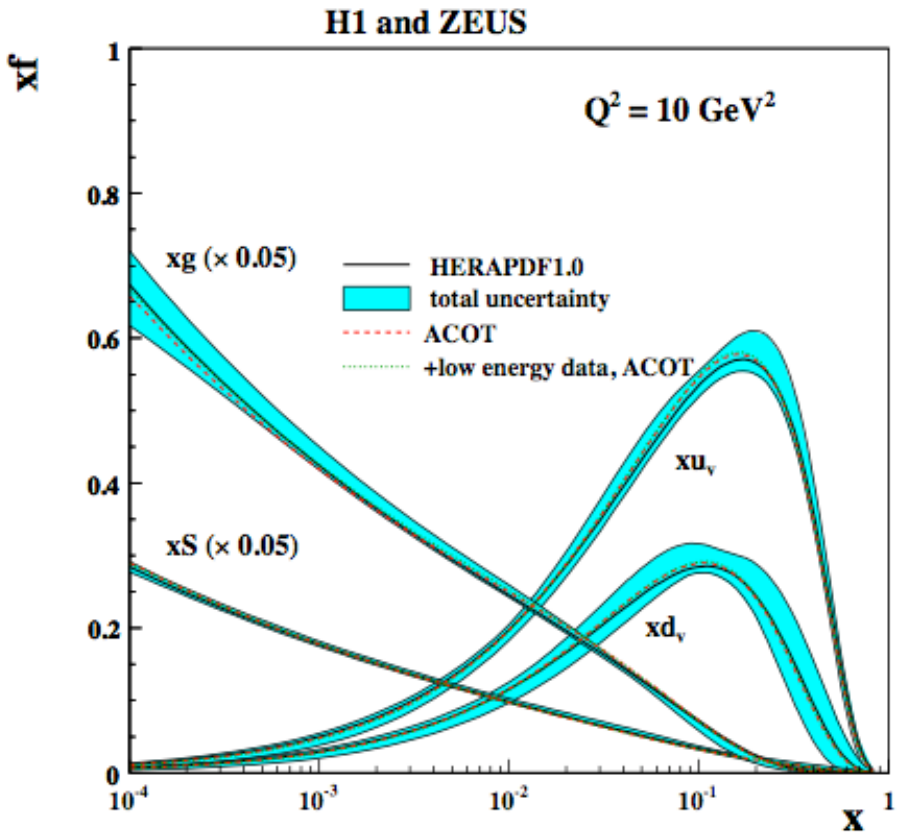
Compare ACOT schemes to HERAPDF1.0

ACOT full fit results in a 5 units improvement in χ^2 compared to ACOTχ

- ACOT full:
  - Slightly less steeper gluon and sea is not changed much
  - Better fit of the high energy data
- ACOTχ :
  - A steeper gluon and sea
  - Better fit of the low energy data



Reminder on HF checks on HERA data alone

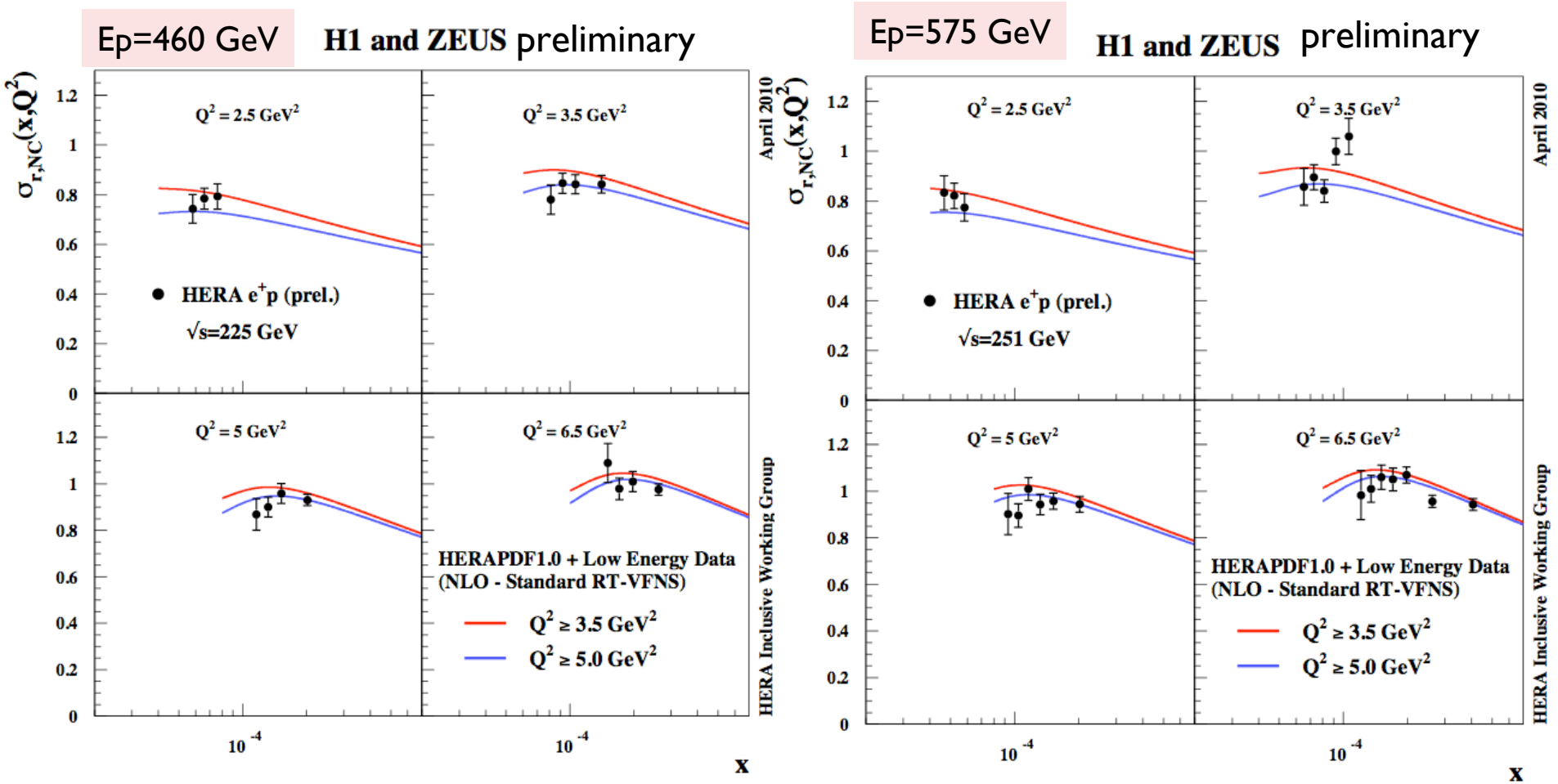


- RT: chi2/dof = 574/582
- ACOT: chi2/dof=562/582

- RT heavy flavour scheme was cross checked against ACOT scheme for HERAPDF1.0
  - We did not observe much difference in the PDF distributions
  - ACOT line is shown in the HERAPDF1.0 paper

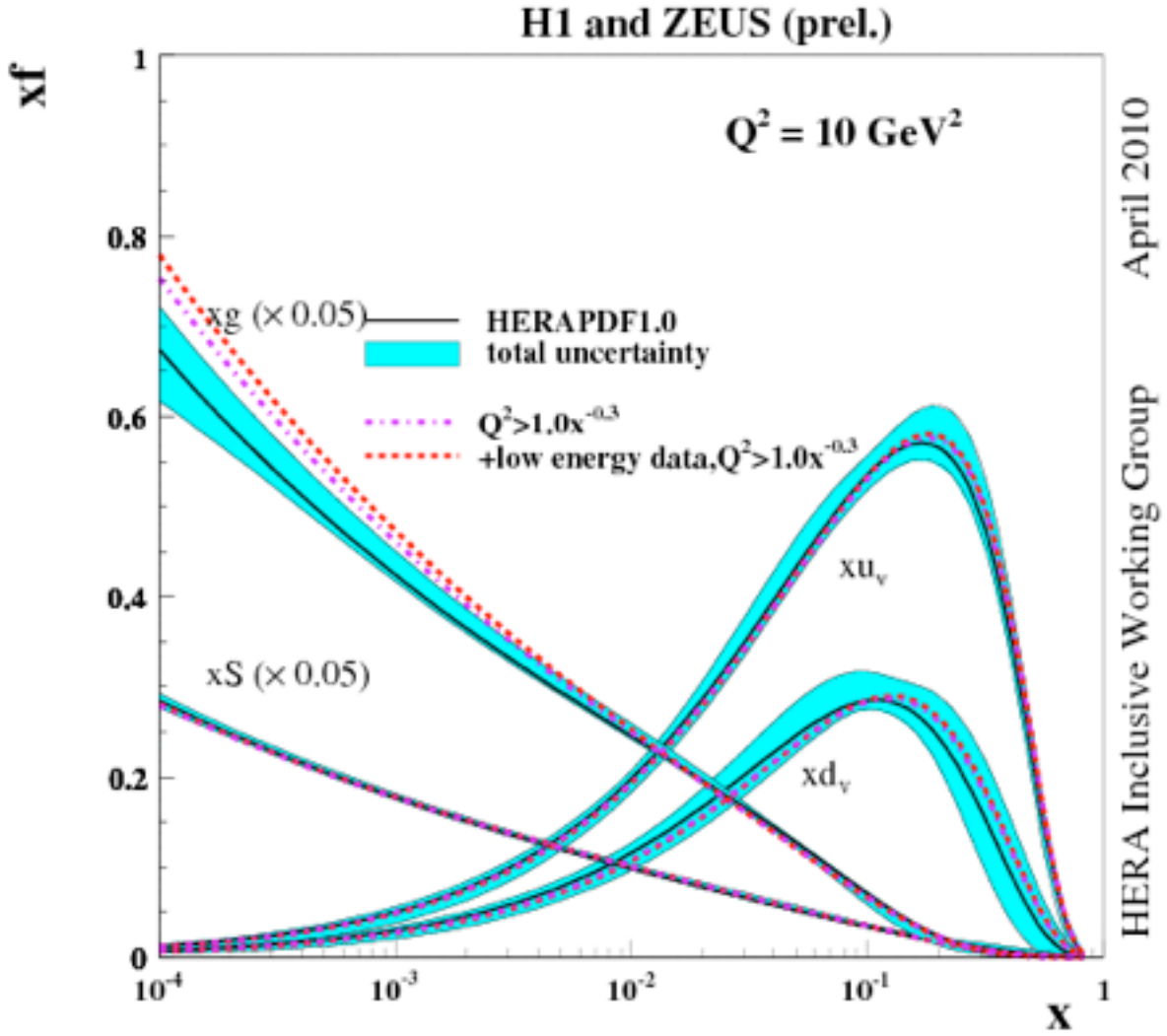
Comparison with Low Energy data

- Note: Q^2>5 GeV^2 cut does not include first 2 bins in the fit.
  - The Q^2 cut case (blue) fits better 460 GeV data which are all located at y>0.35.



Optimal cut?

- Is there a cut which can bring the high energy data alone and extension of the



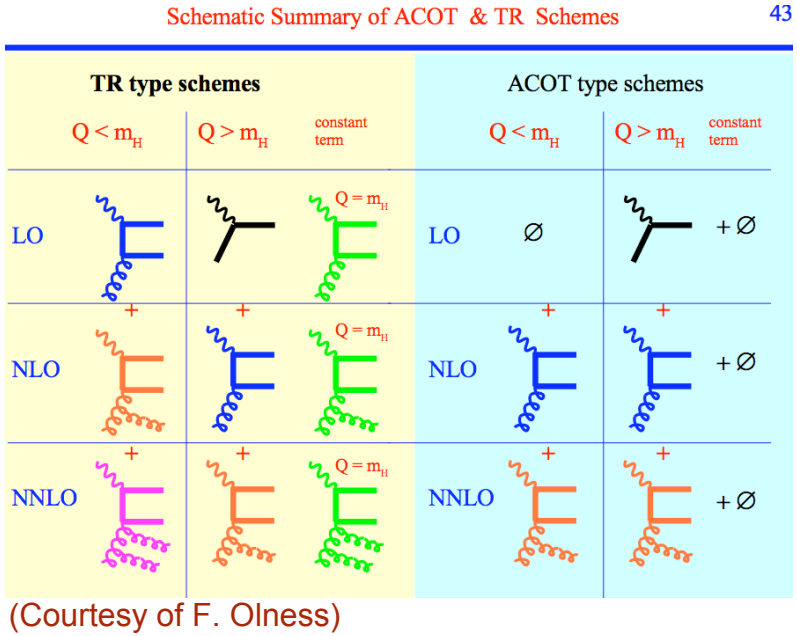
$Q^2>1.0\ x^{-0.3}$	No cut
472.4/533	818.5/806
0.95 (330)	1.13 (379)
N/A	1.04 (224)

- y data results look similar
- ions are needed!

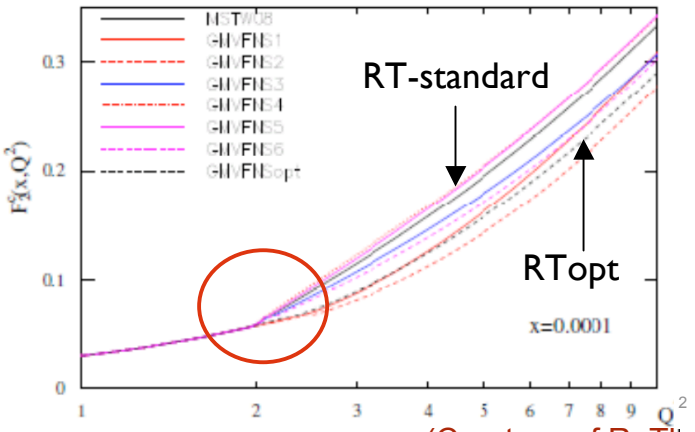
Various Heavy Flavour treatments at NLO

Low Q^2 region is sensitive to the treatment of charm quark production.

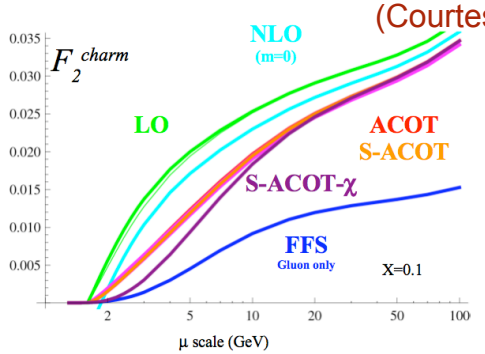
- Compare various schemes taking into account heavy quark production:
  - VFNS RT (standard [MSTW08] and optimal [R. Thorne's presentation])
  - VFNS ACOT (full [Phys.Rev.D50,1994] and χ [Phys.Rev.D62,2000])



(Courtesy of F. Olness)



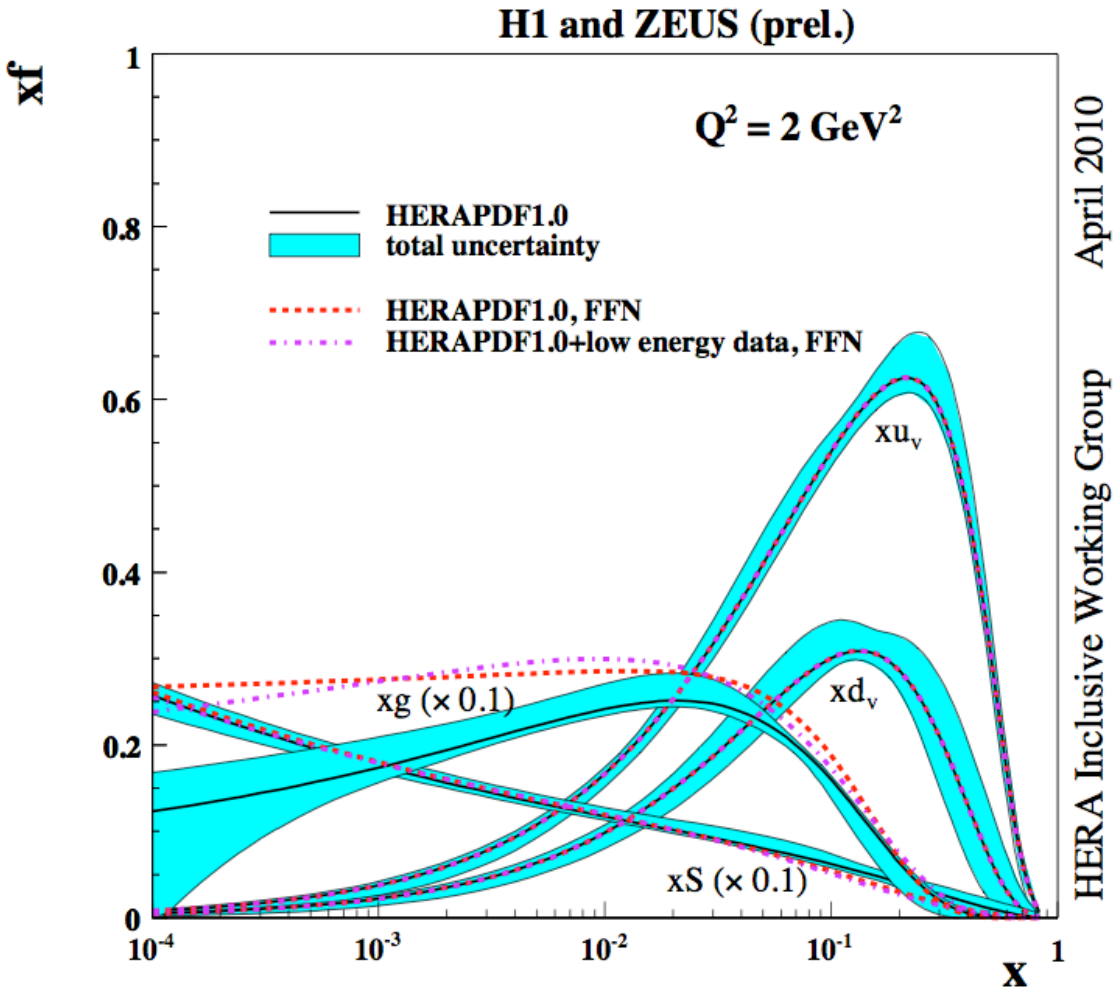
(Courtesy of R. Thorne)



  - FFNS (from QCDNUM17v06 [M. Botje])
- We observe significant differences among these schemes → next slides.

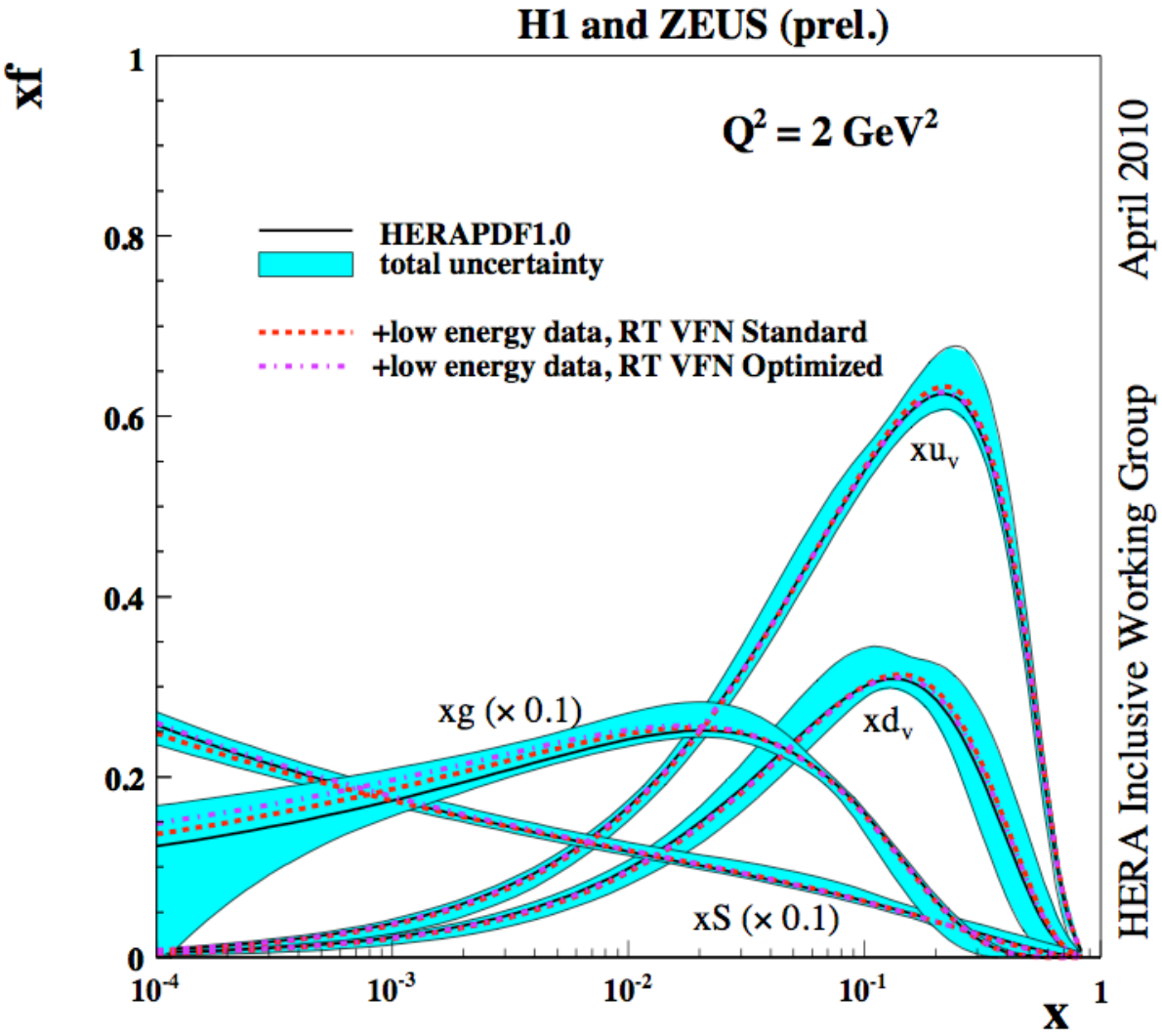
FFNS fits including Low Energy Data

- FFNS (nf=3) results in a similar improvement in χ^2 as observed for ACOT (VFNS) scheme in contrast to RT (VFNS).
  - xF_3 and CC predictions are not available within FFNS scheme, hence we freeze the valence parameters and do not fit for CC data.
- Not much difference is observed between FFNS scheme fits with or without low energy data.
- HERAPDF1.0 (VFNS) is shown as an illustration.



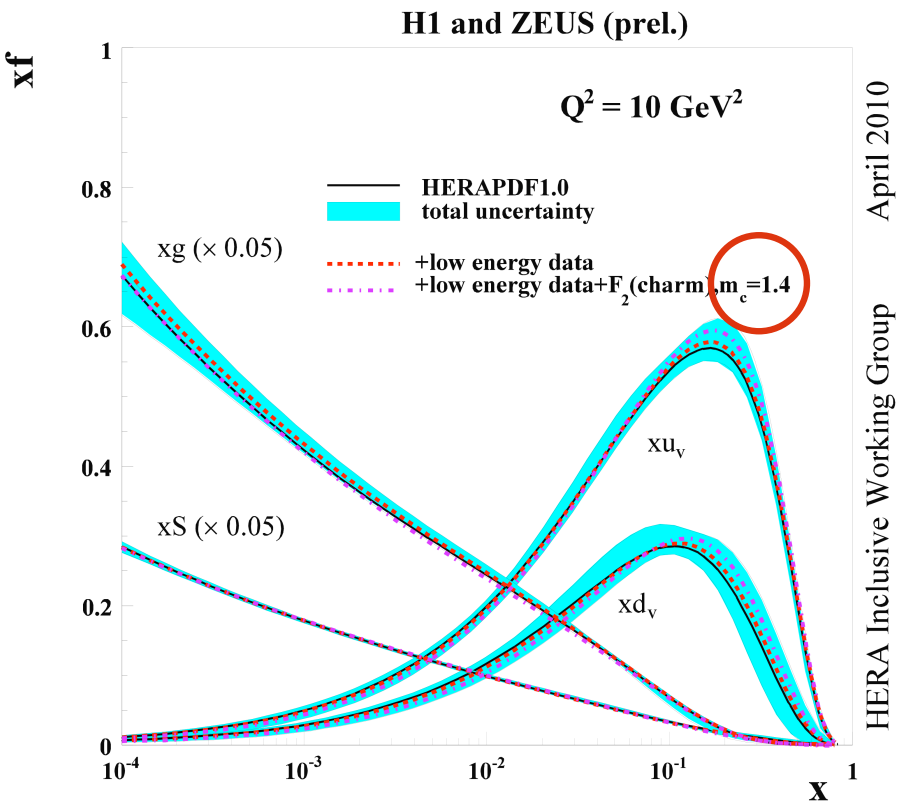
Various RT schemes

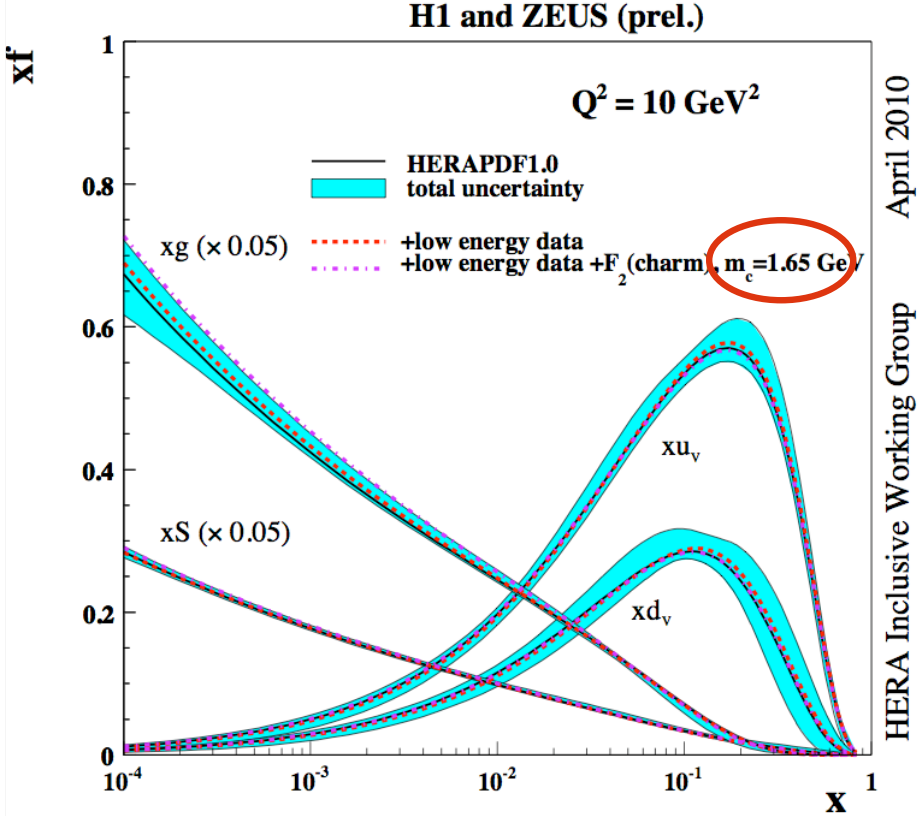
- HERAPDF1.0 (blue) is compared to HERA NLO fits to HERA data including low energy data using Standard and Optimal RT.
  - Little improvement is observed in χ^2 (7 units) and in PDF shapes from the Standard to Optimal RT VFN scheme.
  - The variations are within HERAPDF1.0 errors.



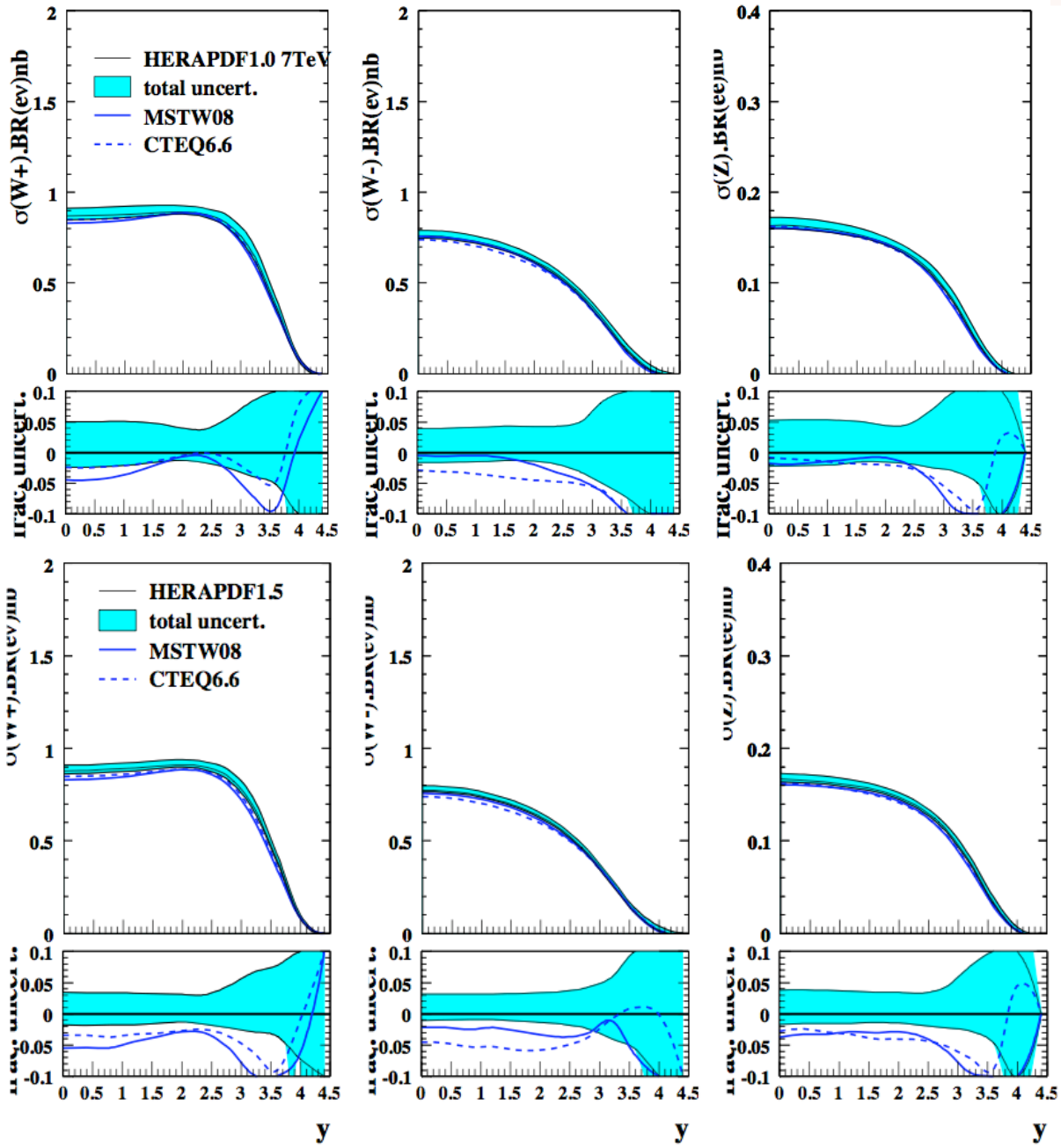
Fits including Low Energy and Charm data

- When including both Low Energy and Charm data in the HERA fits, conclusions about sensitivity to heavy quark schemes and charm mass are not altered.
- Conclusions about sensitivity to the kinematic cut dependence are not altered when including both data in the fit as long as the optimal choice for m_c is made.





LHC predictions



HERAPDF1.0

HERAPDF1.5