Voica Radescu
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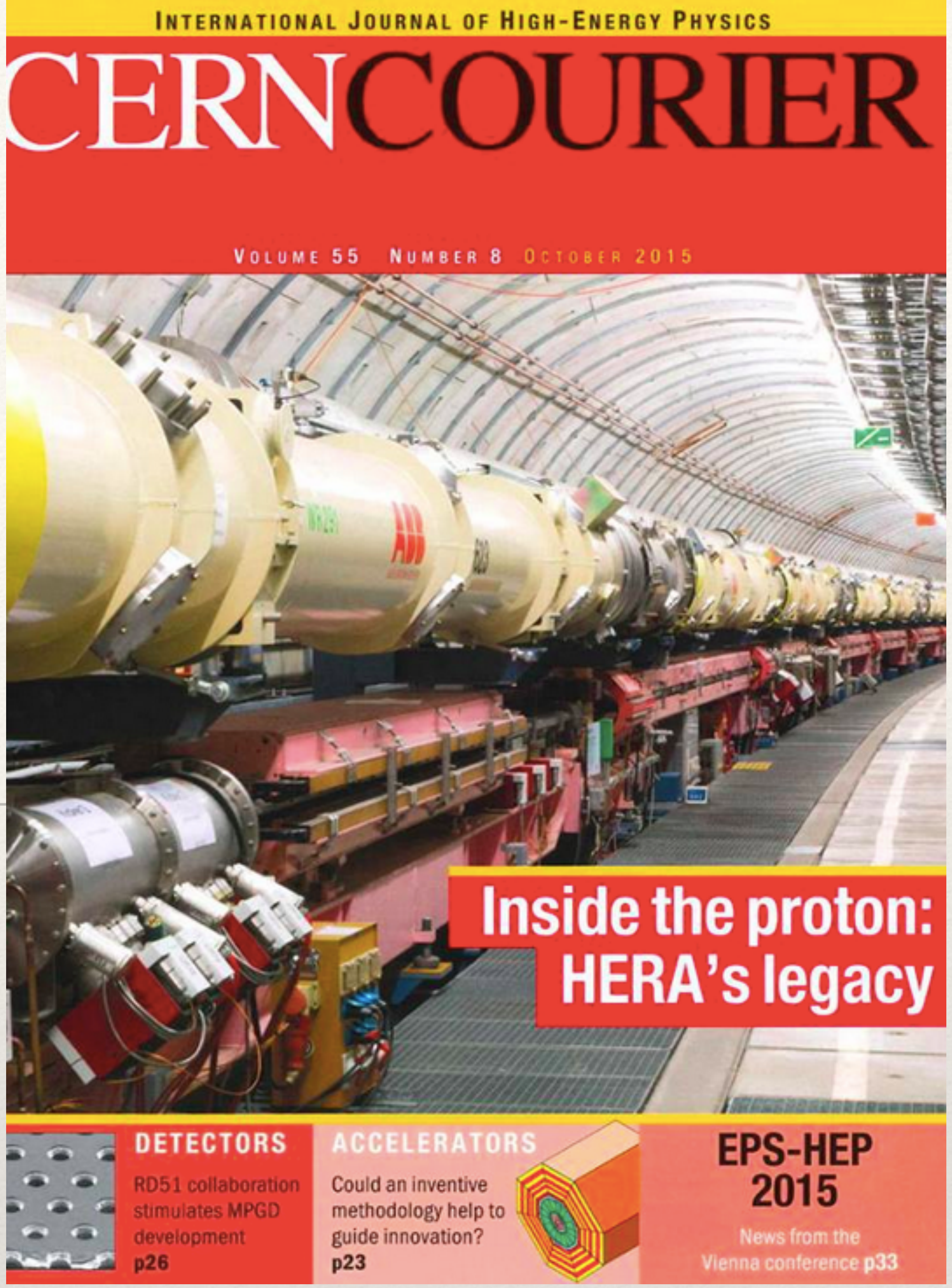
on behalf of H1 and ZEUS



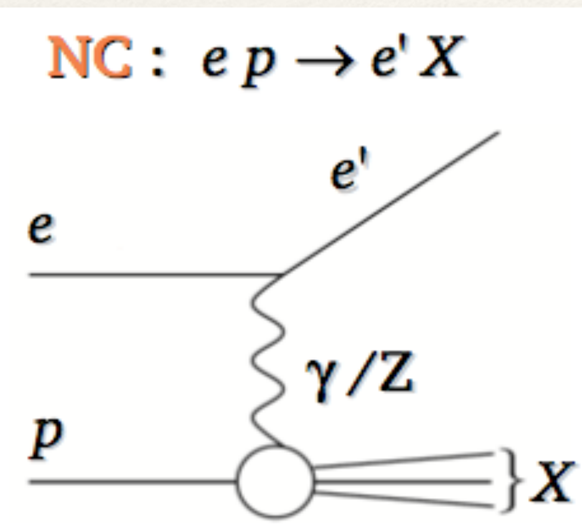
QCD Analysis of the combined HERA structure function data - HERAPDF2.0

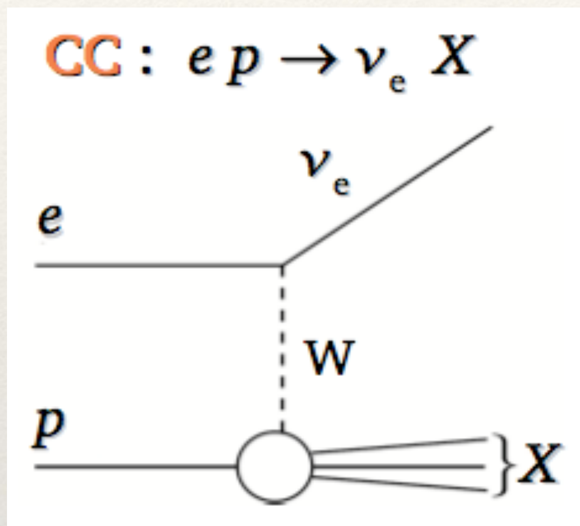
DESY-15-039, arxiv:1506.06042, accepted by EPJC

This paper is dedicated to the memory of Professor Guido Altarelli who sadly passed away as it went to press. The results which it presents are founded on the principles and the formalism which he developed in his pioneering theoretical work on Quantum Chromodynamics in deep-inelastic lepton-nucleon scattering nearly four decades ago.

HERA ep collider (1992-2007) @ DESY

- H1 and ZEUS experiments at HERA collected ~1/fb of data
  - Ep=460/575/820/920 GeV and Ee=27.5 GeV
- 4 types of processes accessed at HERA: **Neutral Current and Charged Current e+p, e-p**

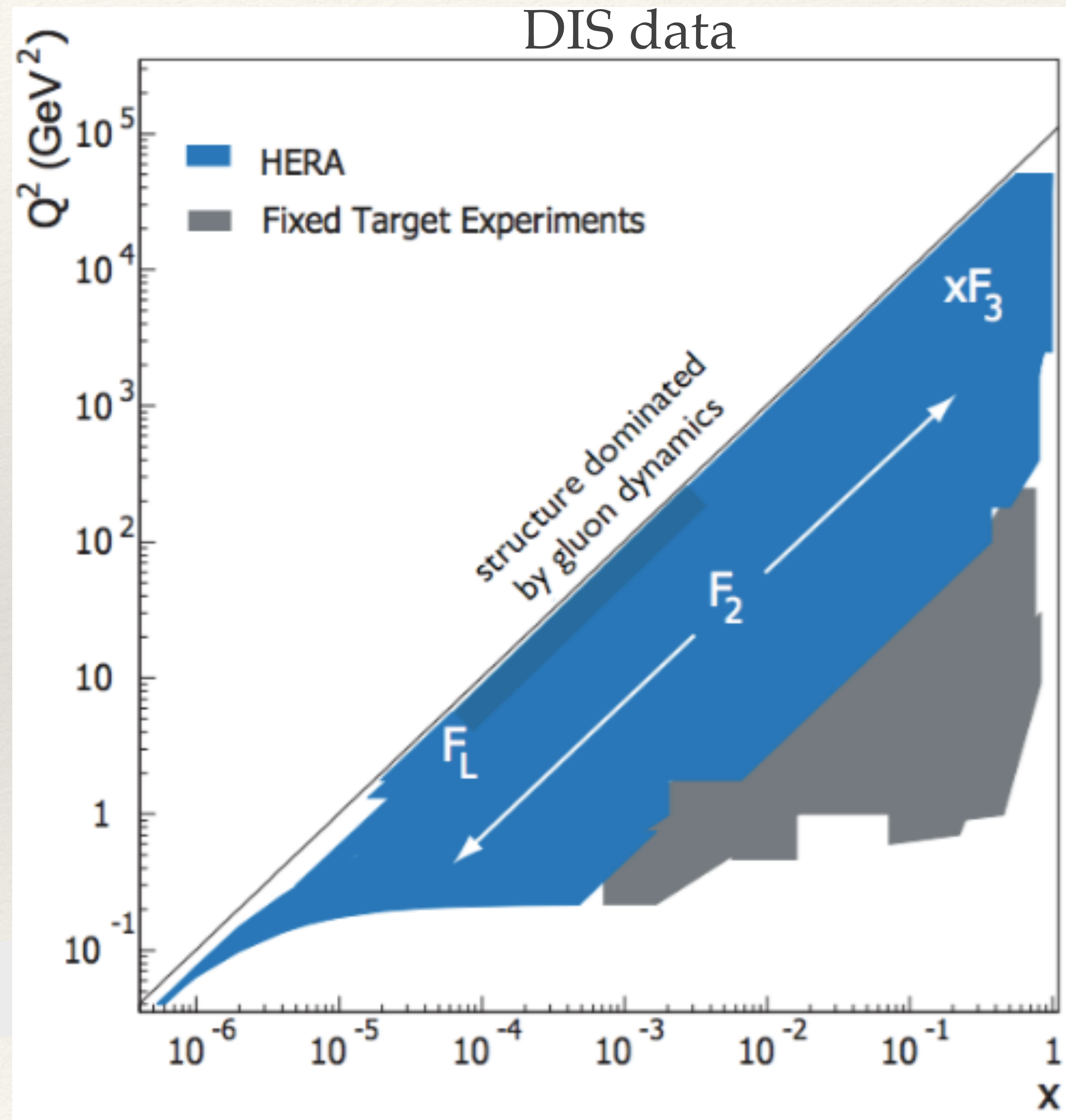




$$\frac{d\sigma^{\pm}_{NC}}{dxdQ^2} = \frac{2\pi\alpha^2}{x}\left[\frac{1}{Q^2}\right]^2 \left[Y_+\tilde{F}_2 \mp Y_- x\tilde{F}_3 - y^2\tilde{F}_L\right]$$

$$\frac{d\sigma^{\pm}_{CC}}{dxdQ^2} = \frac{G_F^2}{4\pi x}\left[\frac{M_W^2}{M_W^2+Q^2}\right]^2 \left[Y_+\tilde{W}_2^{\pm} \mp Y_- x\tilde{W}_3^{\pm} - y^2\tilde{W}_L^{\pm}\right]$$

$$Y_{\pm} = 1 \pm (1-y)^2$$



$\tilde{F}_2 \propto \sum(xq_i + x\bar{q}_i)$ → dominant contribution (all Q2 plane)

$x\tilde{F}_3 \propto \sum(xq_i - x\bar{q}_i)$ → significant contributions at high Q2

$\tilde{F}_L \propto \alpha_s \cdot xg(x,Q^2)$ → high y

HERA ep collider (1992-2007) @ DESY

Data Set		x_{Bj} Grid		Q^2[GeV^2] Grid		$\mathcal{L}$	e^+/e^-	$\sqrt{s}$
		from	to	from	to	pb^{-1}		GeV
HERA I E_p = 820 GeV and E_p = 920 GeV data sets								
H1 svx-mb [2]	95-00	0.000005	0.02	0.2	12	2.1	e^+p	301, 319
H1 low Q^2 [2]	96-00	0.0002	0.1	12	150	22	e^+p	301, 319
H1 NC	94-97	0.0032	0.65	150	30000	35.6	e^+p	301
H1 CC	94-97	0.013	0.40	300	15000	35.6	e^+p	301
H1 NC	98-99	0.0032	0.65	150	30000	16.4	e^-p	319
H1 CC	98-99	0.013	0.40	300	15000	16.4	e^-p	319
H1 NC HY	98-99	0.0013	0.01	100	800	16.4	e^-p	319
H1 NC	99-00	0.0013	0.65	100	30000	65.2	e^+p	319
H1 CC	99-00	0.013	0.40	300	15000	65.2	e^+p	319
ZEUS BPC	95	0.000002	0.00006	0.11	0.65	1.65	e^+p	300
ZEUS BPT	97	0.0000006	0.001	0.045	0.65	3.9	e^+p	300
ZEUS SVX	95	0.000012	0.0019	0.6	17	0.2	e^+p	300
ZEUS NC [2] high/low Q^2	96-97	0.00006	0.65	2.7	30000	30.0	e^+p	300
ZEUS CC	94-97	0.015	0.42	280	17000	47.7	e^+p	300
ZEUS NC	98-99	0.005	0.65	200	30000	15.9	e^-p	318
ZEUS CC	98-99	0.015	0.42	280	30000	16.4	e^-p	318
ZEUS NC	99-00	0.005	0.65	200	30000	63.2	e^+p	318
ZEUS CC	99-00	0.008	0.42	280	17000	60.9	e^+p	318
HERA II E_p = 920 GeV data sets								
H1 NC [1.5p]	03-07	0.0008	0.65	60	30000	182	e^+p	319
H1 CC [1.5p]	03-07	0.008	0.40	300	15000	182	e^+p	319
H1 NC [1.5p]	03-07	0.0008	0.65	60	50000	151.7	e^-p	319
H1 CC [1.5p]	03-07	0.008	0.40	300	30000	151.7	e^-p	319
H1 NC med Q^2 [*y.5]	03-07	0.0000986	0.005	8.5	90	97.6	e^+p	319
H1 NC low Q^2 [*y.5]	03-07	0.000029	0.00032	2.5	12	5.9	e^+p	319
ZEUS NC	06-07	0.005	0.65	200	30000	135.5	e^+p	318
ZEUS CC [1.5p]	06-07	0.0078	0.42	280	30000	132	e^+p	318
ZEUS NC [1.5]	05-06	0.005	0.65	200	30000	169.9	e^-p	318
ZEUS CC [1.5]	04-06	0.015	0.65	280	30000	175	e^-p	318
ZEUS NC nominal [*y]	06-07	0.000092	0.008343	7	110	44.5	e^+p	318
ZEUS NC satellite [*y]	06-07	0.000071	0.008343	5	110	44.5	e^+p	318
HERA II E_p = 575 GeV data sets								
H1 NC high Q^2	07	0.00065	0.65	35	800	5.4	e^+p	252
H1 NC low Q^2	07	0.0000279	0.0148	1.5	90	5.9	e^+p	252
ZEUS NC nominal	07	0.000147	0.013349	7	110	7.1	e^+p	251
ZEUS NC satellite	07	0.000125	0.013349	5	110	7.1	e^+p	251
HERA II E_p = 460 GeV data sets								
H1 NC high Q^2	07	0.00081	0.65	35	800	11.8	e^+p	225
H1 NC low Q^2	07	0.0000348	0.0148	1.5	90	12.2	e^+p	225
ZEUS NC nominal	07	0.000184	0.016686	7	110	13.9	e^+p	225
ZEUS NC satellite	07	0.000143	0.016686	5	110	13.9	e^+p	225

- 41 data sets: 2927 data points are combined to1307 averaged measurements with 169 sources of correlated systematic uncertainties.

HERAPDF1.0

JHEP01 (2010) 109

HERAPDF1.5 (prelim)

HERAPDF2.0

[arxiv:1506.06042]

HERAPDF approach

- HERAPDF uses only HERA data from the combined H1 and ZEUS measurements:
  - use of a pure proton target means no need for heavy target/nuclear corrections.
  - all data are at high W (> 15 GeV) —> higher twist effects are negligible.
  - model independent data combination provides a check of data consistencies and hence it allows the usage of conventional χ^2 tolerance $\Delta\chi^2 = 1$ when setting 68%CL experimental errors

- Extraction of PDFs relies on the factorisation: $\sigma = \hat{\sigma} \otimes \mathrm{PDF}$

- HERAPDF sets were extracted using HERAFitter open source platform [herafitter.org, arxive:1503.05221], cross checked against Mandy's fitter.

QCD Settings for HERAPDF2.0

The QCD settings are optimised for HERA measurements of proton structure functions:

PDFs are parametrised at the starting scale Q_0^2=1.9 GeV^2 as follows:

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

- fixed or constrained by sum-rules
- parameters set equal but free

NC structure functions

$$F_2 = \frac{4}{9}\left(xU + x\bar{U}\right) + \frac{1}{9}\left(xD + x\bar{D}\right)$$

$$xF_3 \sim xu_v + xd_v$$

CC structure functions

$$W_2^- = x(U+\overline{D}), \qquad W_2^+ = x(\overline{U}+D)$$

$$xW_3^- = x(U-\overline{D}), \qquad xW_3^+ = x(D-\overline{U})$$

Due to increased precision of data, more flexibility in functional form is allowed —> 14 free parameters

- PDFs are evolved via evolution equations (DGLAP) to NLO and NNLO ($\alpha_S(M_Z)$=0.118)
- Thorne-Roberts GM-VFNS for heavy quark coefficient functions – as used in MMHT
- χ^2 definition used in the minimisation [MINUIT] accounts for correlated uncertainties:

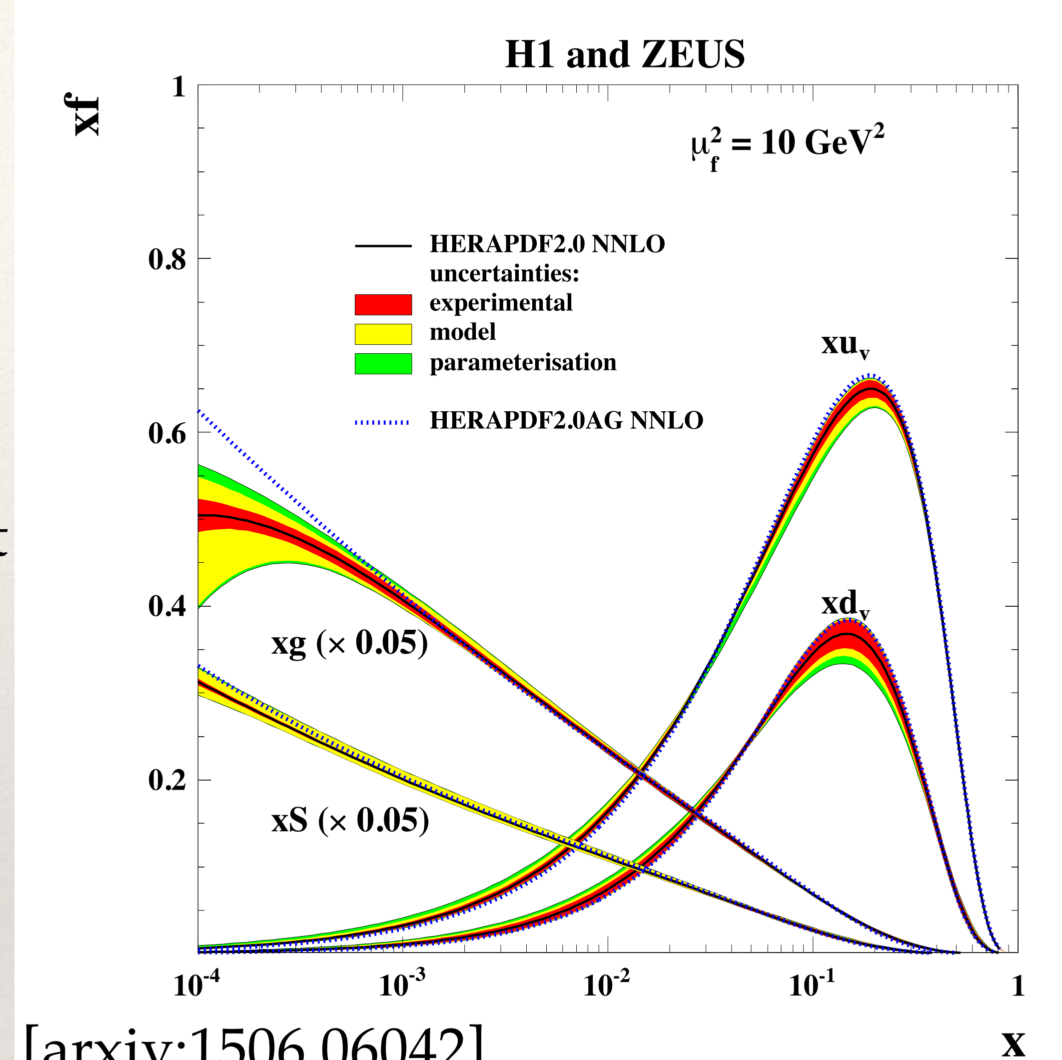
$$\chi^2_{\rm exp}(\boldsymbol{m},\boldsymbol{s}) = \sum_i \frac{\left[m^i - \sum_j \gamma^i_j m^i s_j - \mu^i\right]^2}{\delta^2_{i,\rm stat}\,\mu^i m^i + \delta^2_{i,\rm uncor}\,(m^i)^2} + \sum_j s_j^2 + \sum_i \ln\frac{\delta^2_{i,\rm stat}\mu^i m^i + (\delta_{i,\rm uncor} m^i)^2}{(\delta^2_{i,\rm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

m - th prediction
μ - data
s - sys shift

HERAPDF uncertainties

Different types of PDF uncertainties are considered:

- **Experimental:**
  - Hessian method used:
    - 14 eigenvector pairs, evaluated with $\Delta\chi^2 = 1$
  - Cross check evaluated from the MC replicas



[arxiv:1506.06042]

- **Model:**
  - variations of all assumed input parameters in the fit

Variation	Standard Value	Lower Limit	Upper Limit
Q^2_{min} [GeV^2]	3.5	2.5	5.0
Q^2_{min} [GeV^2] HiQ2	10.0	7.5	12.5
M_c(NLO) [GeV]	1.47	1.41	1.53
M_c (NNLO) [GeV]	1.43	1.37	1.49
M_b [GeV]	4.5	4.25	4.75
f_s	0.4	0.3	0.5
$\alpha_s(M_Z^2)$	0.118	–	–
μ_{f_0} [GeV]	1.9	1.6	2.2

- **Parametrisation:** only HERAPDF includes this as an additional uncertainty
  - Variation of $Q^2_0 = 1.9 \pm 0.3$ GeV^2 and addition of 15th parameters

The value of $\alpha_S(M_Z)$ is not treated as an uncertainty:

- PDFs are supplied for $\alpha_S(M_Z)$ values from 0.110 to 0.130 in steps of 0.001

HERAPDF sets:

https://www.desy.de/h1zeus/herapdf20/

HERAPDF2.0 (NNLO and NLO, RT-OPT scheme) Nominal fit	
NNLO fit - experimental uncertainties	HERAPDF20_NNLO_EIG
NNLO fit - model and parametrisation uncertainties	HERAPDF20_NNLO_VAR
NNLO fit - alphas variations	HERAPDF20_NNLO_ALPHAS
NLO fit - experimental uncertainties	HERAPDF20_NLO_EIG
NLO fit - model and parametrisation uncertainties	HERAPDF20_NLO_VAR
NLO fit - alphas variations	HERAPDF20_NLO_ALPHAS
HERAPDF2.0HiQ2 (RT-OPT scheme, Q^2>10 GeV^2)	
NNLO fit - experimental uncertainties	HERAPDF20_HiQ2_NNLO_EIG
NLO fit - experimental uncertainties	HERAPDF20_HiQ2_NLO_EIG
NNLO fit - model and parametrisation uncertainties	HERAPDF20_HiQ2_NNLO_VAR
NLO fit - model and parametrisation uncertainties	HERAPDF20_HiQ2_NLO_VAR
HERAPDF2.0AG (LO, NLO and NNLO, RT-OPT scheme, non-negative gluon)	
LO fit - experimental uncertainties	HERAPDF20_LO_EIG
NLO fit - experimental uncertainties	HERAPDF20_AG_NLO_EIG
NNLO fit - experimental uncertainties	HERAPDF20_AG_NNLO_EIG
HERAPDF2.0Jets (RT-opt scheme, also including HERA jet and HERA charm data)	
NLO fit - experimental uncertainties	HERAPDF20_Jets_NLO_EIG
NLO fit - model and parametrisation uncertainties	HERAPDF20_Jets_NLO_VAR
HERAPDF2.0FF3A (fixed-flavour-number scheme, variant A)	
NLO fit - experimental uncertainties	HERAPDF20_NLO_FF3A_EIG
NLO fit - model and parametrisation uncertainties	HERAPDF20_NLO_FF3A_VAR
HERAPDF2.0FF3B (fixed-flavour-number scheme, variant B)	
NLO fit - experimental uncertainties)	HERAPDF20_NLO_FF3B_EIG
NLO fit - model and parametrisation uncertainties	HERAPDF20_NLO_FF3B_VAR

—>fits with Q2>3.5

—>fits with Q2>10

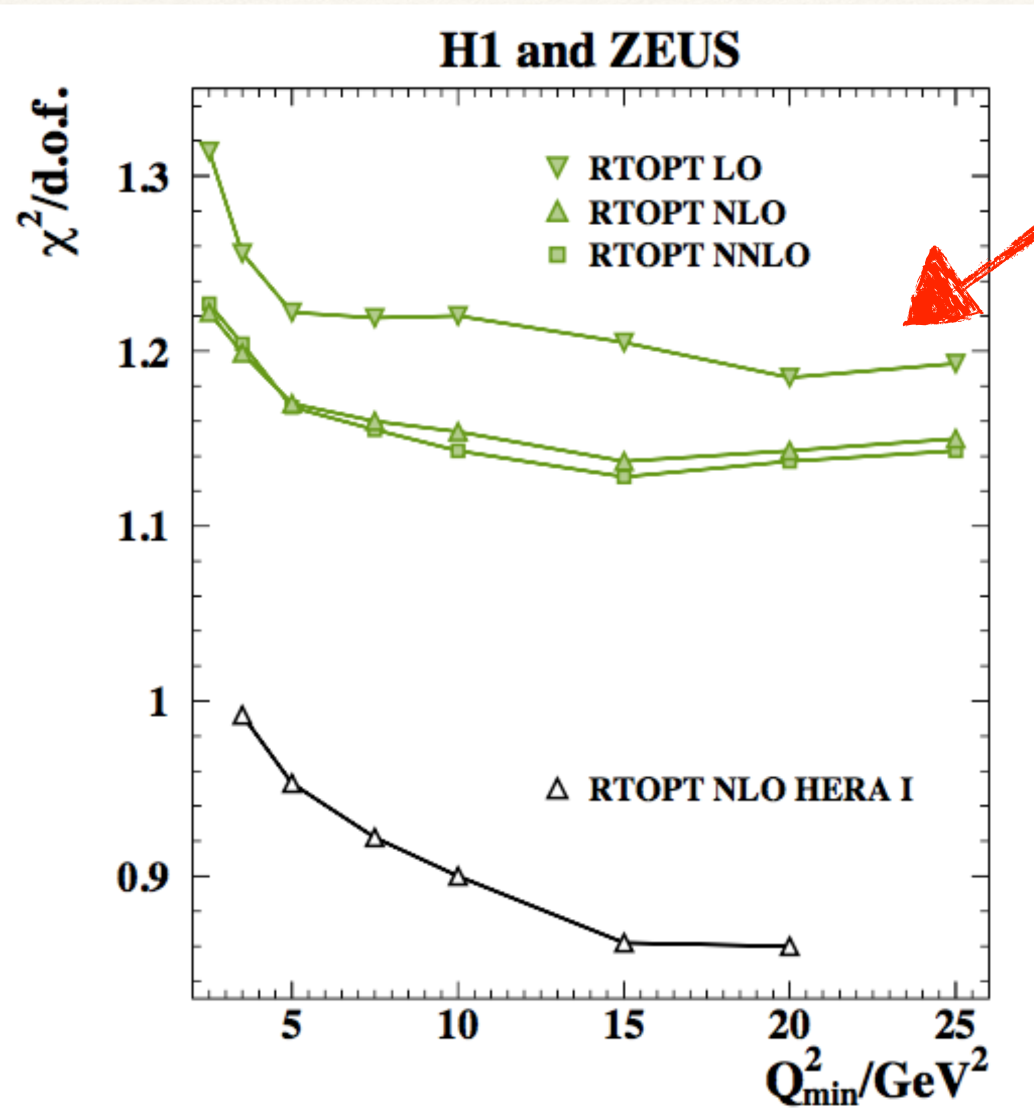
—>fits with positive definite gluon

—>fits with free alphas, adding jet and charm data

—>fits using FFNS

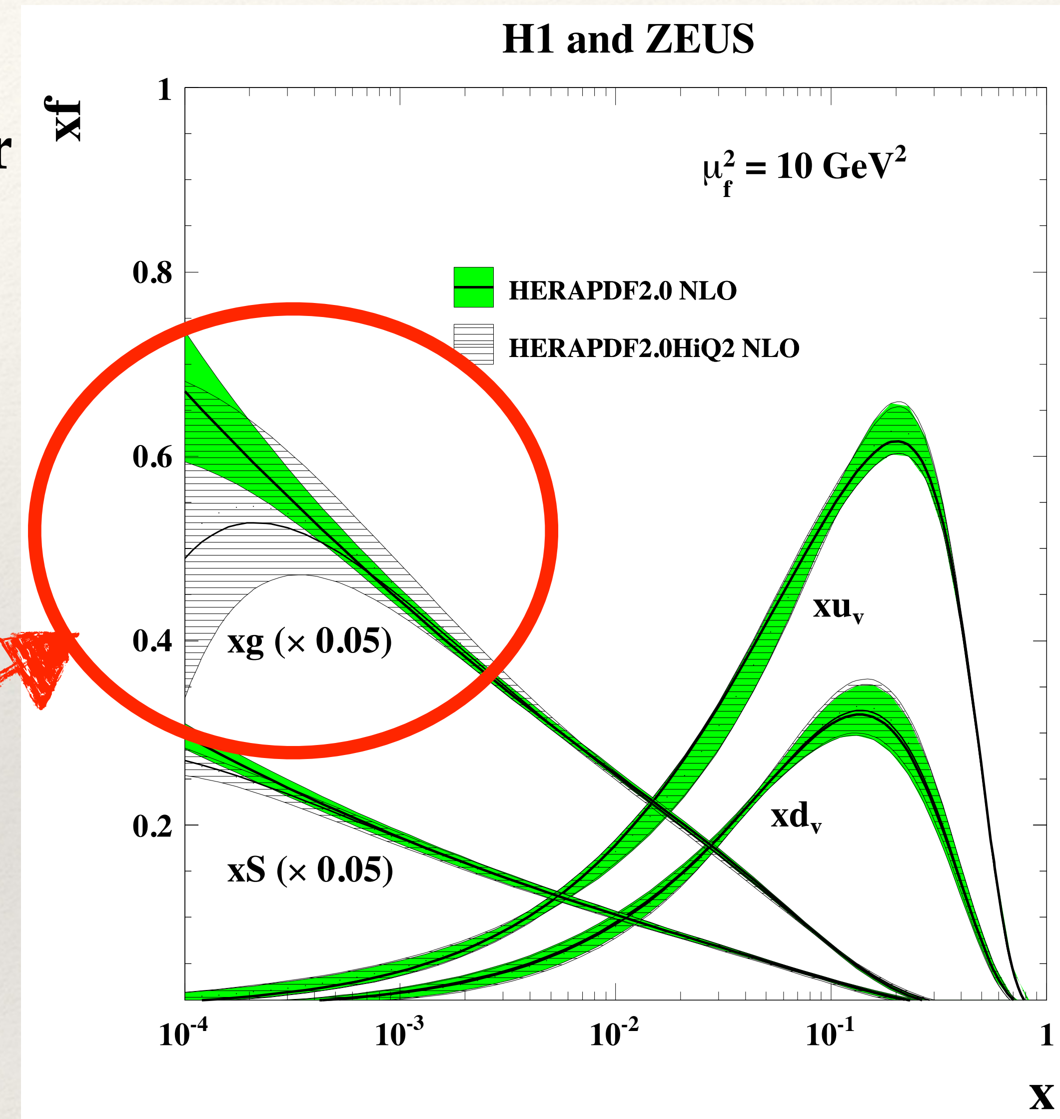
Q^2 cut dependence on PDFs

- HERA data provides a unique access to the low x, low Q^2 region to investigate:
  - the validity of the DGLAP mechanism



NLO is significantly better than LO, but NNLO is not obviously better than NLO

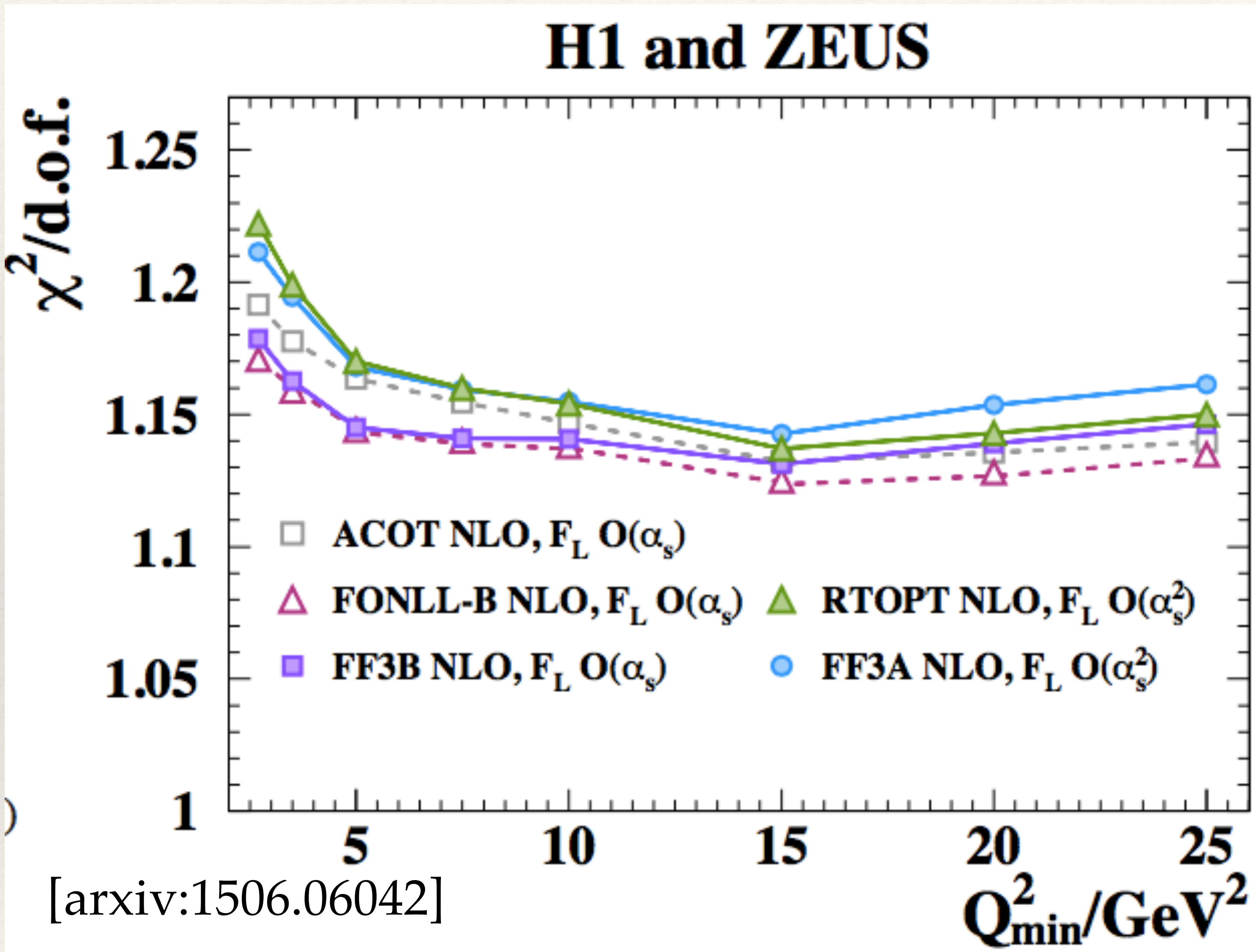
low Q² data very important to constrain low x PDFs!



- LHAPDF sets for HERAPDF are presented for both variants:
  - Q2 > 3.5 HERAPDF2.0 (LO, NLO, NNLO) - nominal
  - Q2> 10 HERAPDF2.0HiQ2 (NLO, NNLO)

Q^2 cut dependence

- HERA data provides a unique access to the low x, low Q^2 region to investigate:
  - the validity of the DGLAP mechanism
  - the various scheme dependence (fixed vs variable flavours)



[arxiv:1506.06042]

ACOT -> as used by CT
RT -> as used by MMHT
FONLL ->as used by NNPDF
FF3A ->as used by ABM

Treating FL to O(αS) yields better χ2 than treating FL to O(αS2) quasi independent of heavy flavour scheme

Low Q^2 remains an interesting region to investigate (low x phenomenology)

Q^2 cut dependence

- HERA data provides a unique access to the low x, low Q^2 region to investigate:
  - the validity of the DGLAP mechanism
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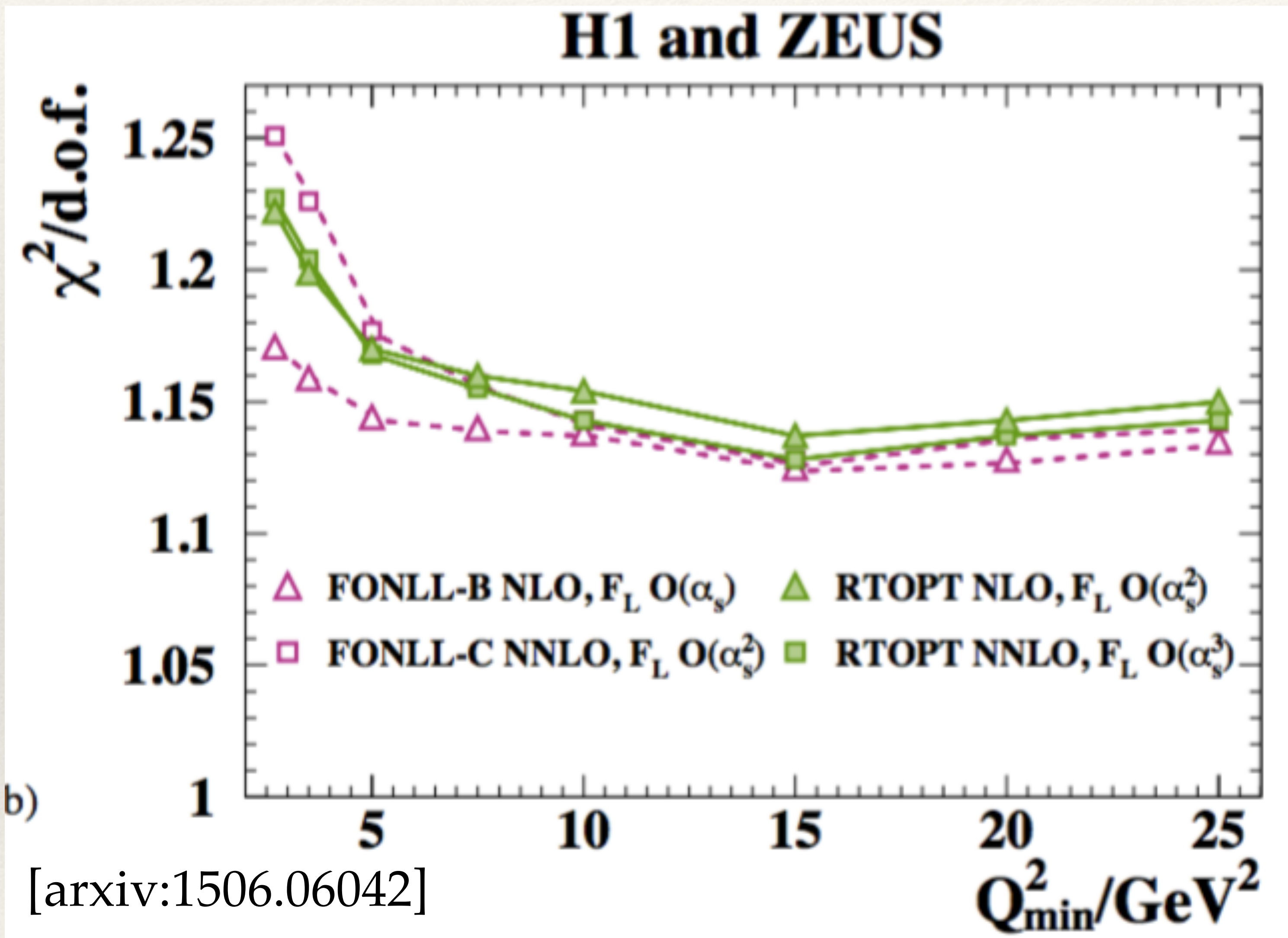

[arxiv:1506.06042]

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Low Q^2 remains an interesting region to investigate (low x phenomenology)

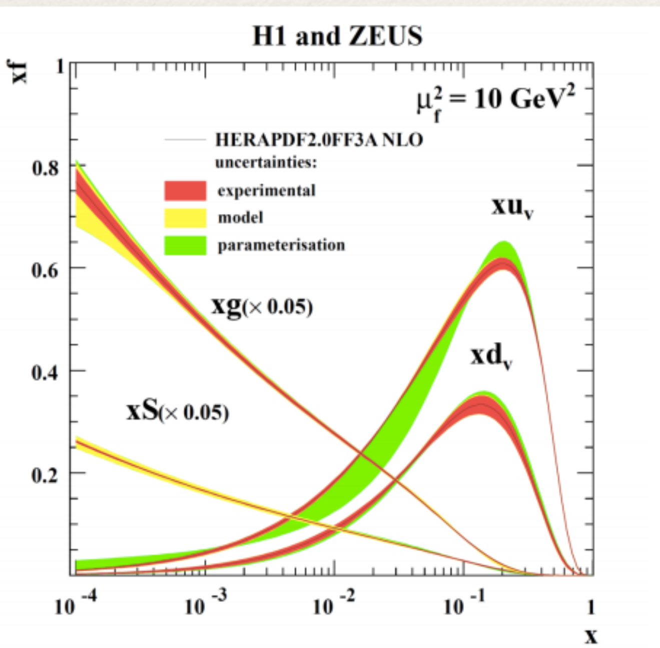
HERAPDF2.0 Fixed Flavour Number

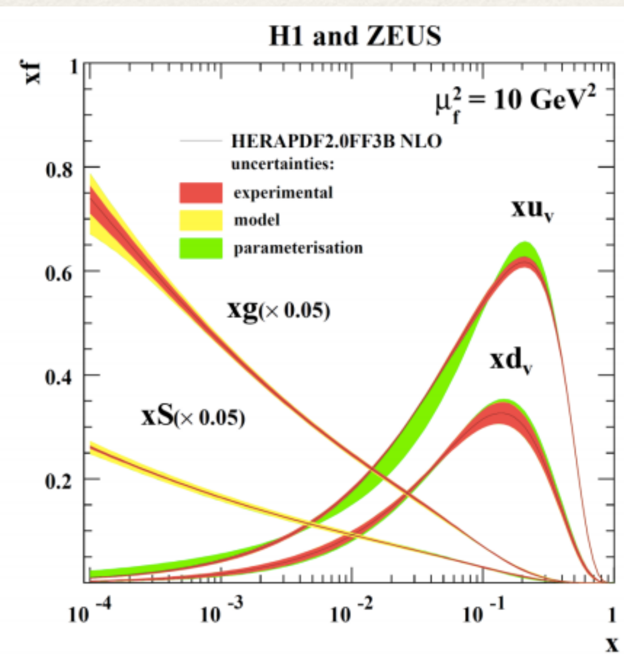
HERAPDF2.0 also provides 2 variants of FFNS scheme: FF3A and FF3B [available in lhapdf format]

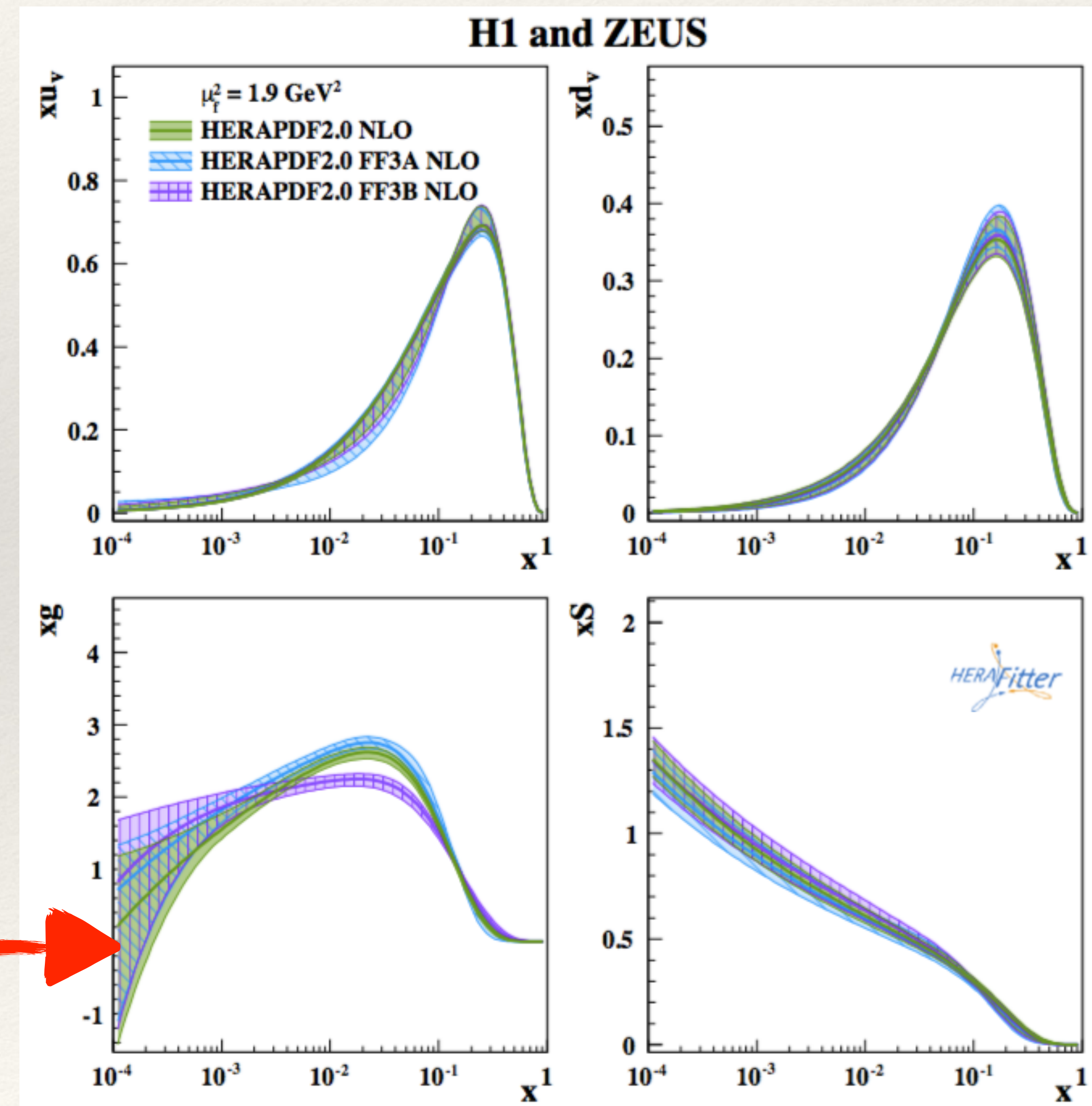
3 flavour running of α_s → FF3A

Variable-flavour running of α_s → FF3B

scheme	$\alpha_s(M_Z^2)$	F_L	m_c [GeV]	m_b [GeV]
FF3A	$\alpha_s^{N_F=3} = 0.106375$	$O(\alpha_s^2)$	$m_c^{pole} = 1.44$	$m_b^{pole} = 4.5$
FF3B	$\alpha_s^{N_F=5} = 0.118$	$O(\alpha_s)$	$m_c(m_c) = 1.26$	$m_b(m_b) = 4.07$







Difference in FF3A and FF3B gluon is due to treatment of $O(\alpha s)$ in FL and due to the VFN running of αs in FF3B

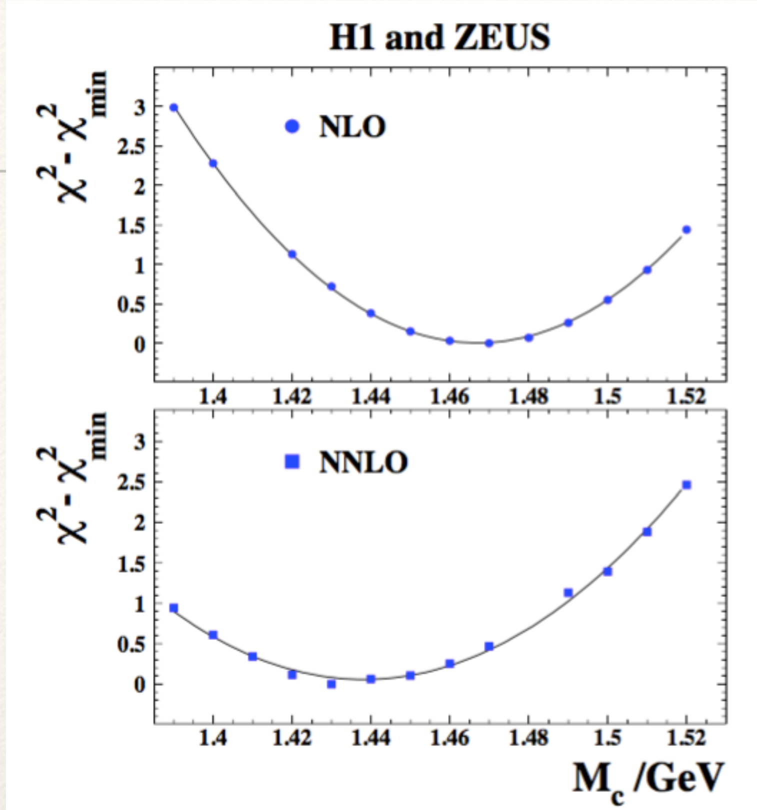
HERAPDF2.0Jets

HERAPDF2.0Jets is based on inclusive + charm + jet data:

- data from the HERA charm combination has its main effect to determine the optimal charm mass parameter and determine its variation for the standard HERAPDF2.0.
  - This variation is much reduced compared to HERAPDF1.0
- Seven data sets on inclusive jet, dijet, trijet production at low and high Q^2, from ZEUS and H1 have been added to the HERAPDF2.0 fit

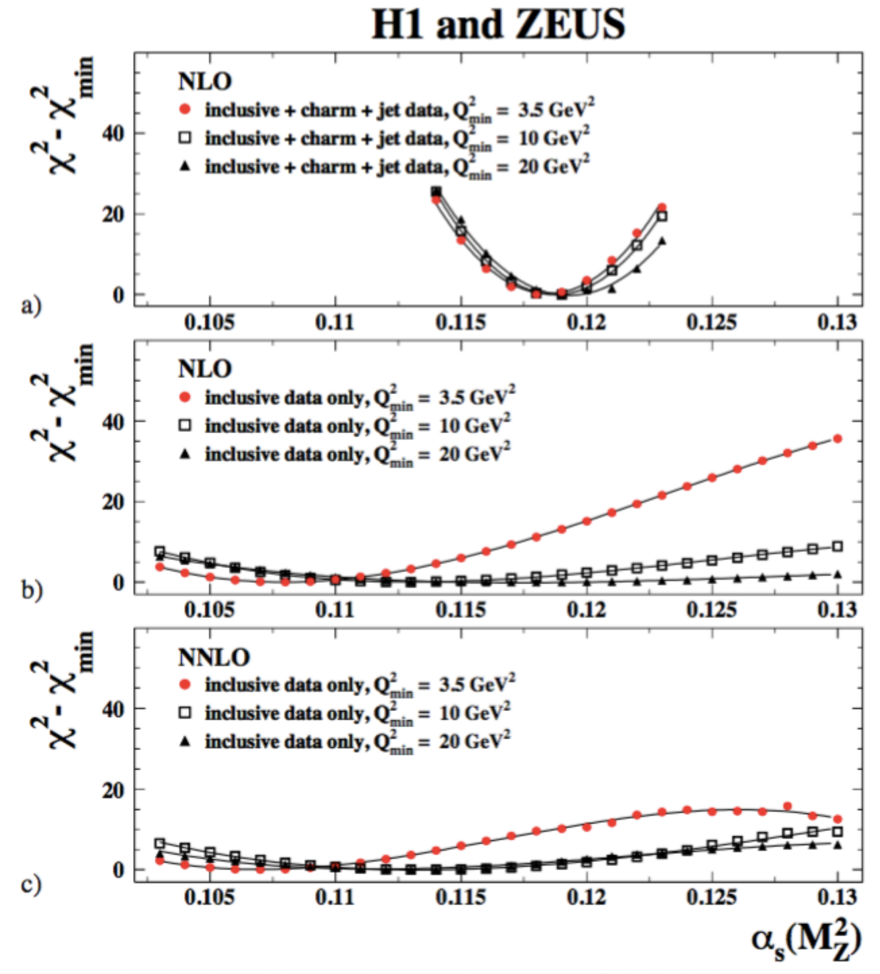
  PLB547(2001)164, EPJC70(2010)965, EPJC67(2010)1, PLB653(2007)134 and EPJC75(2015)2

  - Inclusive data alone cannot determine $\alpha_S(M_Z)$ reliably either at NLO or at NNLO When jet data are added one can make a simultaneous fit for PDF parameters and $\alpha_S(M_Z)$ at NLO



$$\alpha_S(M_Z) = 0.1183 \pm 0.0009_{(exp)} \pm 0.0005_{(model/param)} \pm 0.0012_{(had)} \, {}^{+0.0037}_{-0.0030}(\text{scale})$$

the fitted value is in agreement with the chosen fixed value —> PDFs are similar for fixed vs fitted



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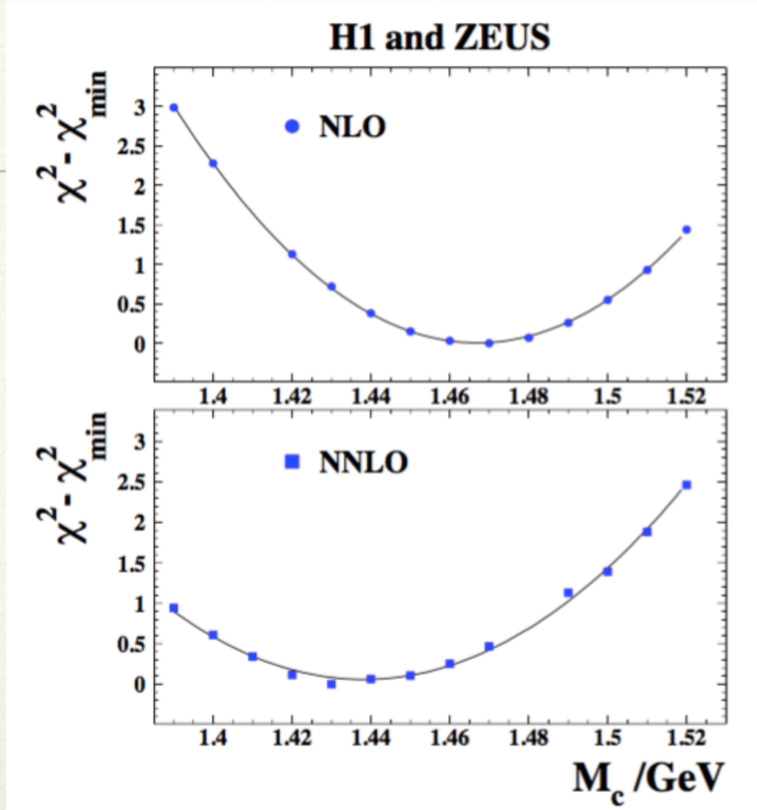

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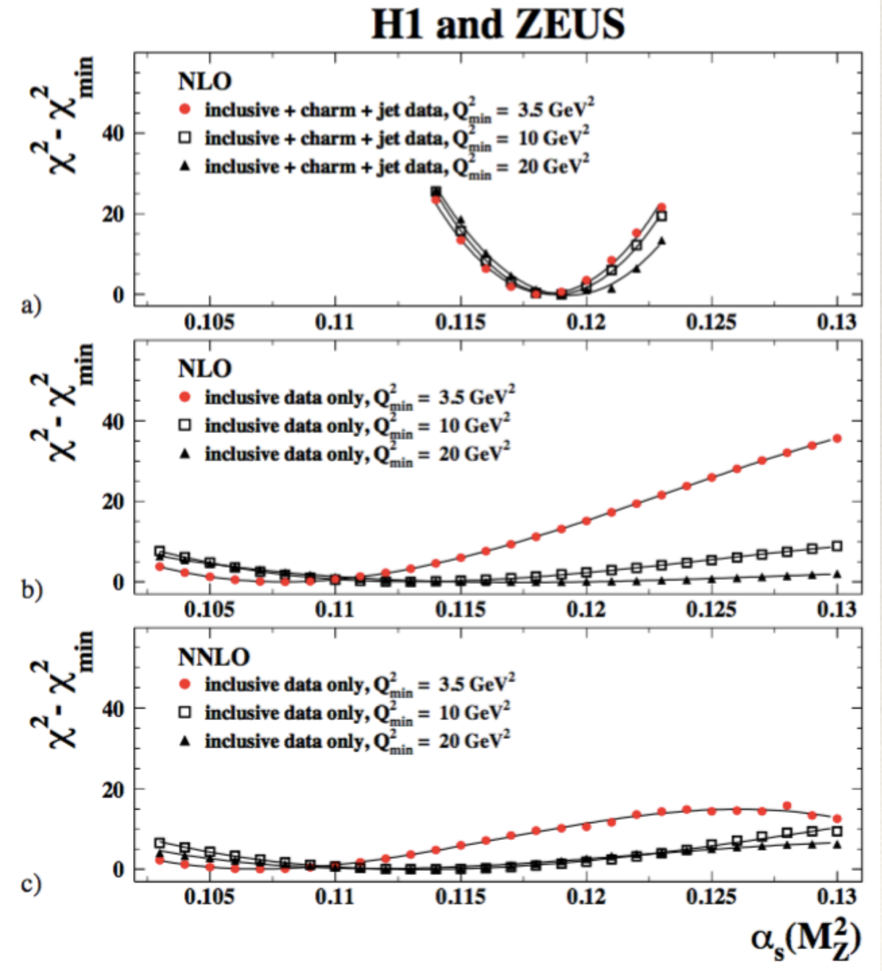
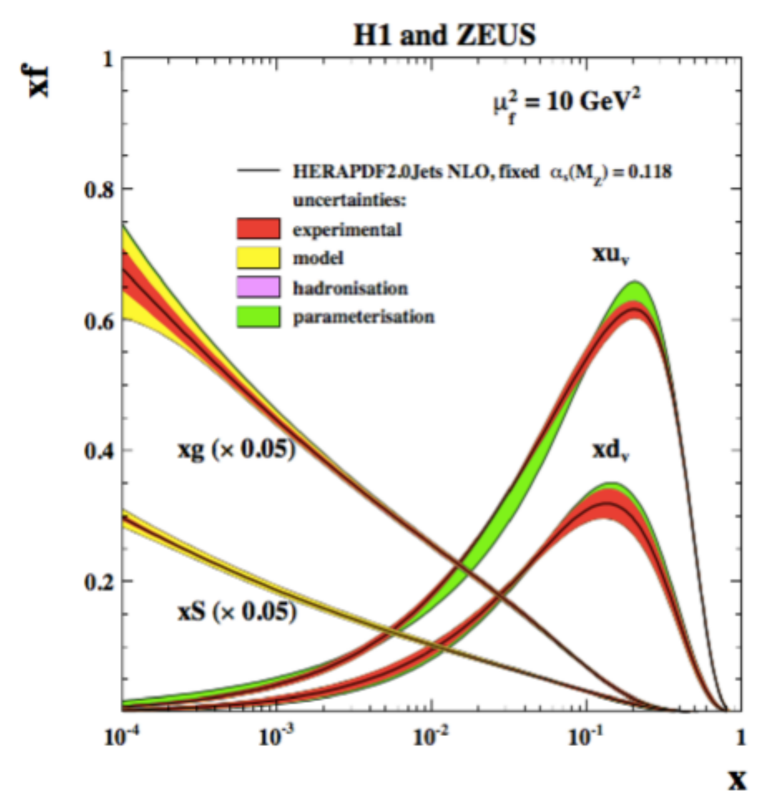
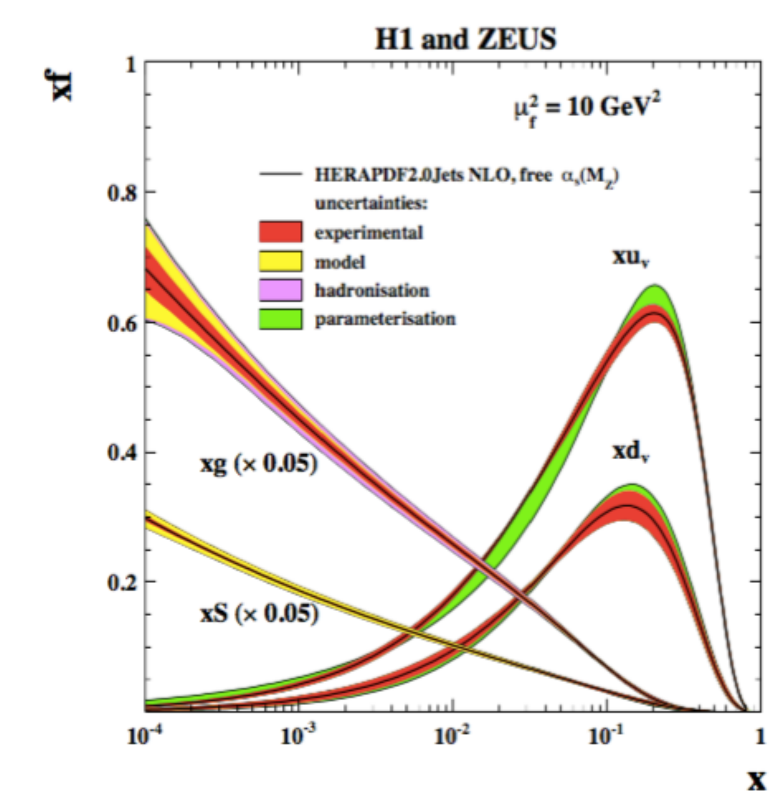




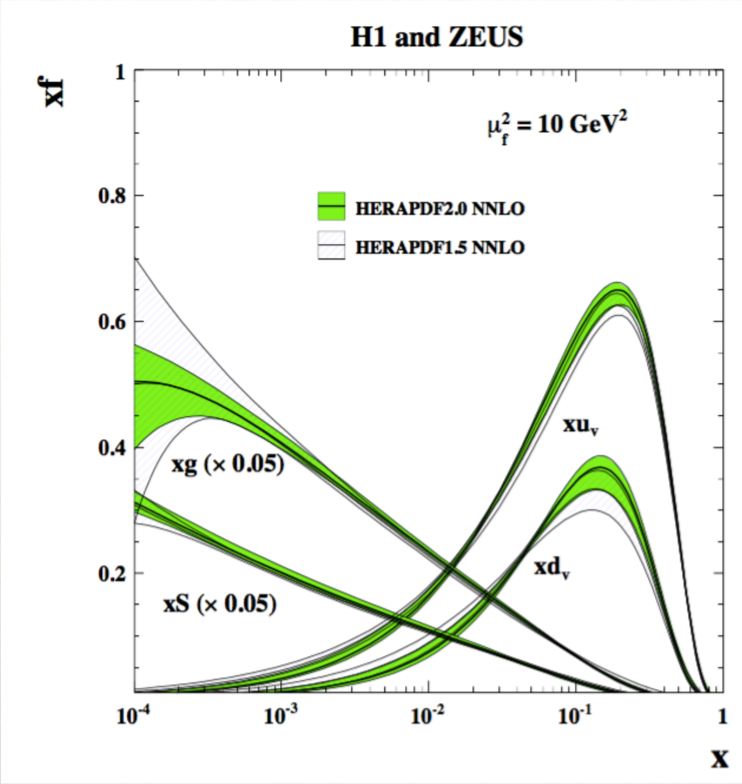


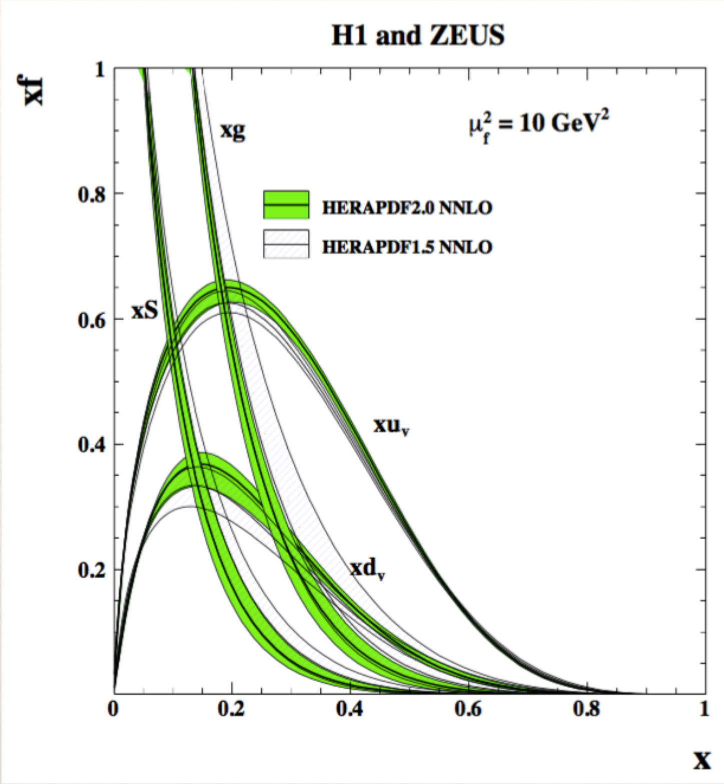
HERAPDF2.0 vs HERAPDF1.5 (NNLO)

- HERAPDF1.5 used only a part of HERA Run 2 data
- Differences in the QCD fit procedure:

	HERAPDF2.0		HERAPDF1.5	
	NNLO	NLO	NNLO	NLO
Data as in Table 1	combination		preliminary combination	
Uncertainties:				
Experimental	Hessian		Hessian	
Procedural	7		3	
Parameterisation	as in Equations 27 to 31		as in Equations 27 to 31	
Number of Parameters	14	14	14**	10 *
– Variations	15 [D_{u_v}]	15 [D_{u_v}]	none	11 [D_{u_v}], 12 [$D_{\bar{U}}$]
$\mu^2_{f_0}$ [GeV^2]	1.9	1.9	1.9	1.9
– Variations	1.6, 2.2	1.6, 2.2	1.5, 2.5	1.5*^{f}, 2.5*
M_c [GeV]	1.43	1.47	1.4	1.4*
– Variations	1.37*^{c}, 1.49	1.41, 1.53	1.35*^{c}, 1.65	1.35*^{c}, 1.65*
M_b [GeV]	4.5	4.5	4.75	4.75*
– Variations	4.25, 4.75	4.25, 4.75	4.30, 5.00	4.30, 5.00*
f_s [GeV]	0.40	0.40	0.31	0.31*
– Variations	0.30, 0.50	0.30, 0.50	0.23, 0.38	0.23, 0.38*
Q^2_{min} [GeV^2] of Data	3.5	3.5	3.5	3.5*
– Variations	2.5, 5.0	2.5, 5.0	2.5, 5.0	2.5, 5.0*
Fixed α_s	0.118	0.118	0.1176	0.1176*

Table 16: Settings for HERAPDF2.0 and HERAPDF1.5.
*: Setting was chosen exactly as for HERAPDF1.0.
**: Parameter number 14 was D_{u_v} and not $D_{\bar{U}}$.
*^{f}: For $\mu^2_{f_0} = 1.5\,\mathrm{GeV}^2$, also A'_g and B'_g were introduced (as for HERAPDF1.0 NLO).
*^{c}: $\mu^2_{f_0} = 1.8\,\mathrm{GeV}^2$ to assure $\mu^2_{f_0} < M^2_c$ (as for HERAPDF1.0 NLO).





HERAPDF1.5 gluon was rather hard compared to global
HERAPDF2.0 gluon has a softer gluon and reduced uncertainties

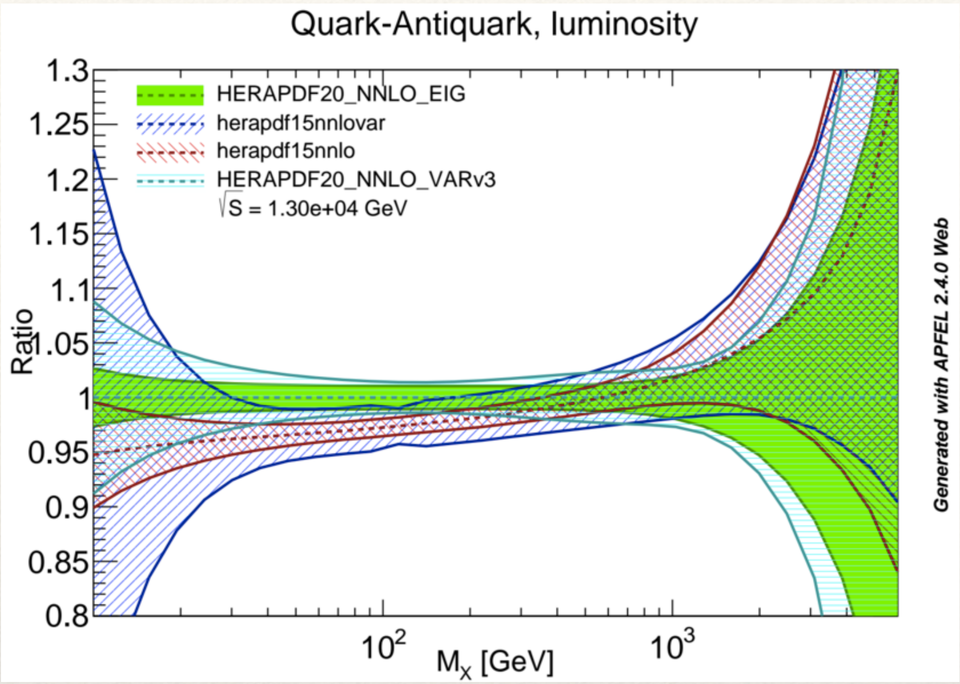
HERAPDF1.5 also had a harder high-x sea
HERAPDF2.0 has reduced uncertainties at high-x

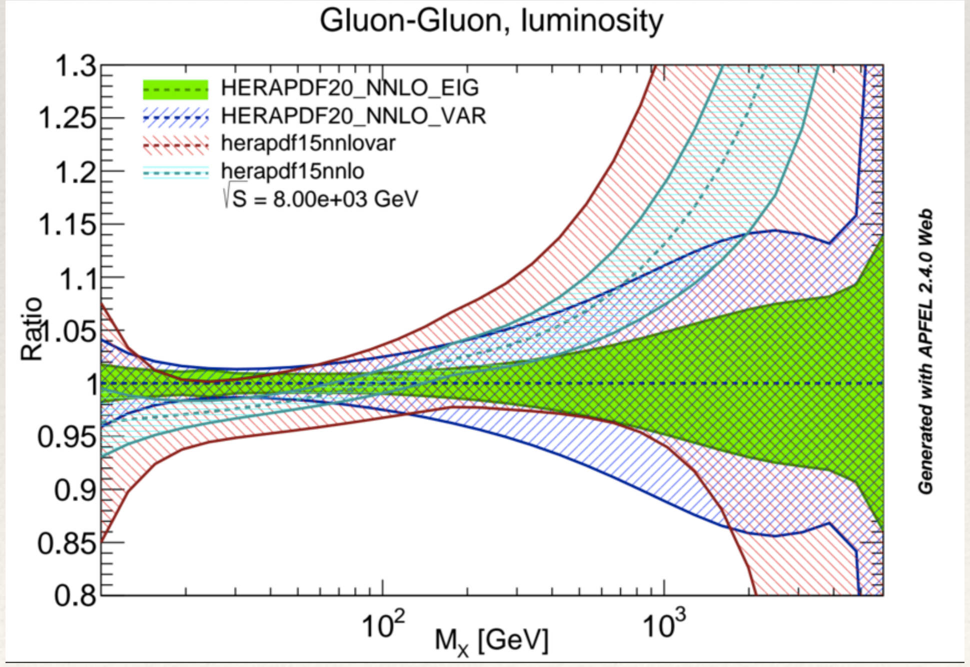
HERAPDF2.0 vs HERAPDF1.5 (NNLO)

- HERAPDF1.5 used only a part of HERA Run 2 data
- Differences in the QCD fit procedure:

	HERAPDF2.0		HERAPDF1.5	
	NNLO	NLO	NNLO	NLO
Data as in Table 1	combination		preliminary combination	
Uncertainties:				
Experimental	Hessian		Hessian	
Procedural	7		3	
Parameterisation	as in Equations 27 to 31		as in Equations 27 to 31	
Number of Parameters	14	14	14**	10 *
– Variations	15 [D_{u_v}]	15 [D_{u_v}]	none	11 [D_{u_v}], 12 [$D_{\bar{U}}$]
$\mu^2_{f_0}$ [GeV^2]	1.9	1.9	1.9	1.9
– Variations	1.6, 2.2	1.6, 2.2	1.5, 2.5	1.5^{*f}, 2.5*
M_c [GeV]	1.43	1.47	1.4	1.4*
– Variations	1.37^{*c}, 1.49	1.41, 1.53	1.35^{*c}, 1.65	1.35^{*c}, 1.65*
M_b [GeV]	4.5	4.5	4.75	4.75*
– Variations	4.25, 4.75	4.25, 4.75	4.30, 5.00	4.30, 5.00*
f_s [GeV]	0.40	0.40	0.31	0.31*
– Variations	0.30, 0.50	0.30, 0.50	0.23, 0.38	0.23, 0.38*
Q^2_{min} [GeV^2] of Data	3.5	3.5	3.5	3.5*
– Variations	2.5, 5.0	2.5, 5.0	2.5, 5.0	2.5, 5.0*
Fixed α_s	0.118	0.118	0.1176	0.1176*

Table 16: Settings for HERAPDF2.0 and HERAPDF1.5.
*: Setting was chosen exactly as for HERAPDF1.0.
**: Parameter number 14 was D_{u_v} and not $D_{\bar{U}}$.
*f: For $\mu^2_{f_0} = 1.5\,\mathrm{GeV}^2$, also A'_g and B'_g were introduced (as for HERAPDF1.0 NLO).
*c: $\mu^2_{f_0} = 1.8\,\mathrm{GeV}^2$ to assure $\mu^2_{f_0} < M^2_c$ (as for HERAPDF1.0 NLO).

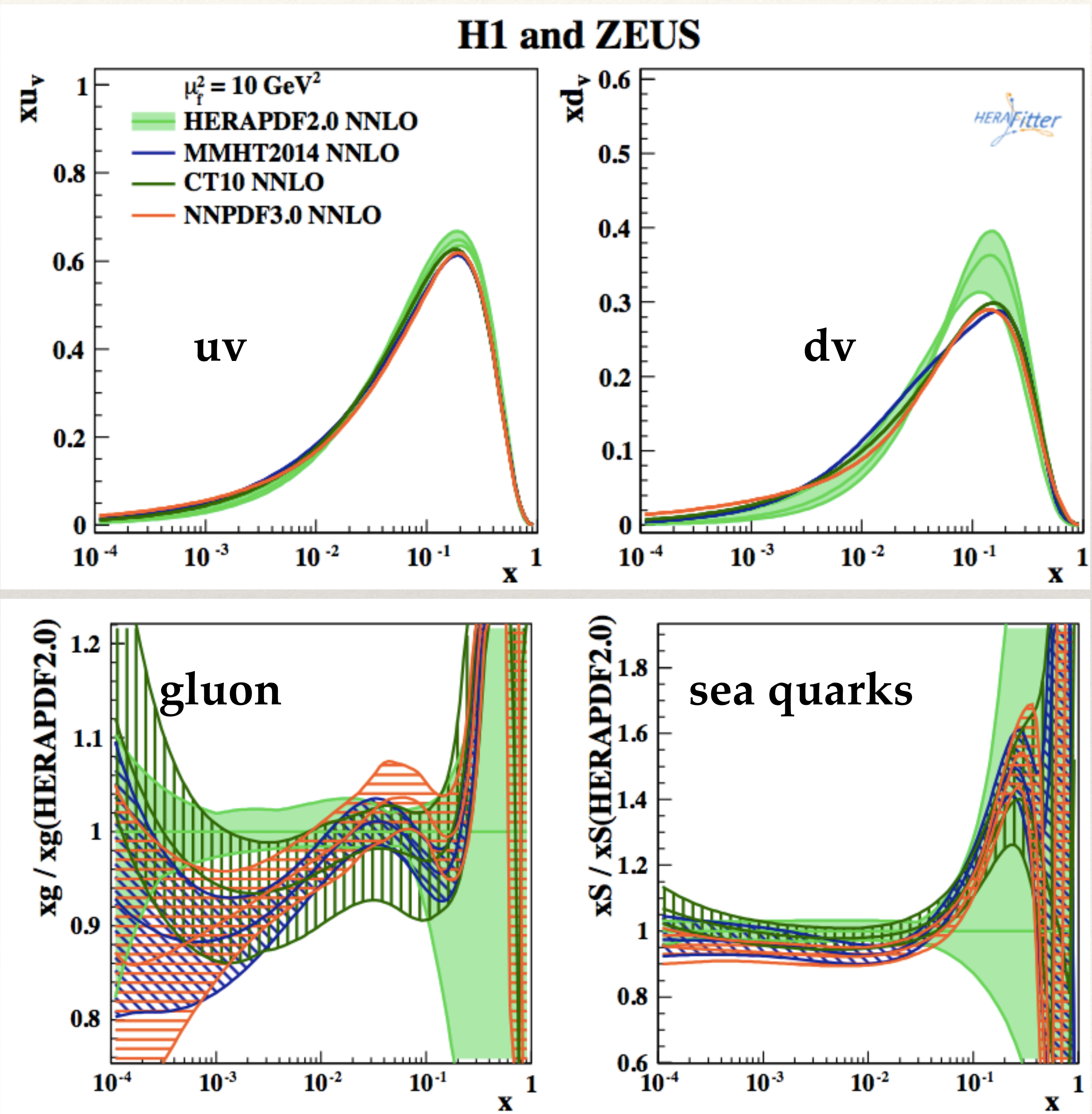




The uncertainties on
gg and qqbar reduced for HERAPDF2.0

HERAPDF2.0 vs other PDF sets

- HERAPDF sets are extracted solely from ep data and require no assumptions or corrections, hence provide an important cross check of PDF universality (process independence):



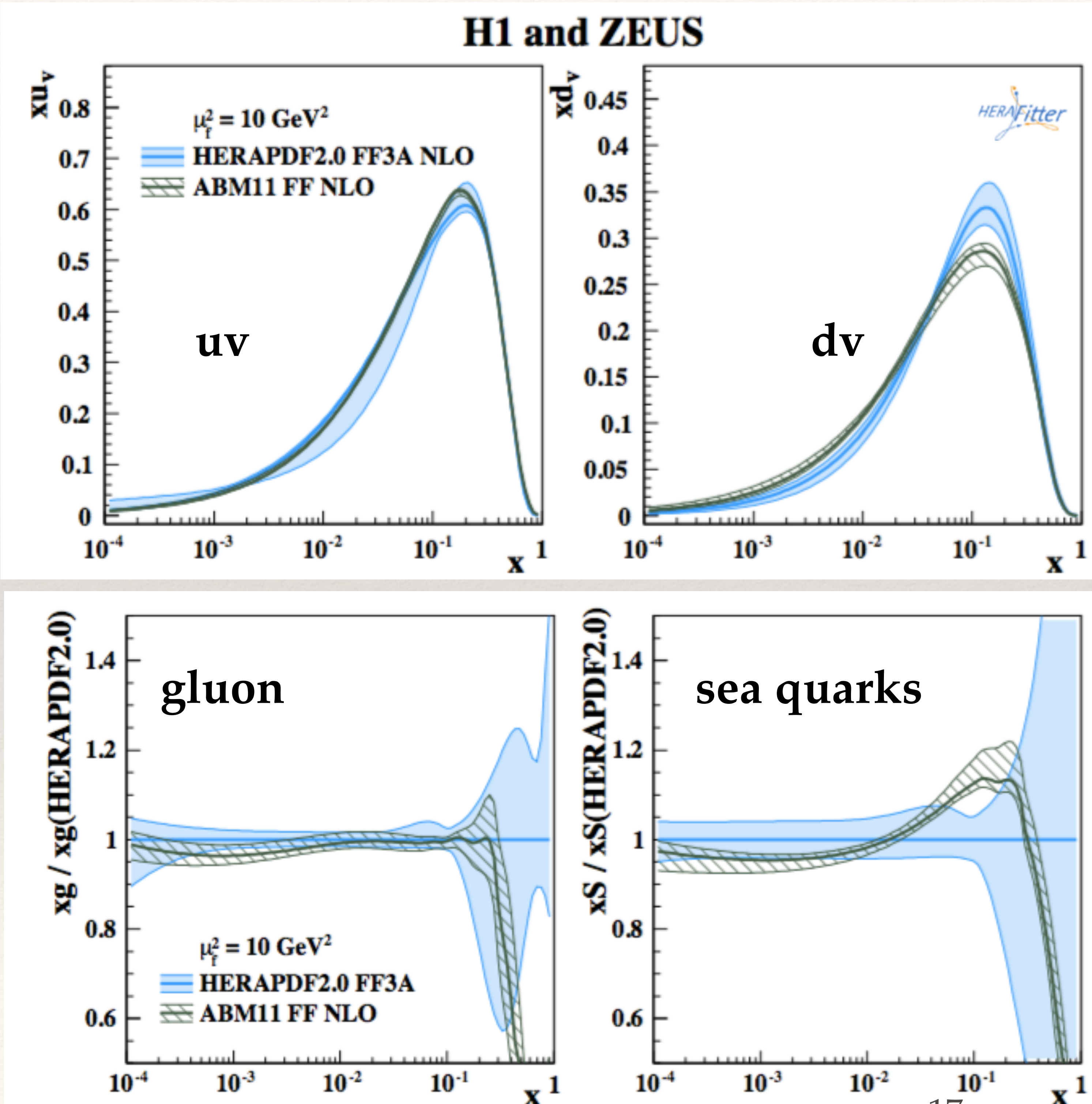
high x valence different:
new high- x data and use of proton target only

At NNLO gluon and sea quarks are both compatible with other PDFs

[arxiv:1506.06042]

HERAPDF2.0 vs other PDF sets

- HERAPDF sets are extracted solely from ep data and require no assumptions or corrections, hence provide an important cross check of PDF universality (process independence):



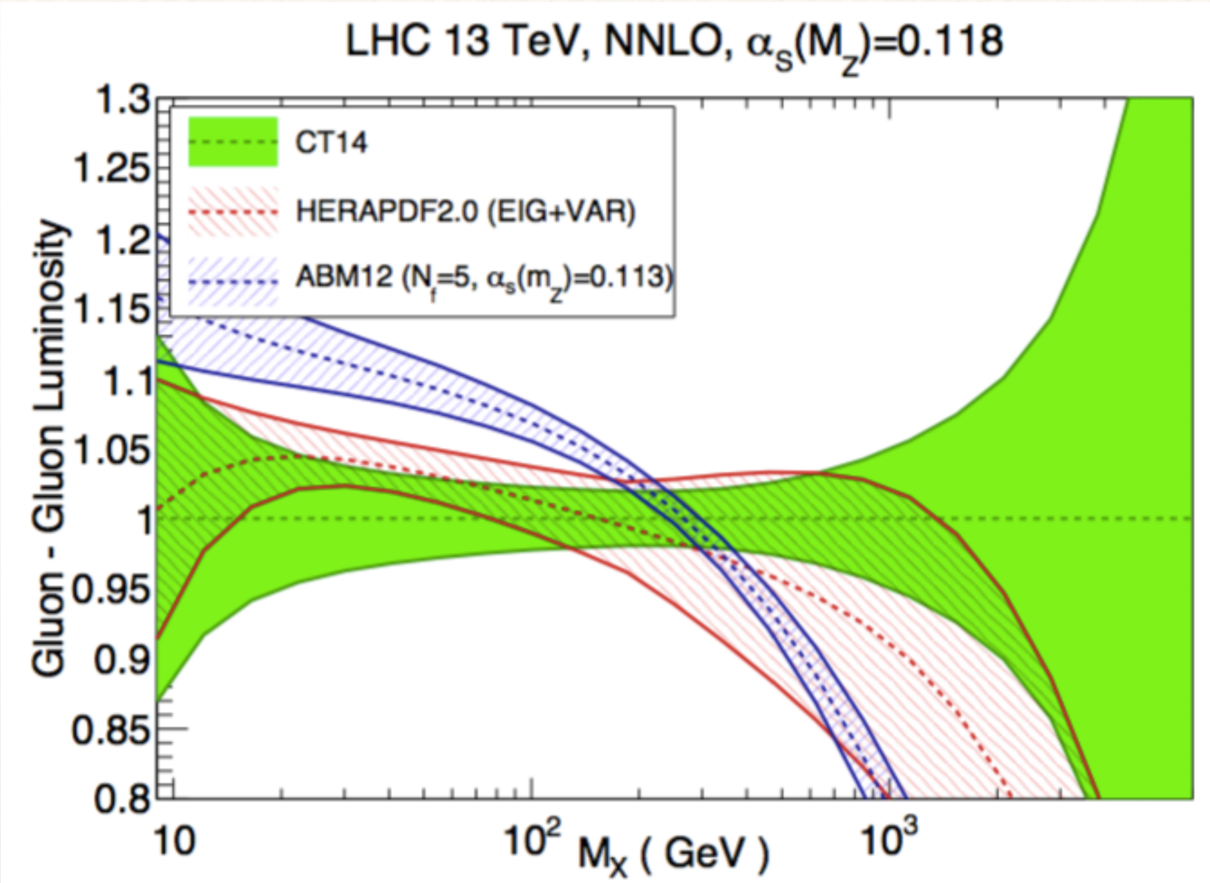
high x valence different:
new high- x data and use of proton target only

Comparison of FF3A to ABM
Similar difference of valence shape as noted for VFN schemes
FF3A and ABM gluons are compatible

[arxiv:1506.06042]

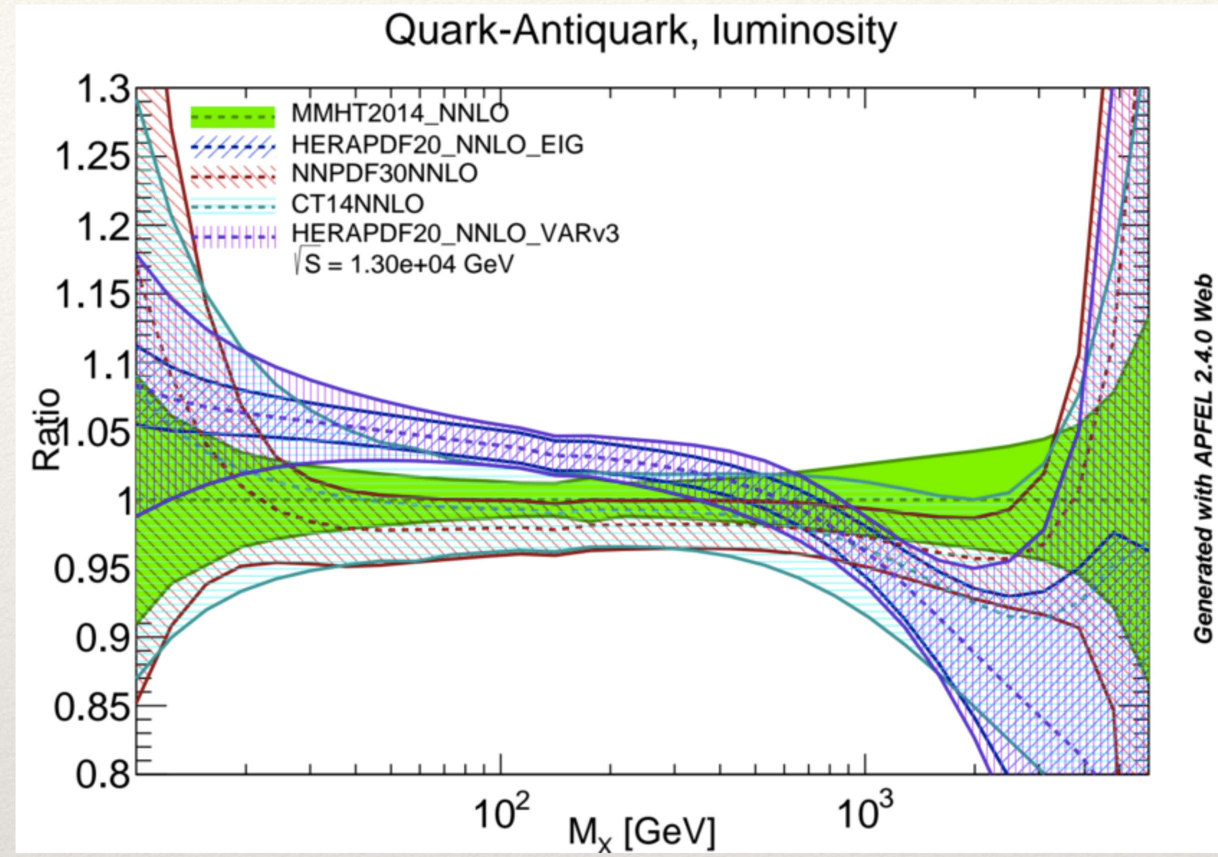
HERAPDF2.0 vs other PDF sets: luminosity plots

- Gluon-Gluon*



Results are compatible with global PDFs

Quark-Antiquark



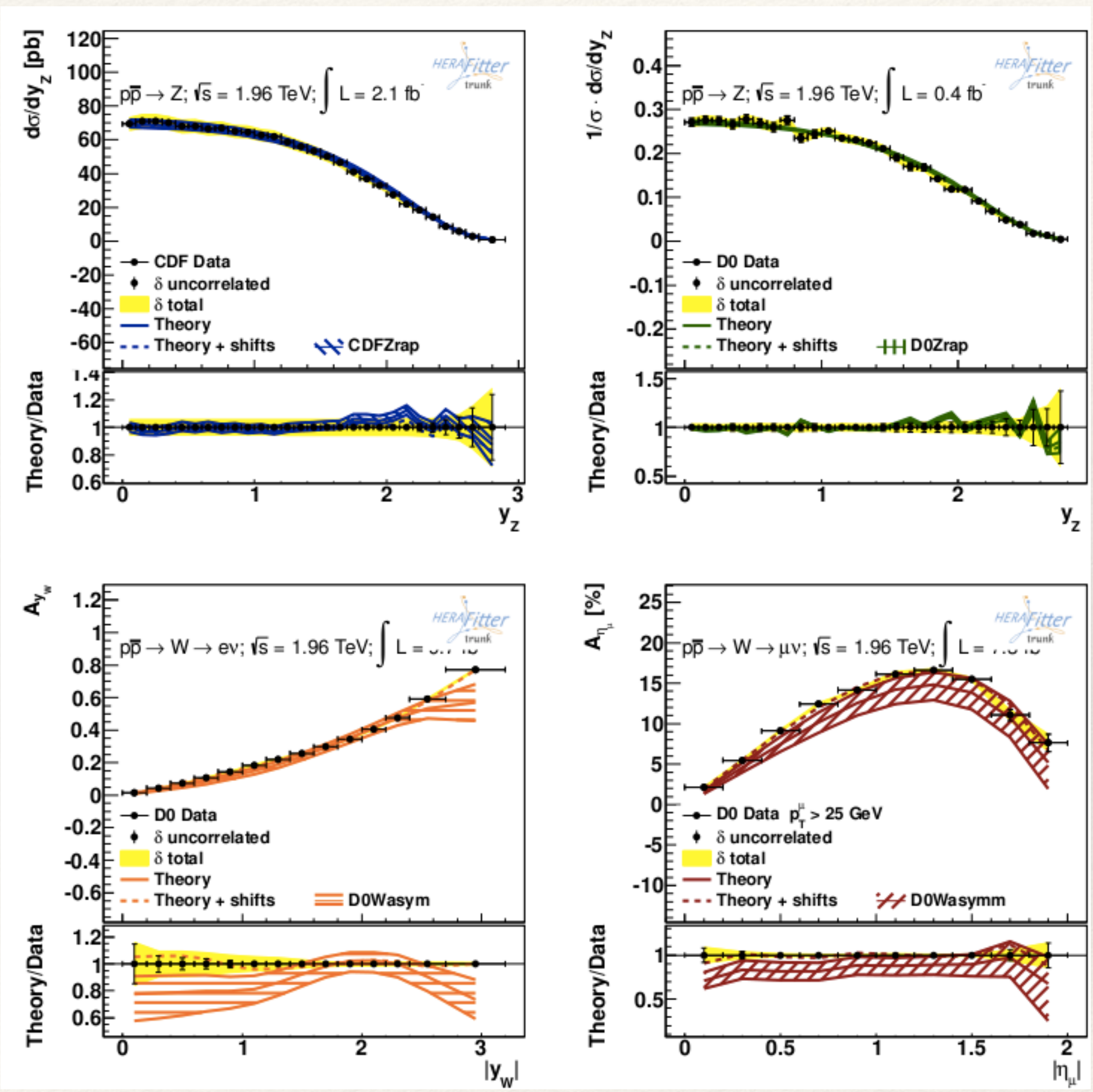
HERAPDF2.0 is by 5% higher than global PDFs in intermediate mass range

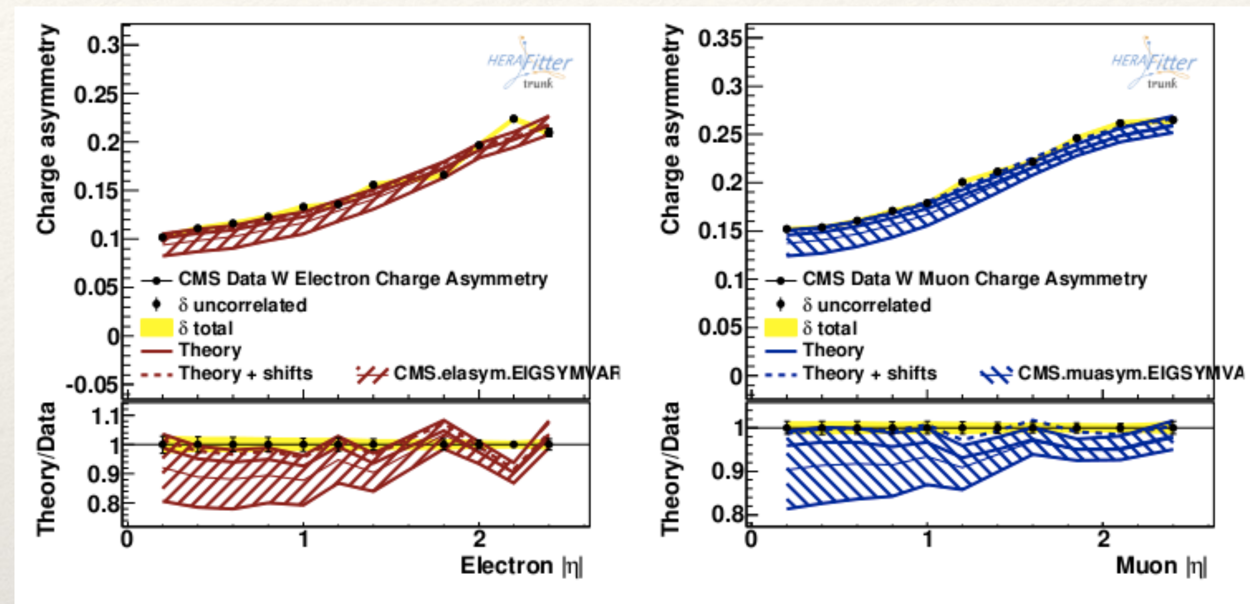
Absence of data at low and high mass range leads to blow-up in uncertainties

*plots taken from PDF4LHC recommendation arxiv:1510.03865

HERAPDF2.0 vs world data [using HERAFitter]

- HERAPDF sets are extracted solely from ep data and require no assumptions or corrections, hence provide an important cross check of PDF universality (process independence):

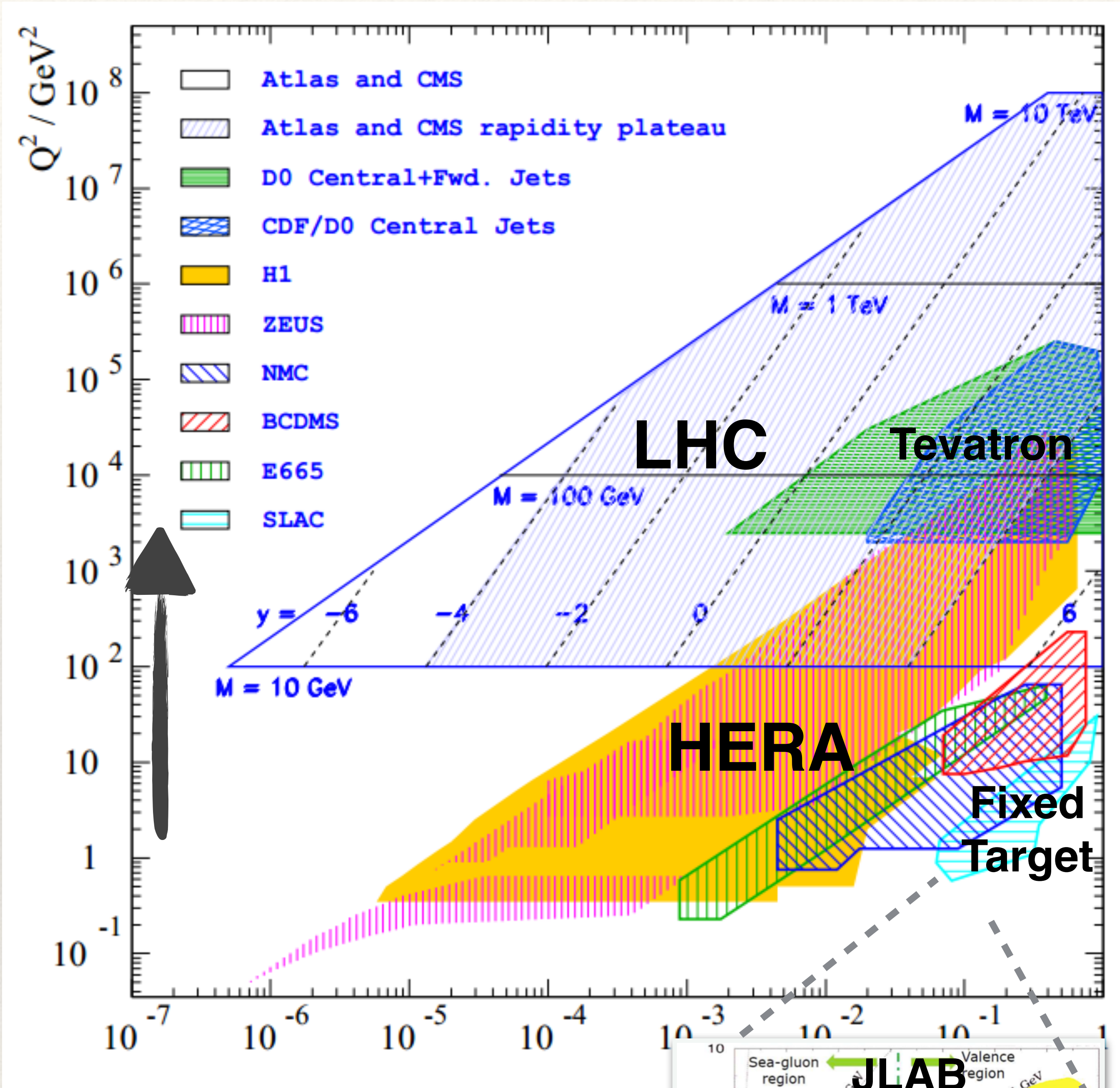


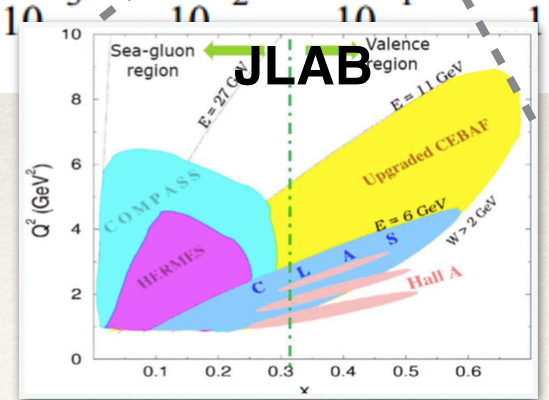


Similar level of agreement as for the global PDFs

[arxiv:1506.06042]

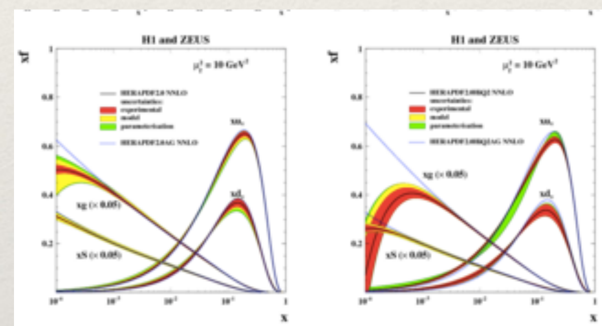
Summary

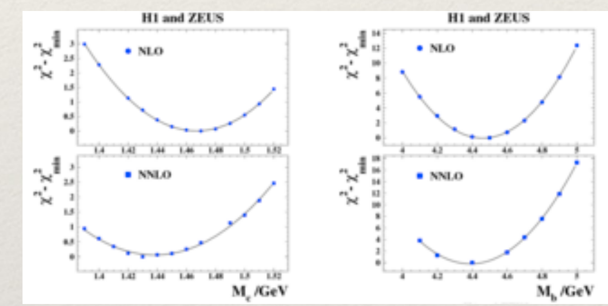


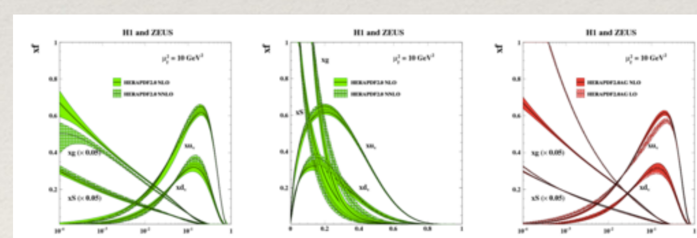


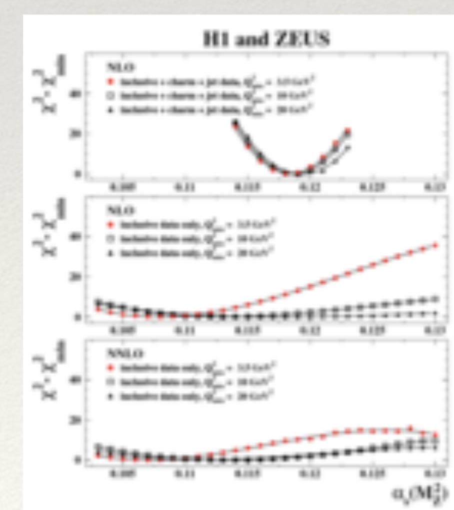
HERA has finalised its separate measurements relevant to PDFs and has combined them into final measurements to reach its ultimate precision:

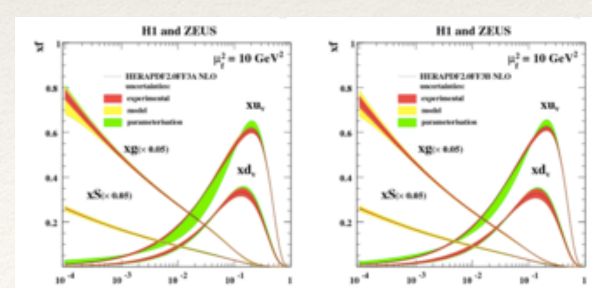
- PDFs, mc, mb, alphas









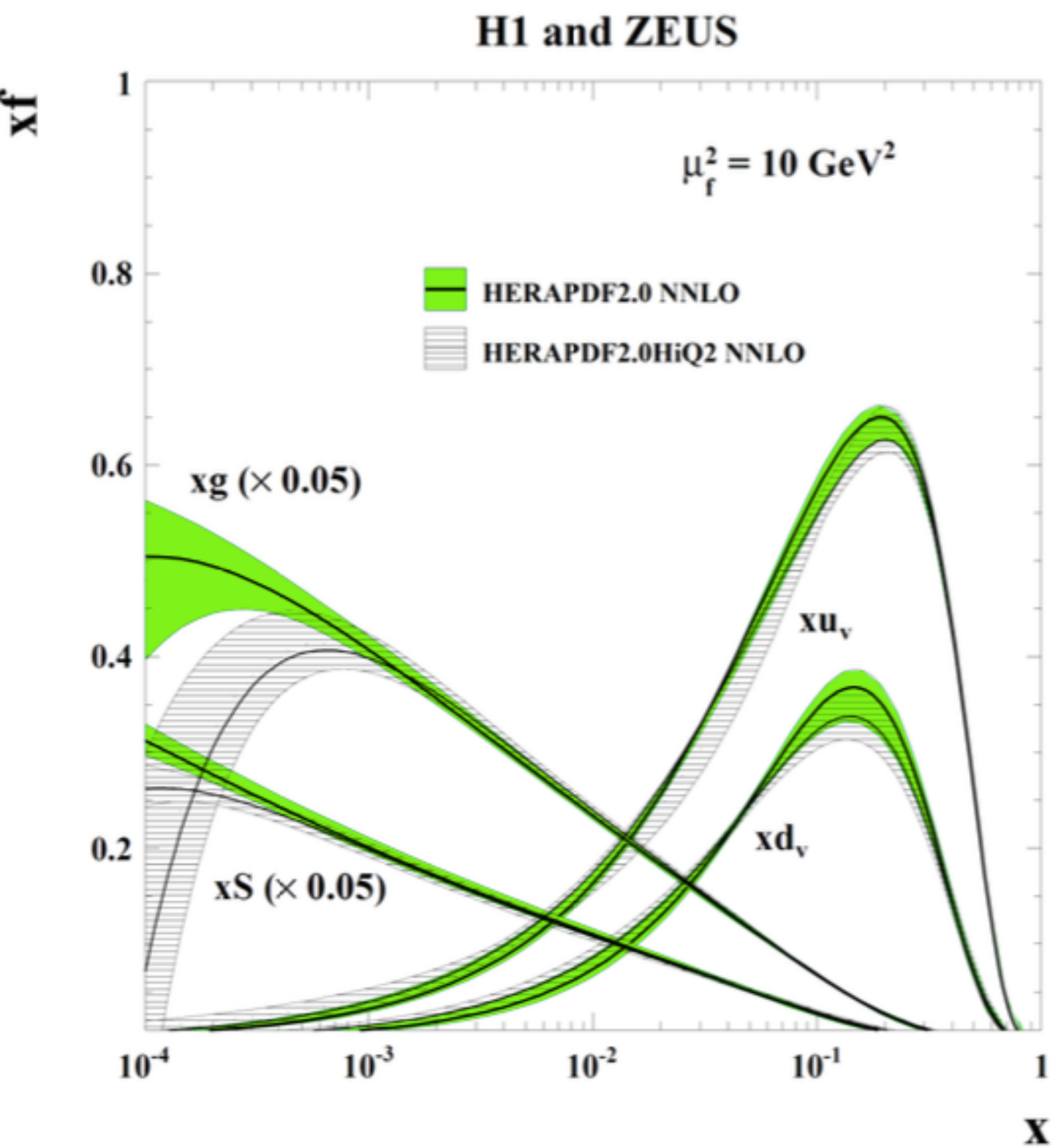


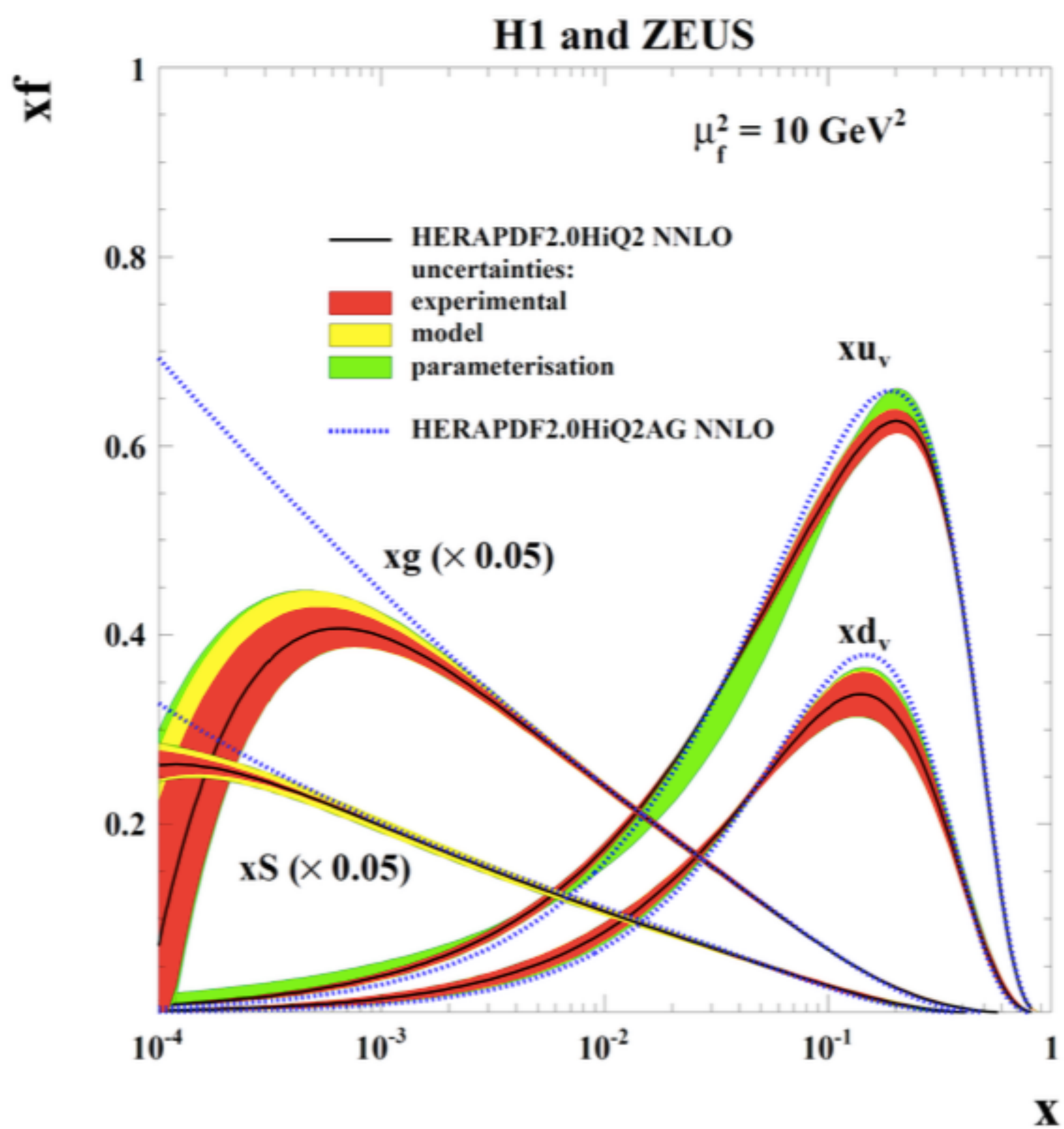
Many Thanks!

back-up slides

not necessarily useful …

HERAPDF2.0 Q2>10

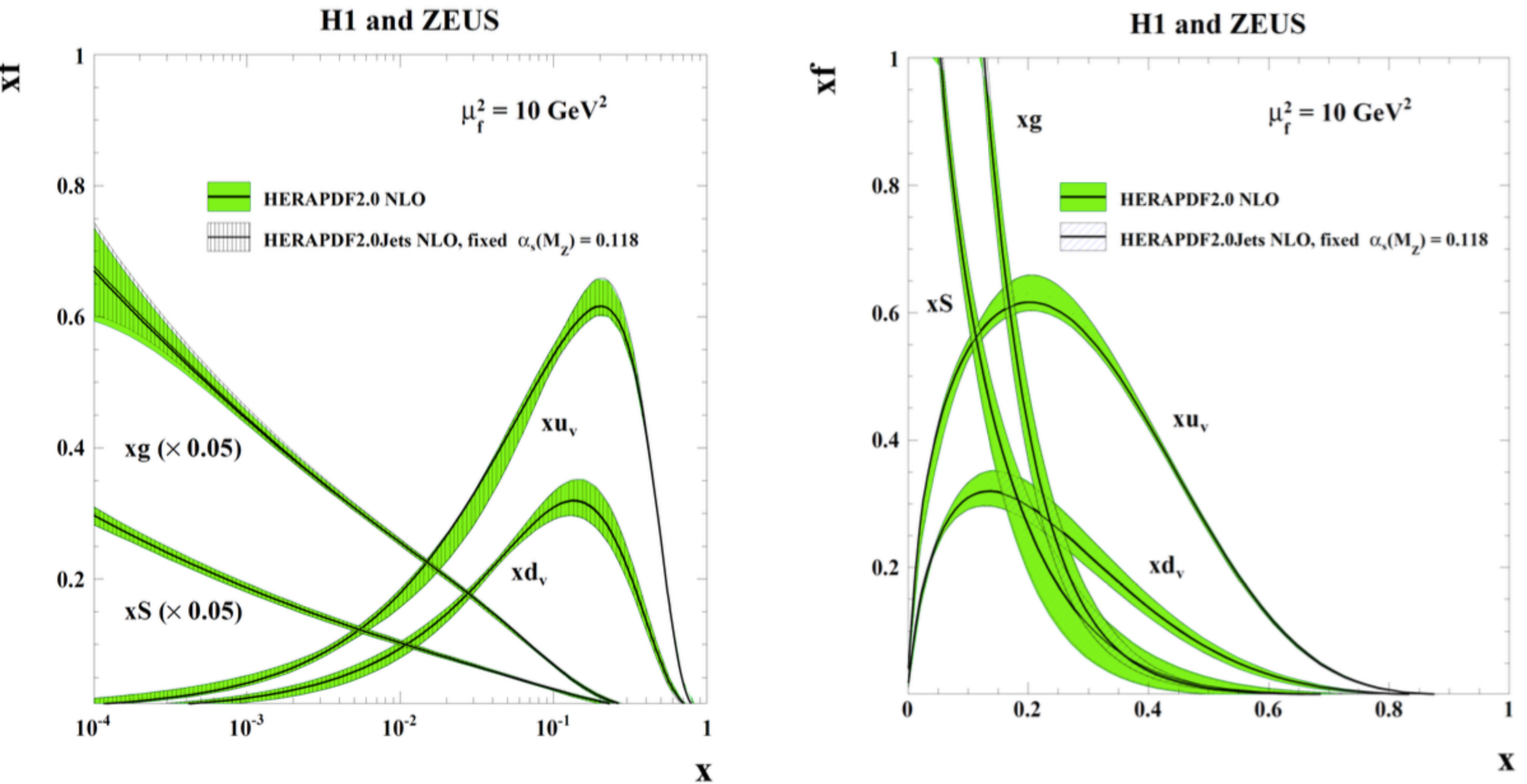




At very low-x and moderate Q^2 --as in LHCb --the NNLOfit for Q^2_{min}=10 gives a negative gluon and a negative longitudinal cross section, and thus is not fit for purpose.

HERAPDF2.0 vs HERAPDF2.0jets

The fits with and without jet data and charm data are very compatible

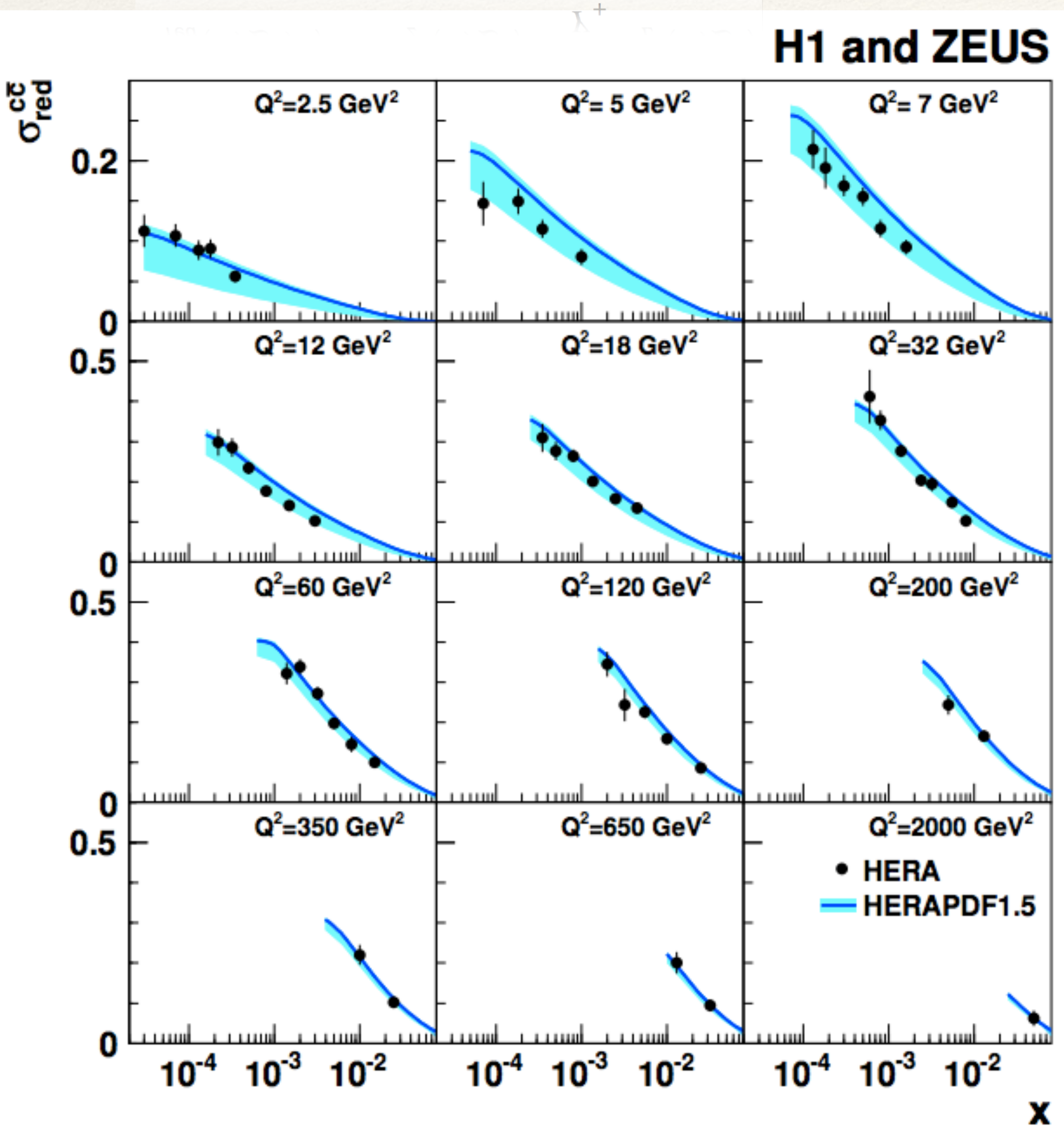


F2 charm Structure Function

EPJC 73 (2013) 2311

- Rates at HERA in DIS regime σ(b) : σ(c) ≈ O(1%) : O(20%) of σ_{TOT}
- Charm data combination is performed at charm cross sections level:
  - they are obtained from xsec in visible phase space and extrapolated to full space

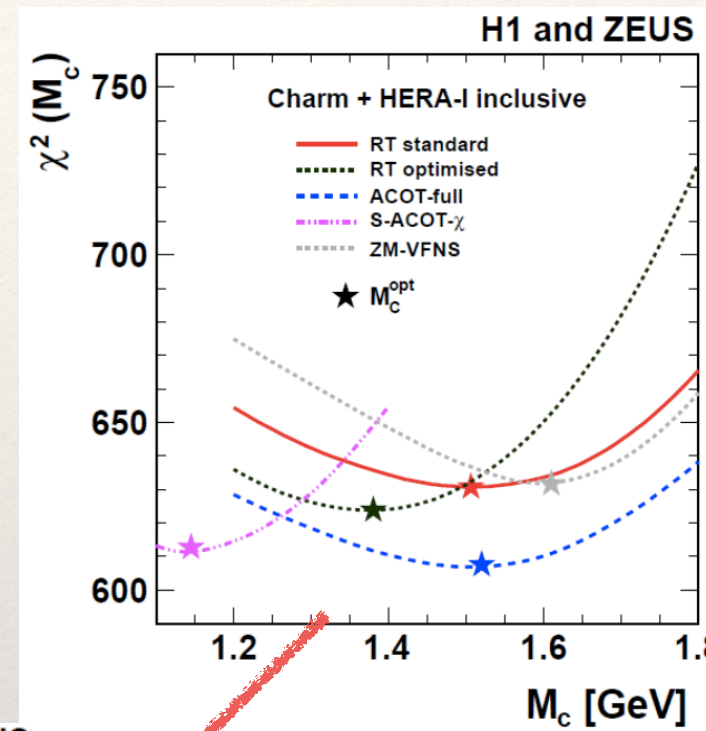
$$\sigma_{red}^{c\bar{c}}(x,Q^2,s) = F_2^{c\bar{c}}(x,Q^2) - \frac{y^2}{Y_+} F_L^{c\bar{c}}(x,Q^2)$$

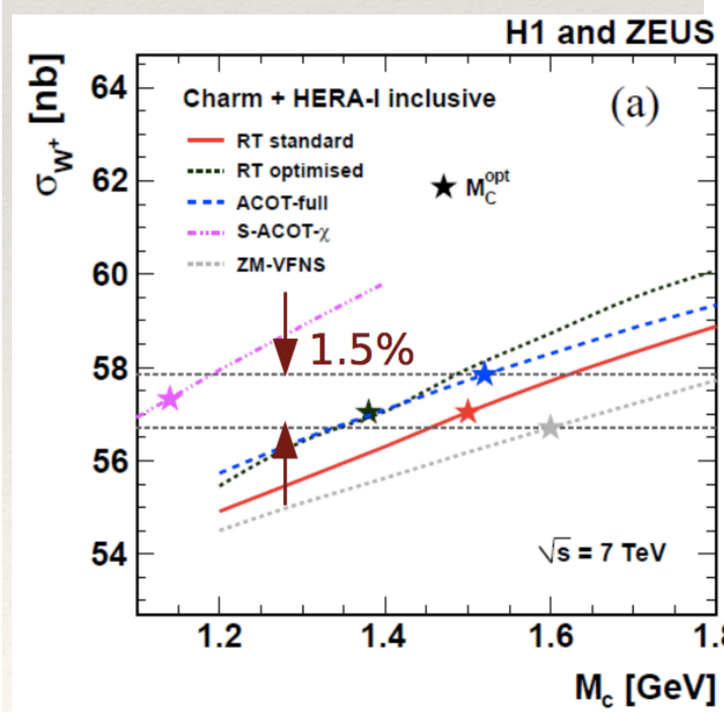


QCD Fits

HERA I+charm

Different calculation schemes prefer different Mc

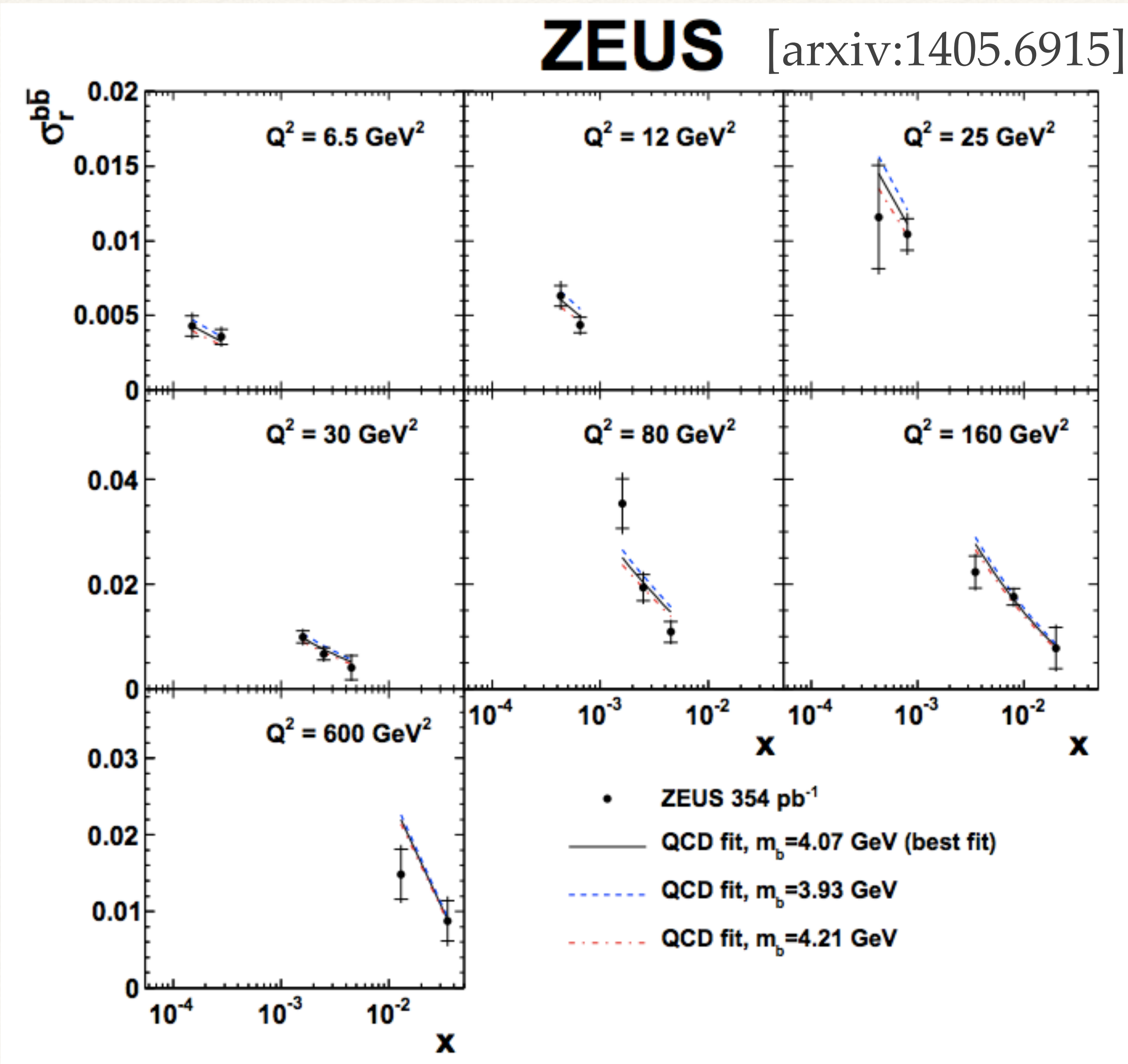




measurements help reduce uncertainties of predictions for the LHC

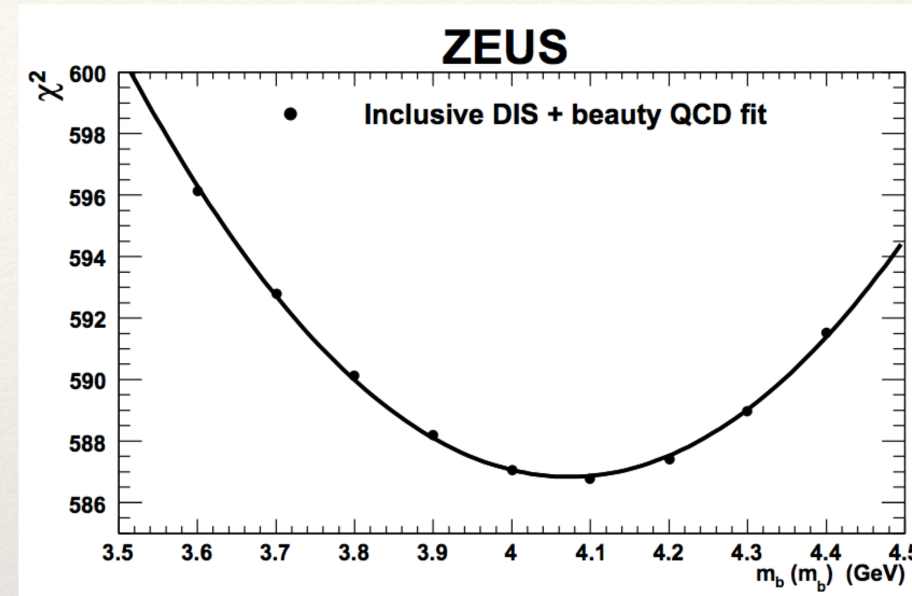
Running beauty mass from F2b

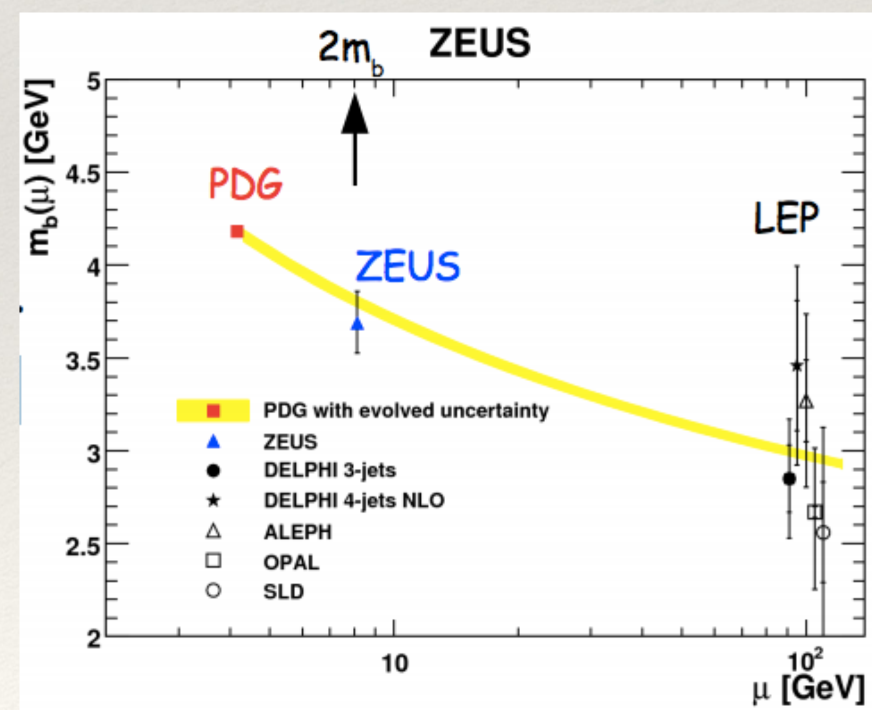
- The value of the running beauty mass is obtained using HERAFitter (via OPENQCDRAD):
  - chi2 scan method from QCD fits in FFN scheme to the combined HERA I inclusive data + beauty measurements, beauty-quark mass is defined in the $\overline{\text{MS}}$ scheme.



QCD Fits

HERA I+beauty





The extracted $\overline{\text{MS}}$ beauty-quark mass is in agreement with PDG average and LEP results.