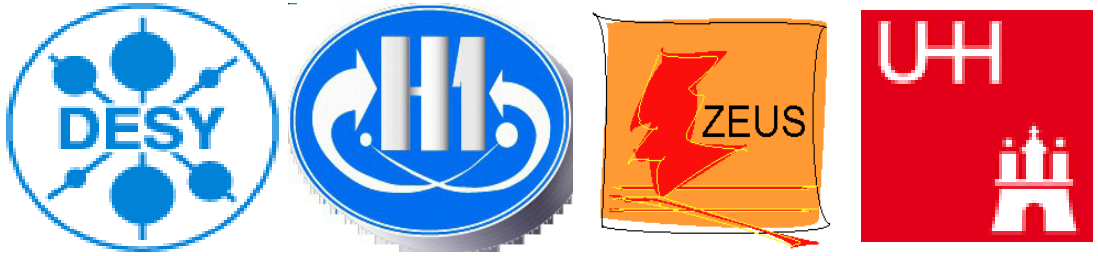


Proton Structure and α_s from HERA

e-Print: arXiv:1506.06042 submitted 19 June

Andrii Gizhko

(on behalf of H1 and ZEUS collaborations)

QCD`15 conference , Montpellier, France
29.06.15

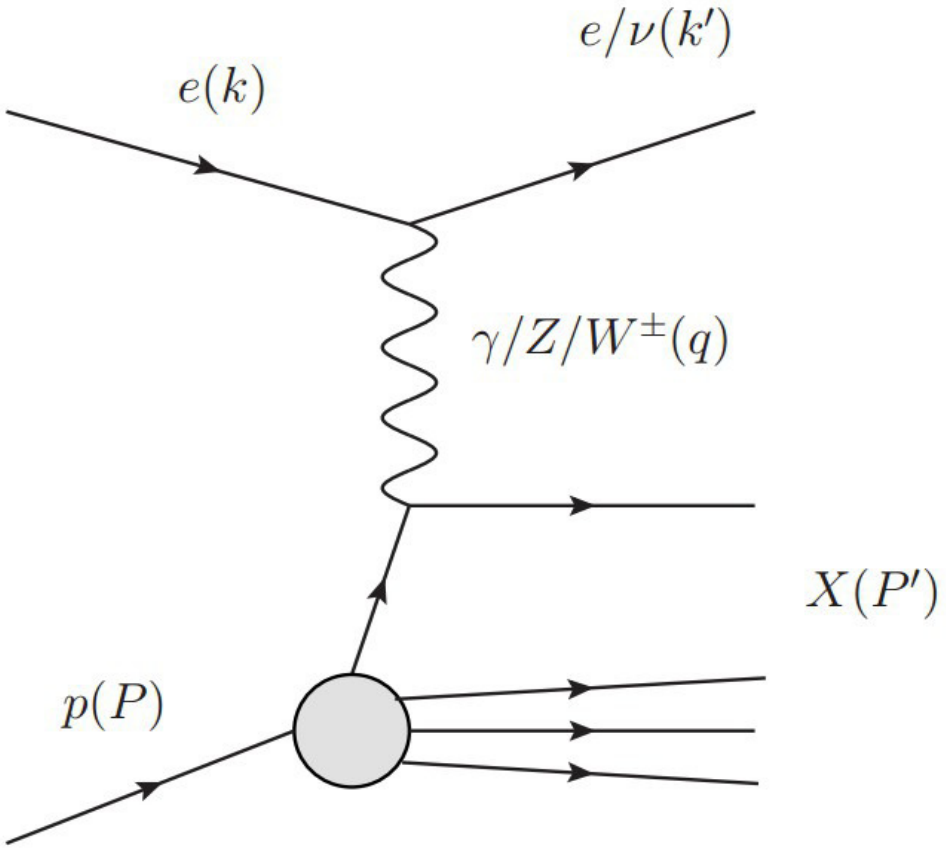
HERA collider

E_p=920(460,575) GeV

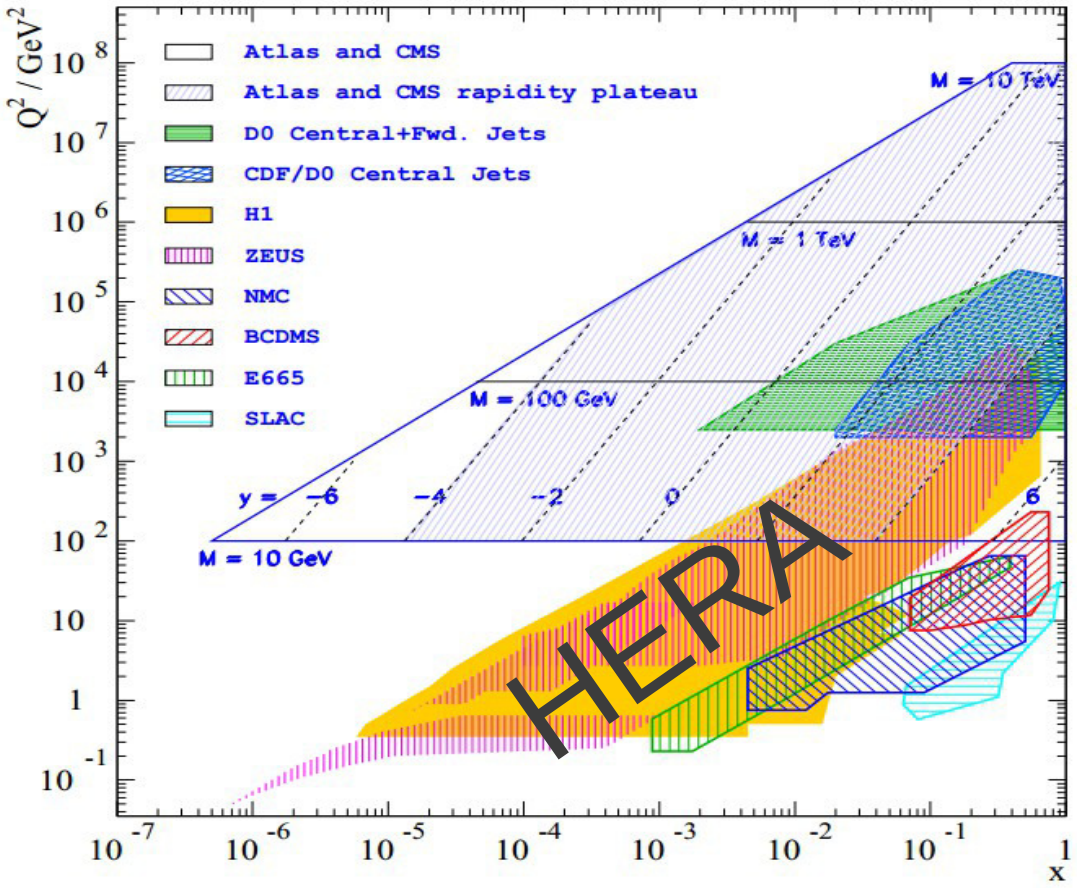
E_e = 27.5 GeV

√s = 318 (225,252) GeV

Collected ~0.5fb^{-1} per experiment



Deep inelastic scattering



$$Q^2 = -q^2 = -(k - k')^2$$

$$x_{Bj} = \frac{Q^2}{2\,pq} \qquad y = \frac{pq}{pk}$$

$$s = (p + k)^2 \qquad Q^2 = xys$$

HERA data combination

All inclusive DIS results are final and published

2927 original measurements

combined to

1307 averaged measurements

$$p^{i,k} = \frac{\mu^{i,k} - \mu^{i,ave}\left(1 - \sum_j \gamma_j^{i,k} b_{j,ave}\right)}{\sqrt{\Delta_{i,k}^2 - \Delta_{i,ave}^2}}$$

Consistent data sets :
total χ^2/ndf = 1685/1620

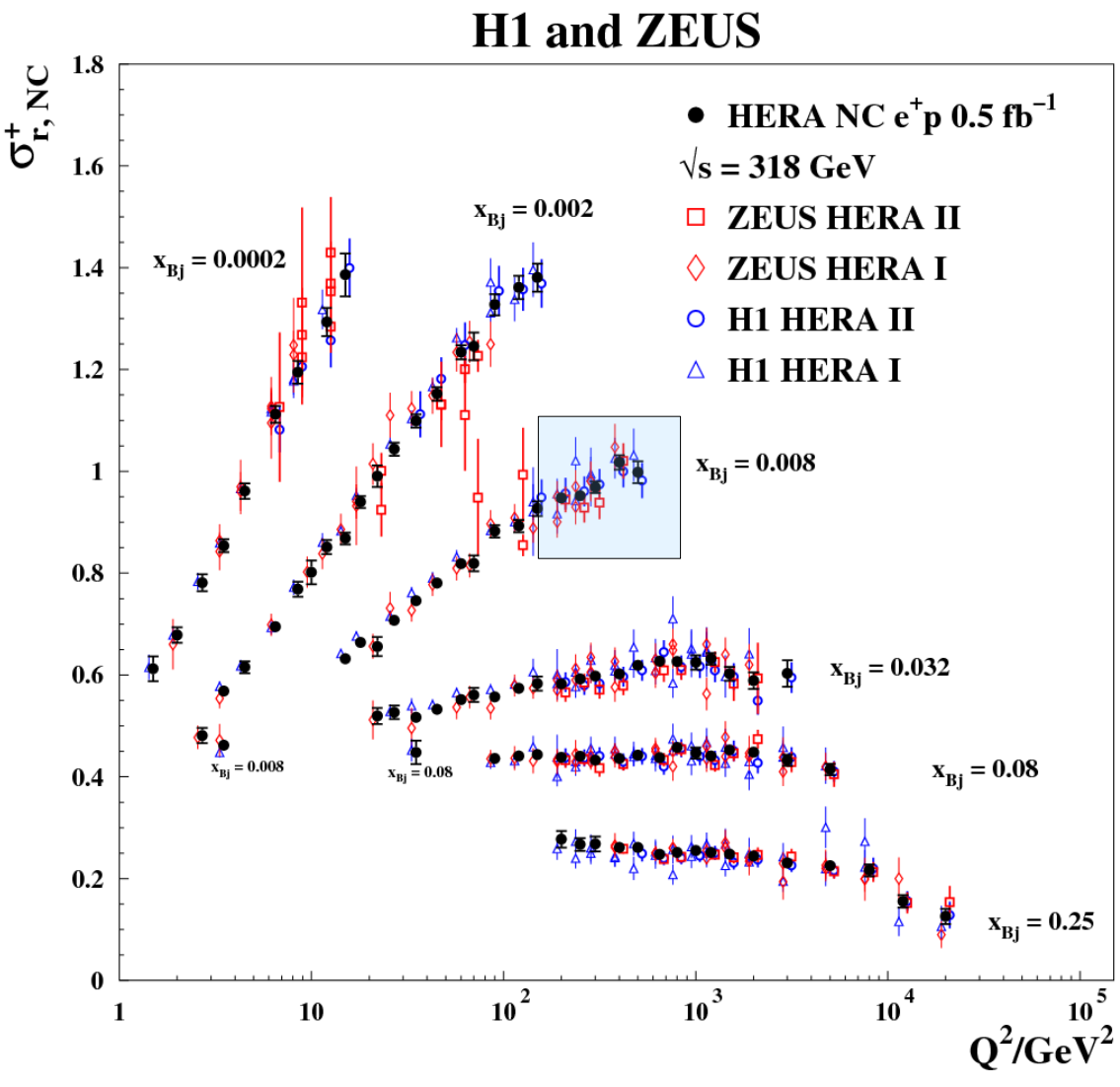
Correlations of systematic uncertainties were taken into account

Data Set		x_{Bj} Grid from	to	Q^2[GeV^2] Grid from	to	$\mathcal{L}$ pb^{-1}	e^+/e^-	$\sqrt{s}$ GeV
HERA I E_p = 820 GeV and E_p = 920 GeV data sets								
H1 svx-mb	95-00	0.000005	0.02	0.2	12	2.1	e^+p	301, 319
H1 low Q^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	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

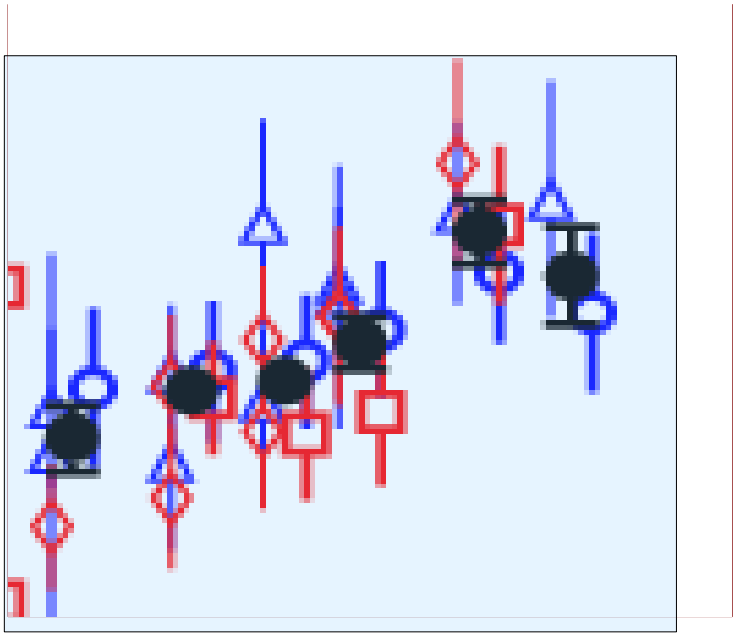
Full HERA I data HERA II data HERA II data LER

Combined reduced cross-sections

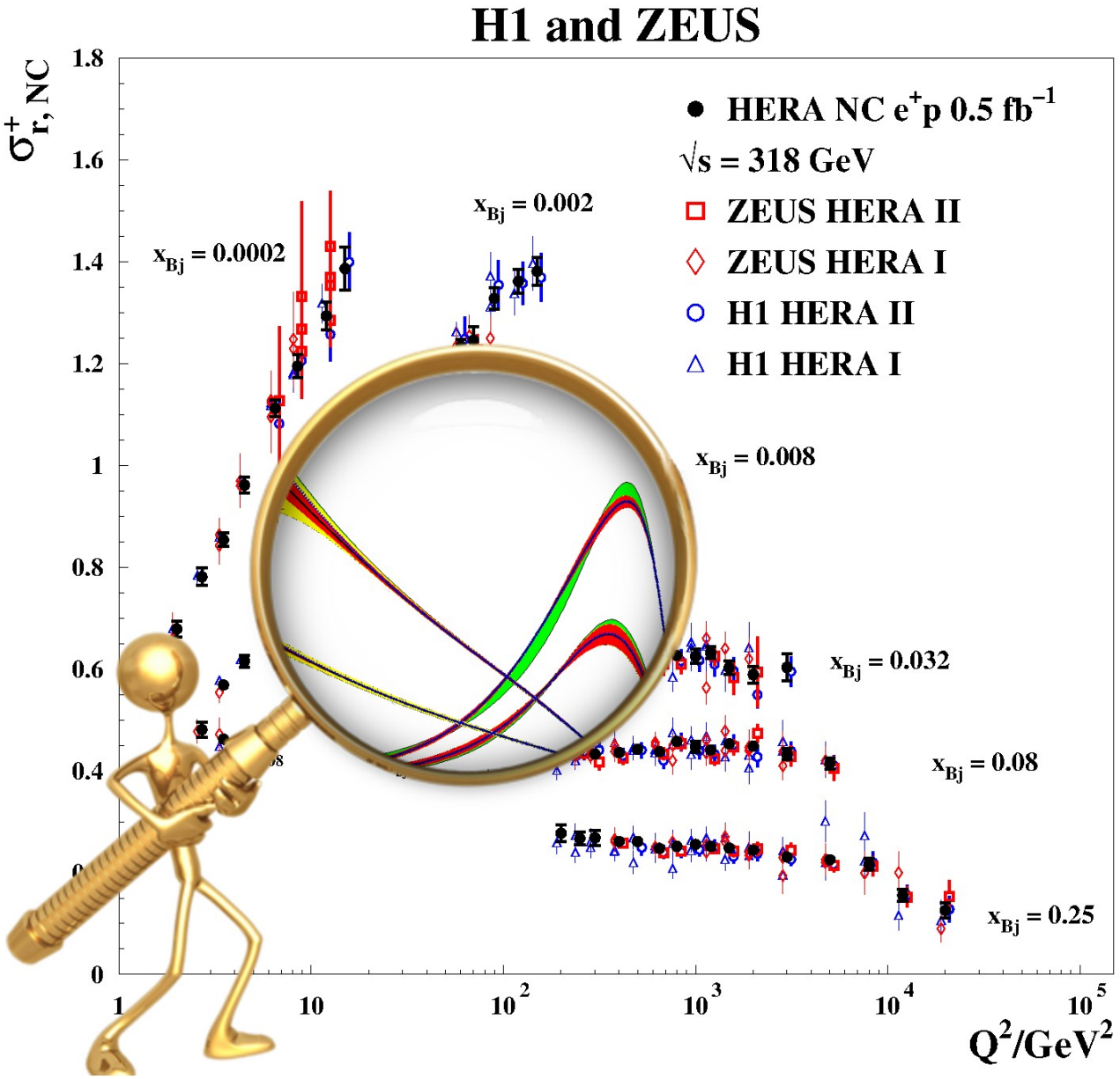
$$\sigma^{\pm}_{r,NC} = \frac{Q^4 x}{2\pi\alpha^2 Y_+}\frac{d^2\sigma^{e^{\mp}p}_{NC}}{dxdQ^2} = \tilde{F}_2 \mp \frac{Y_-}{Y_+} x\tilde{F}_3 - \frac{y^2}{Y_+}\tilde{F}_L$$



- up to ~6 points averaged together
- good precision



Extraction of PDFs from inclusive data



HERAPDF2.0: settings for QCD fit

- QCD fits are performed using **HERAFitter** package www.herafitter.org

- The fits are performed using the HERA data only

- PDFs (14p) are parametrized at $Q_0^2 = 1.9$ GeV^2

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

- PDF evolution is performed using DGLAP equations

- Heavy flavour coefficients are obtained with GM VFNS (RT OPT)

HERAPDF2.0: errors estimation

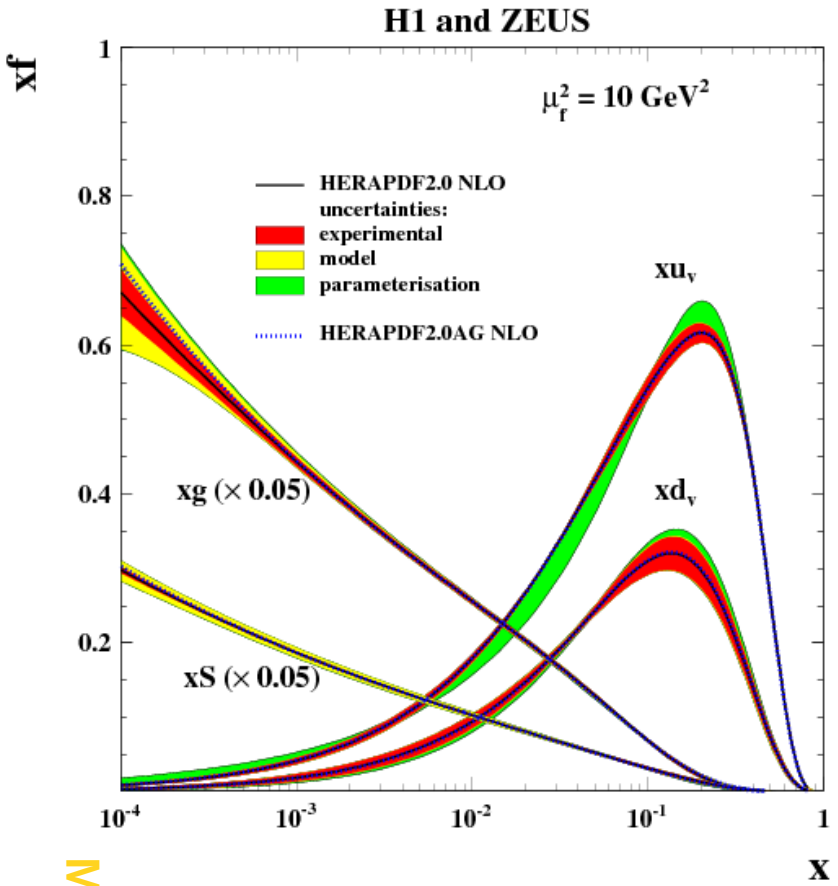
Full systematic correlation treatment

Experimental uncertainties:
$\Delta\chi^2 = 1$ => 68% CL

Parametrization uncertainties:

The largest deviation taken

Model uncertainties :

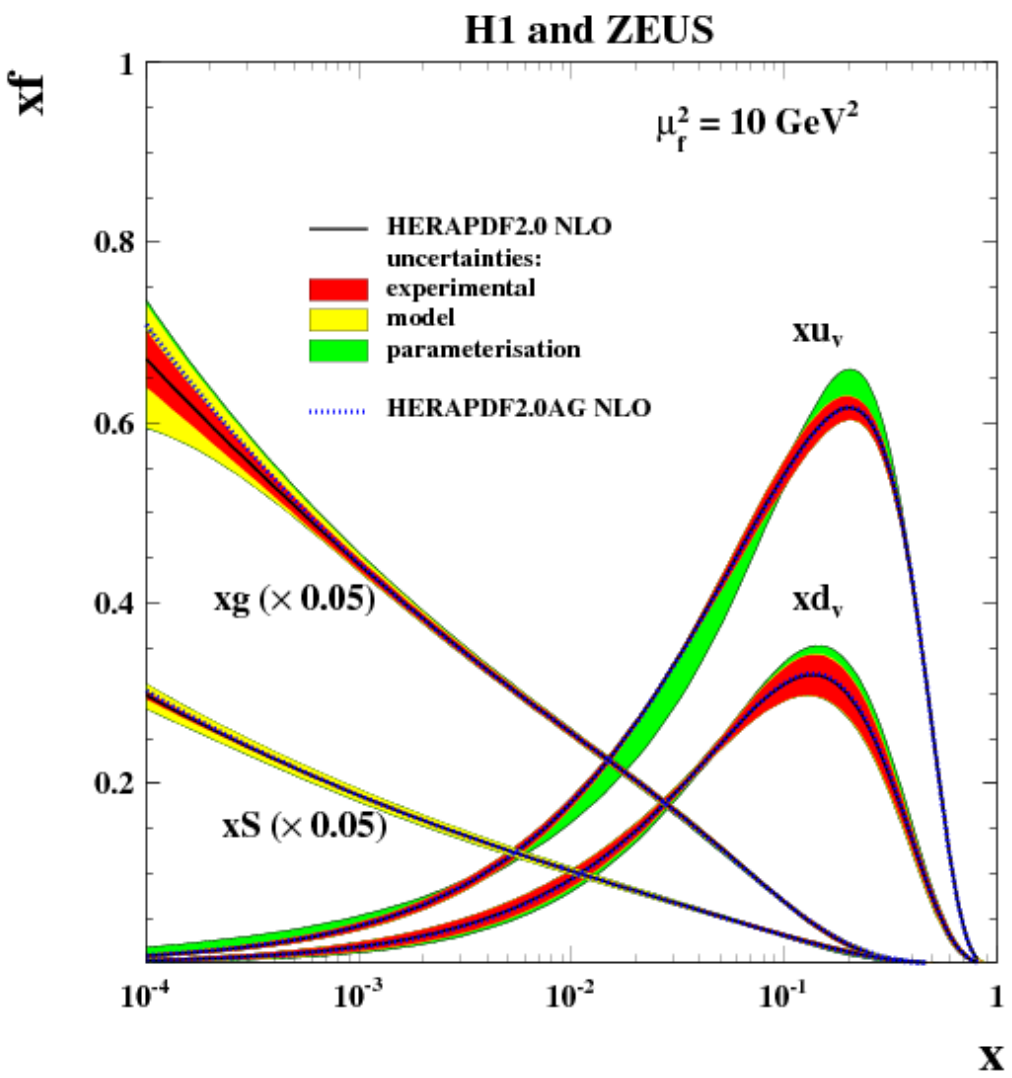


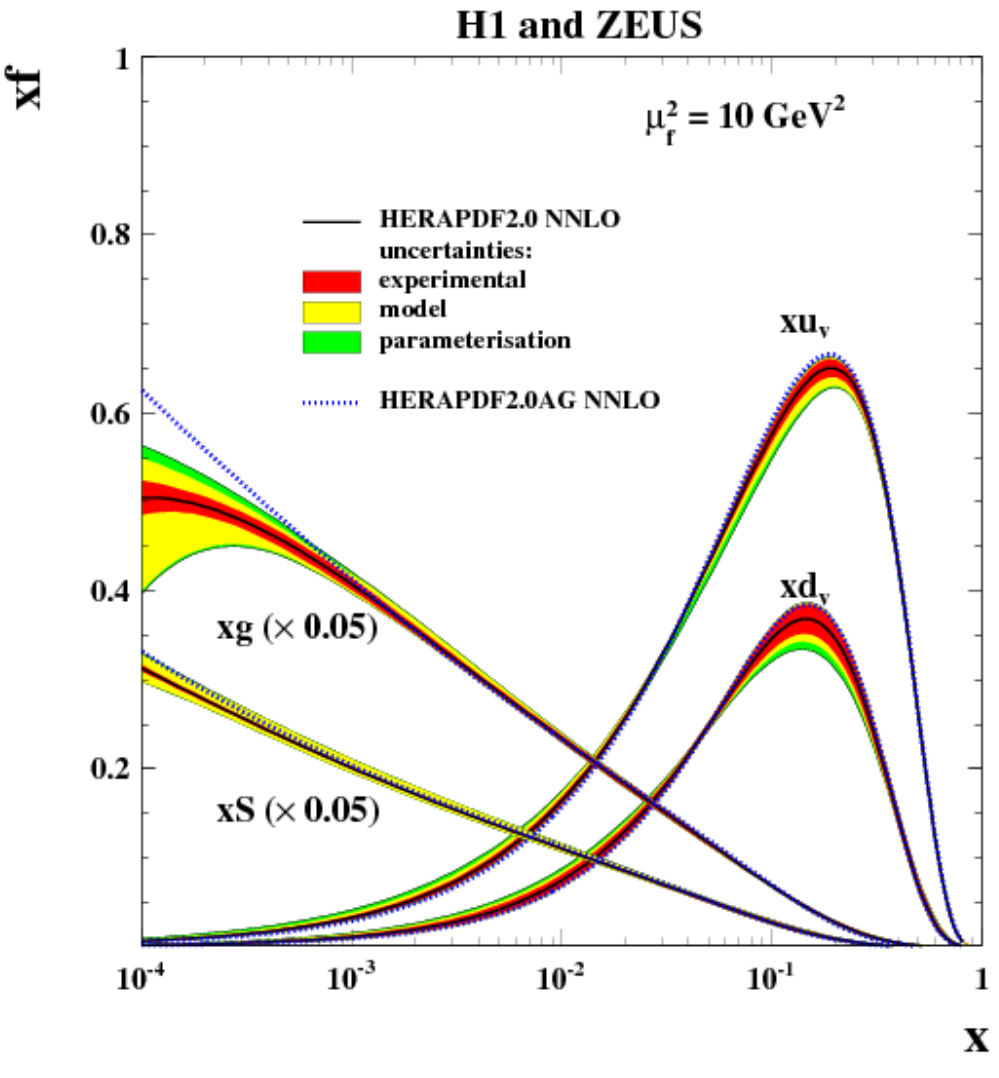
Variation	Standard Value	Lower Limit	Upper Limit
$Q^2_{\min}$ [GeV^2]	3.5	2.5	5.0
$Q^2_{\min}$ [GeV^2] HiQ2	10.0	7.5	12.5
M_c(NLO) [GeV]	1.47	1.41	1.53
M_c (NNLO) [GeV]	1.43	1.37	1.49
M_b [GeV]	4.5	4.25	4.75
f_s	0.4	0.3	0.5
μ_{f_0} [GeV]	1.9	1.6	2.2

Model uncertainties

Par. Uncertainty + parametrization variation

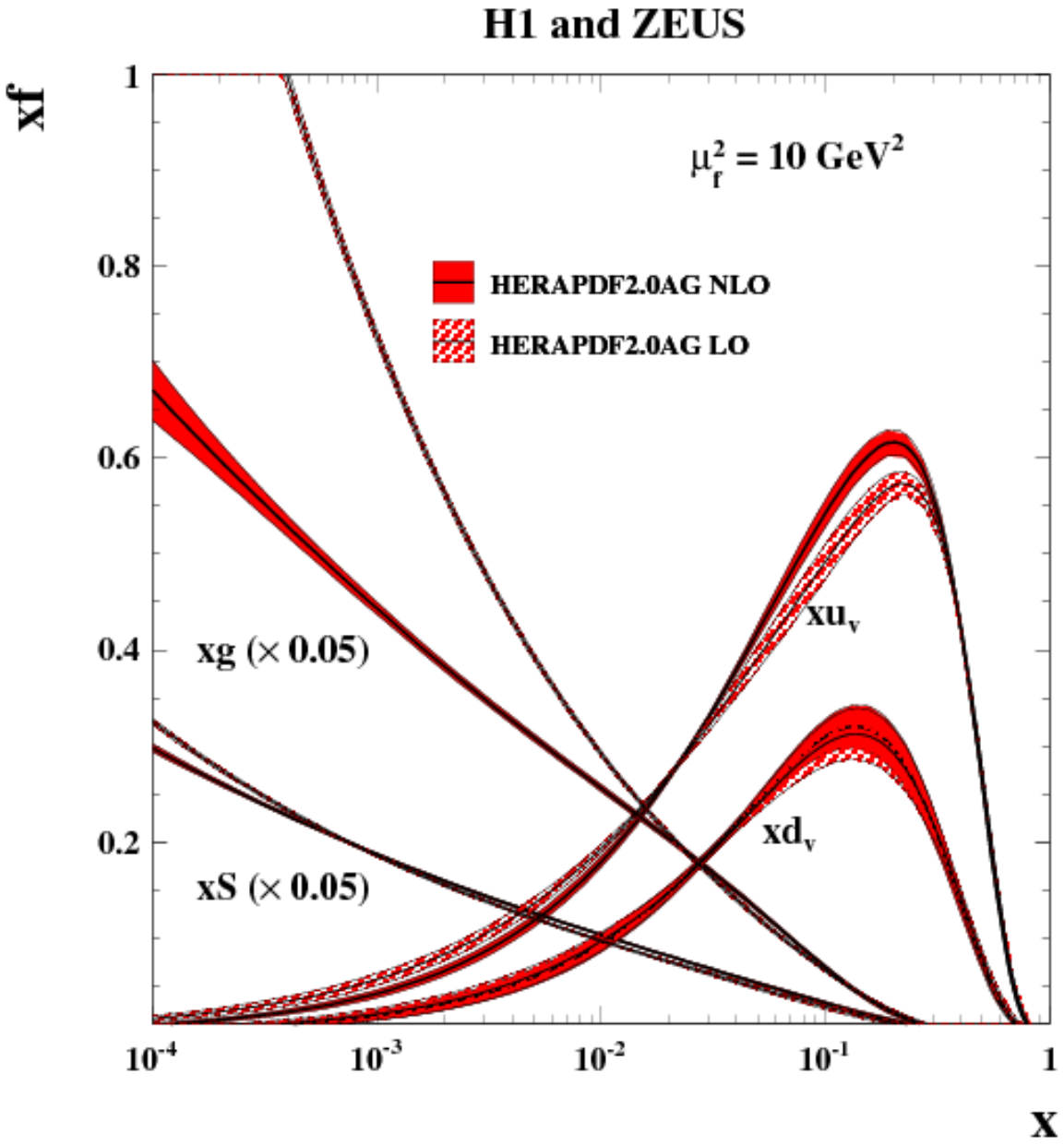
HERAPDF2.0 at NLO and NNLO





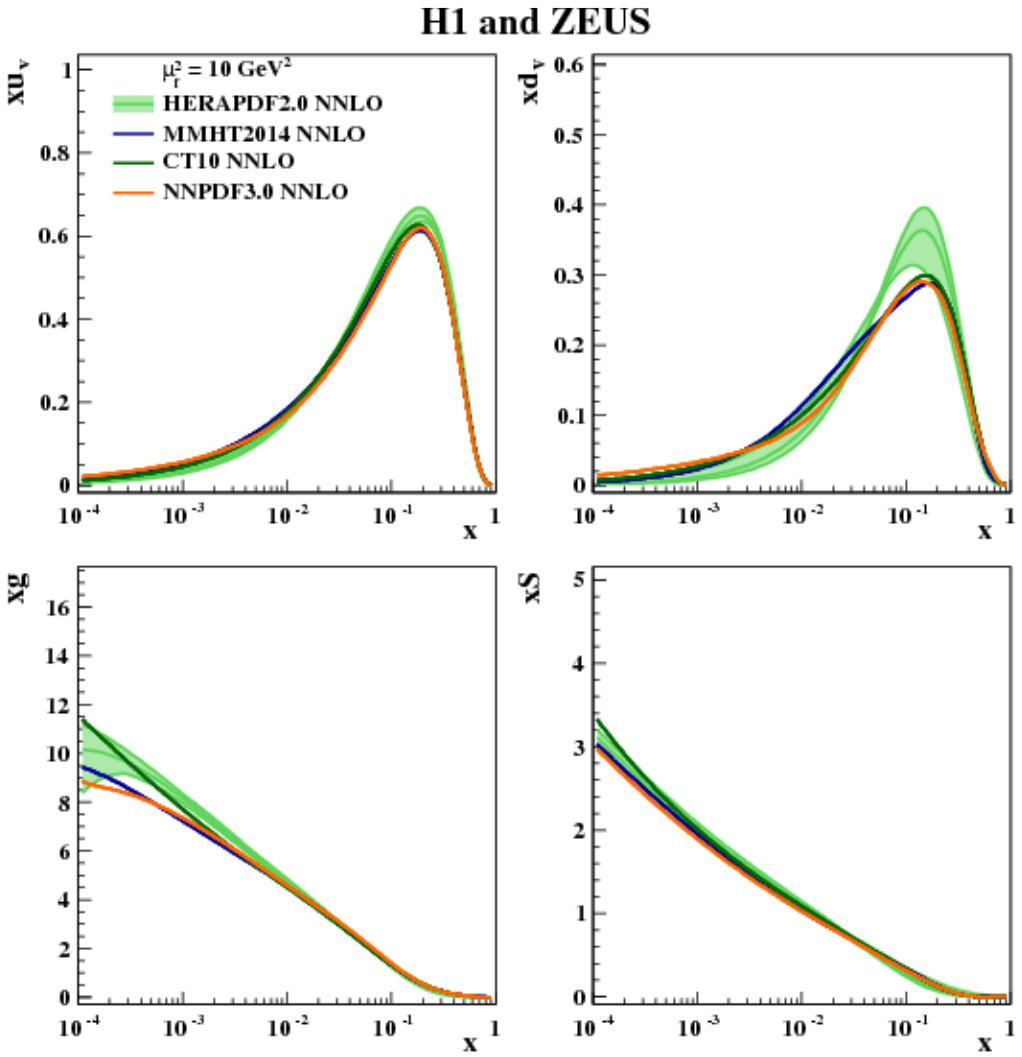
- The PDF presented at various orders of calculations

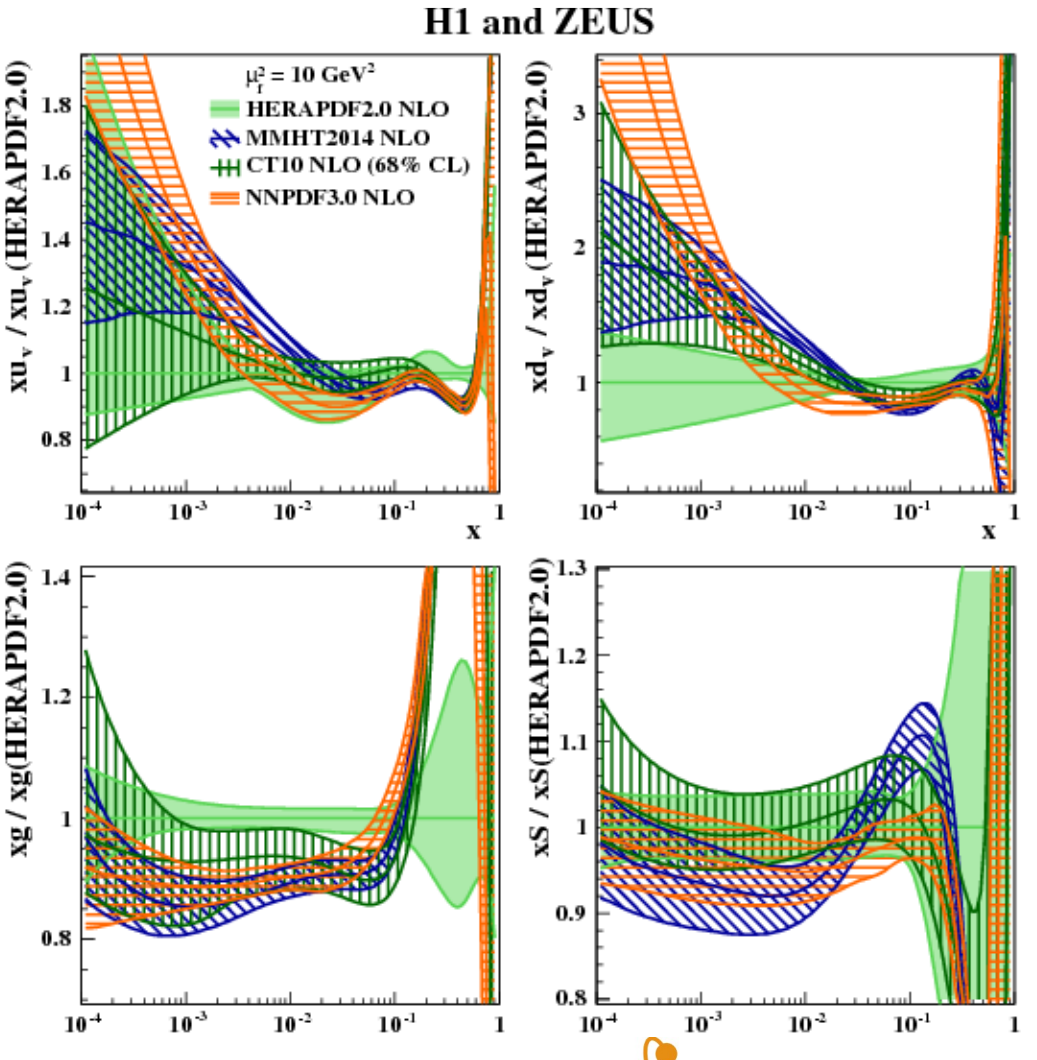
HERAPDF2.0 at LO



- LO parton densities provides for MC event generators

HERAPDF2.0 vs available PDFs





- The largest difference – x u_v at x ~ 0.4
- Various gluon behavior at low x

HERAFitter

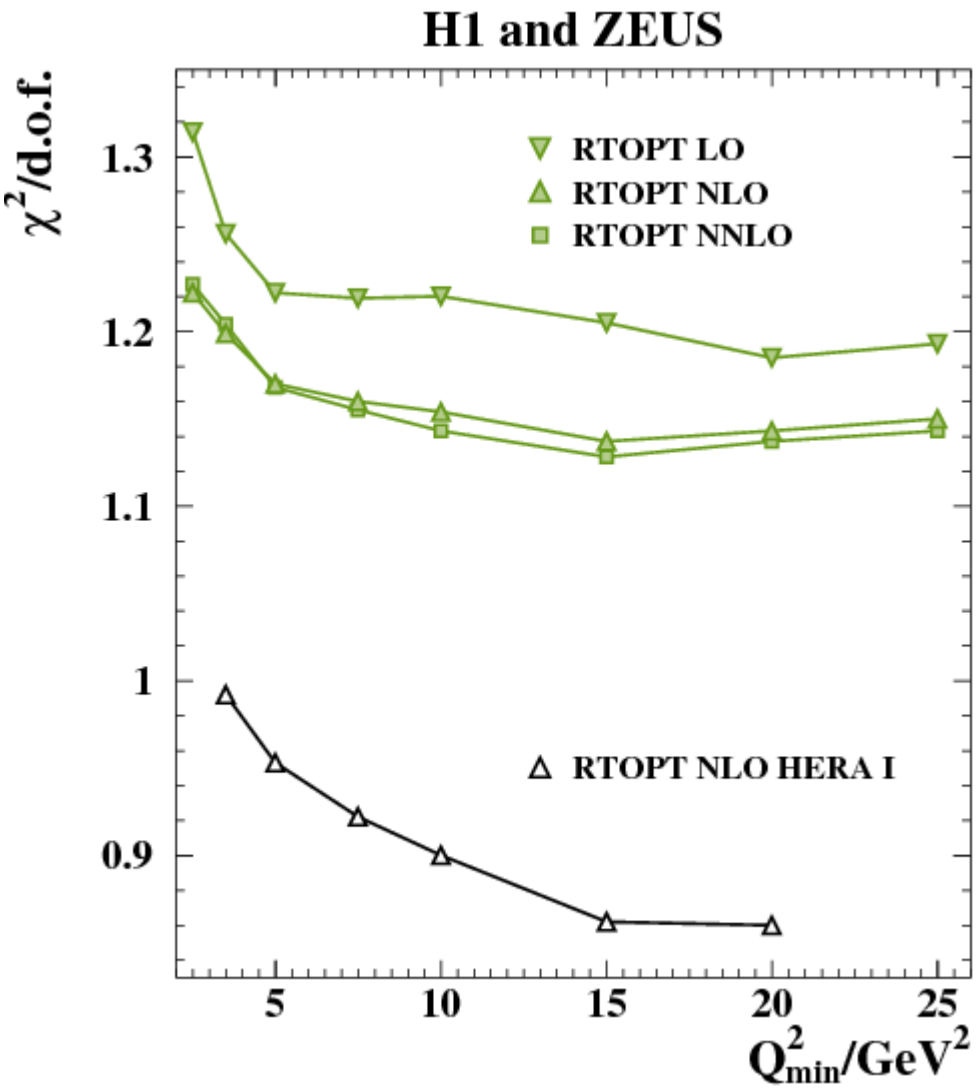
HERAPDF2.0: Q^2_{min} dependence

Q^2_{min} = 3.5 GeV^2 NLO $\frac{\chi^2}{ndf} = \frac{1357}{1131}$

HERAPDF2.0 NNLO $\frac{\chi^2}{ndf} = \frac{1363}{1131}$

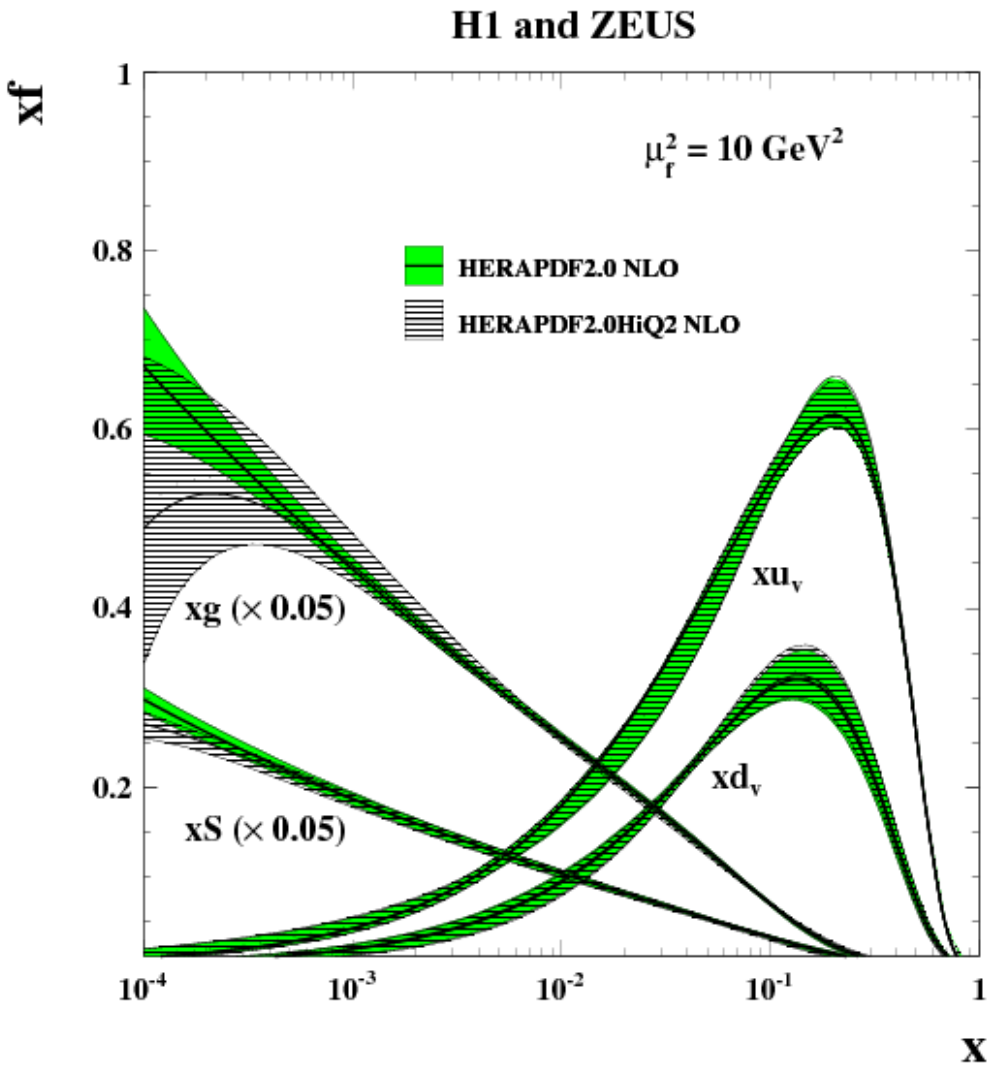
Q^2_{min} = 10 GeV^2 NLO $\frac{\chi^2}{ndf} = \frac{1156}{1002}$

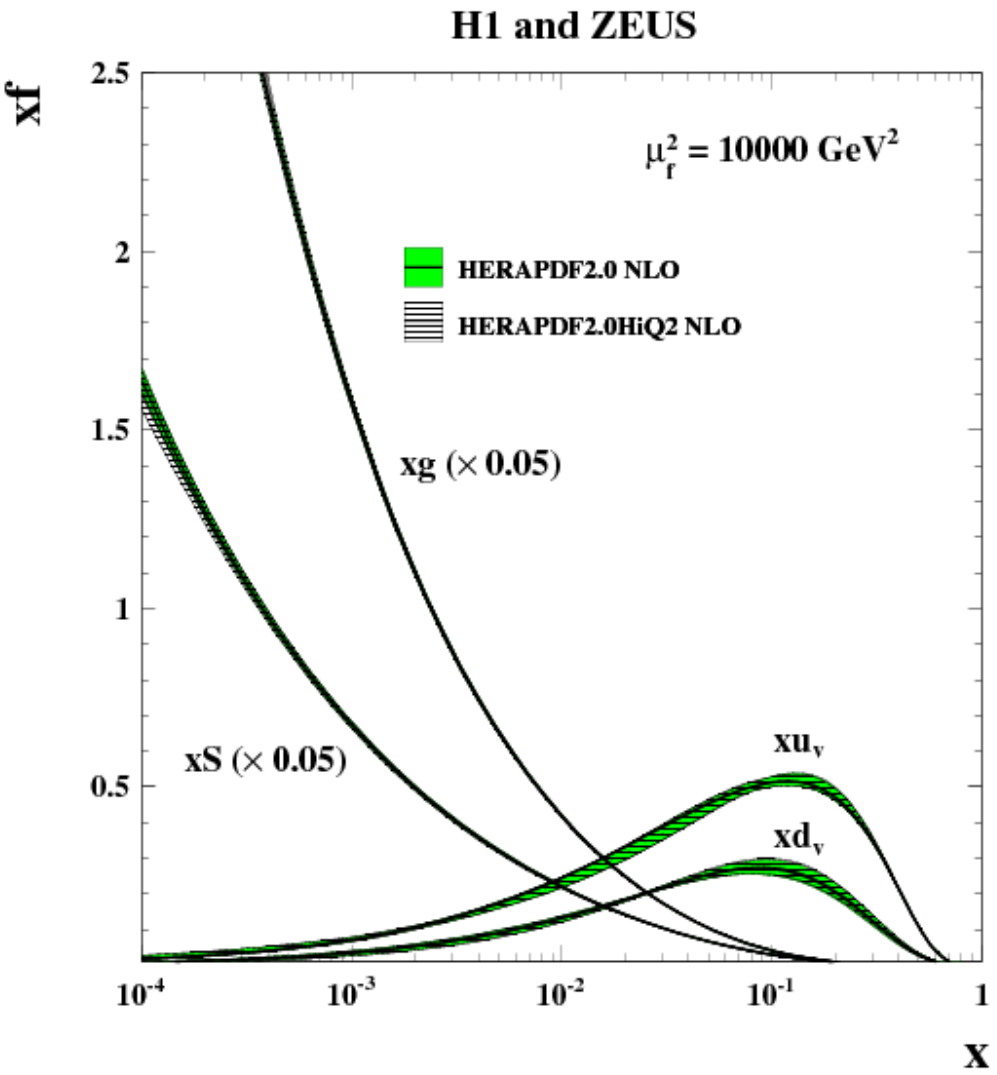
HERAPDF2.0HiQ2 NNLO $\frac{\chi^2}{ndf} = \frac{1146}{1002}$



- shows small tension between low and high Q^2 data

HERAPDF2.0 vs HERAPDF2.0HiQ2

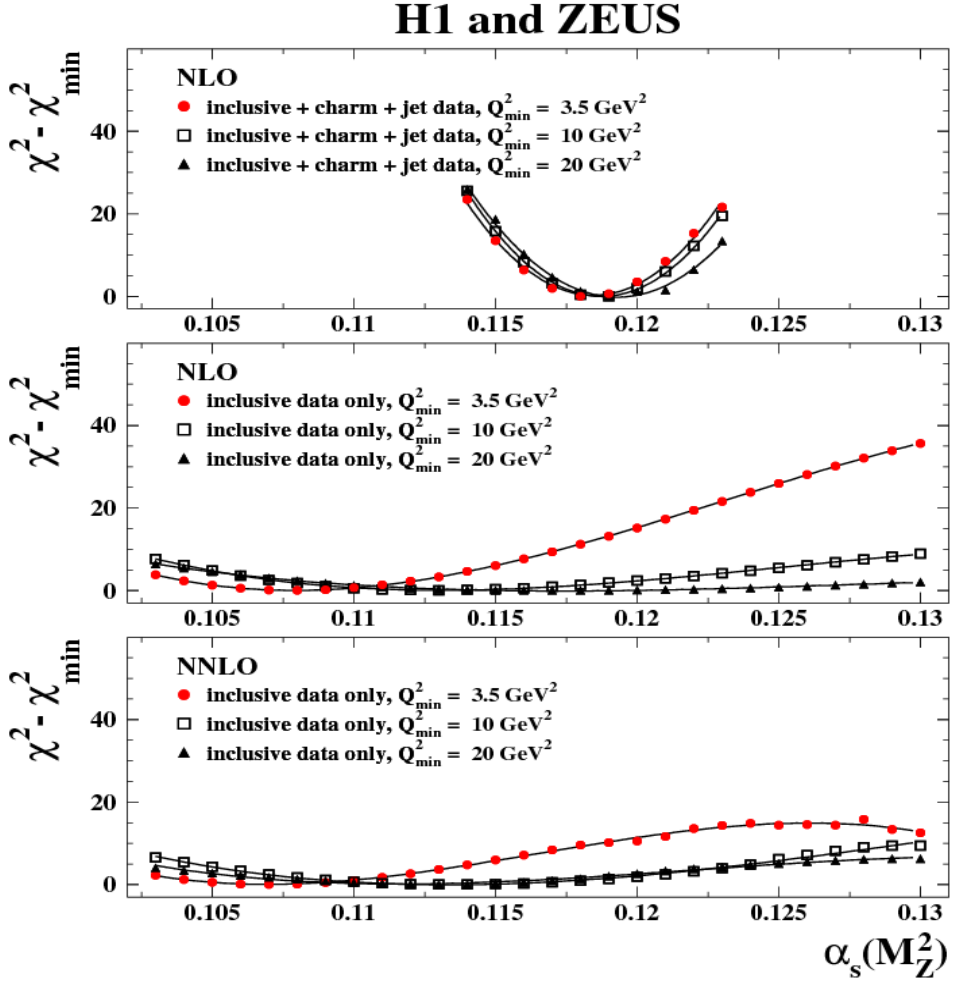




- **Larger uncertainty for HERAPDF2.0HiQ2 gluon at low x (not constrained by data)**
- **PDFs become very alike at higher scales**

HERAPDF2.0 + jets data

ZEUS and H1 jet and charm data were added to inclusive data to acquire sensitivity to α_s



- Minimum of α_s does not depend on Q^2_{min}
- dominant uncertainty coming from scale variation for jets predictions
- inclusive data without additional data almost insensitive to α_s

$$\alpha_s(M^2_z) = 0.1183 \pm 0.0009(exp) \pm$$
$$\pm 0.0005 (model/parameterization) \pm$$
$$\pm 0.0012 (hadronisation) \, ^{+0.0037}_{-0.0030} (scale)$$

Summary

- Combination of full HERAI+II inclusive data performed
- HERAPDF2.0 fits are performed using combined HERAI+II data
- Adding new HERAII data improves PDFs precision
- α_s measurement consistent with world average
- Released PDF sets :
  - HERAPDF2.0 (GMVFNS, with $Q^2_{min} = 3.5\ GeV^2$)
  - HERAPDF2.0HiQ2 (GMVFNS, with $Q^2_{min} = 10\ GeV^2$)
  - HERAPDF2.0AG (HERAPDF2.0 with alternative gluon solution)
  - HERAPDF2.0Jets (HERAPDF2.0 variant with charm and jets data added)
  - HERAPDF2.0FF3A and HERAPDF2.0FF3B (two fixed flavour variants of HERAPDF)