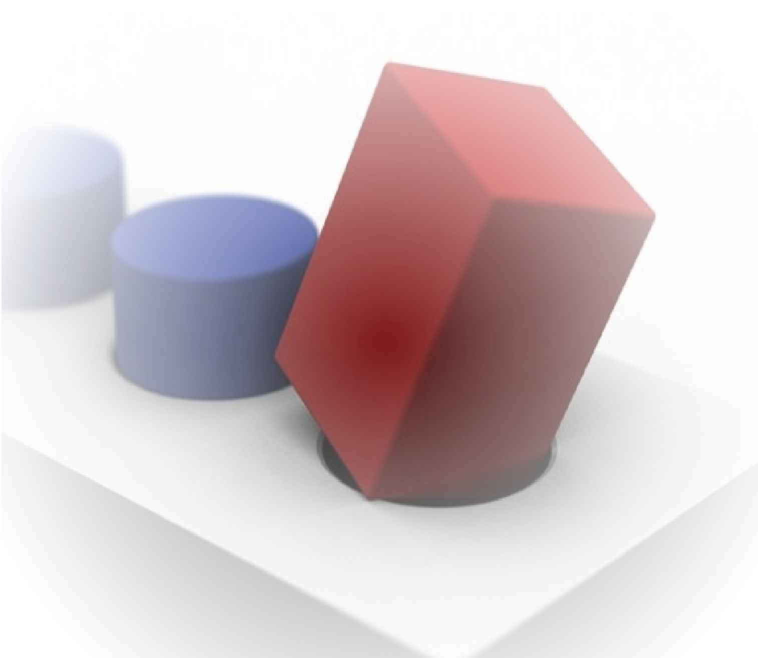
Combined QCD and EW analysis of HERA data



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ZEUS analysis forum
18.11.2015, Hamburg

Analysis setup

- Data used in the analysis (separate datasets, correlations as in HERAPDF2.0):
  - HERAI: H1 + ZEUS;
  - HERAII: H1 unpol. + ZEUS pol.;
  - Reduced E_P runs: H1 + ZEUS;

- HF scheme: GM VFNS NLO (RT OPT).
- $Q_{min}^2 = 3.5$ GeV^2.
- PDFs parametrised with 13p (HERAPDF2.0 - D$\bar{U}$) at $Q_0^2 = 1.9$ GeV^2

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

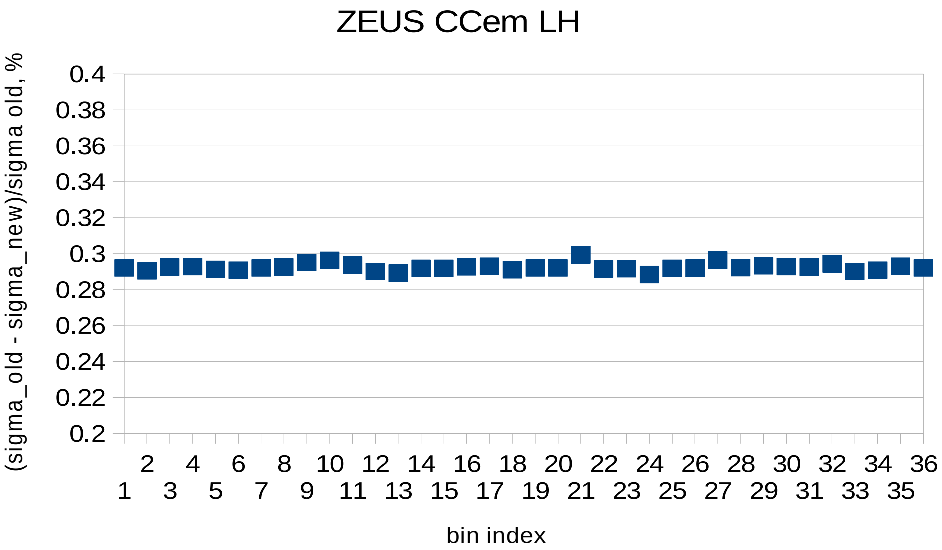
$$xg(x), xu_v(x), xd_v(x), x\bar{U}(x), x\bar{D}(x)$$

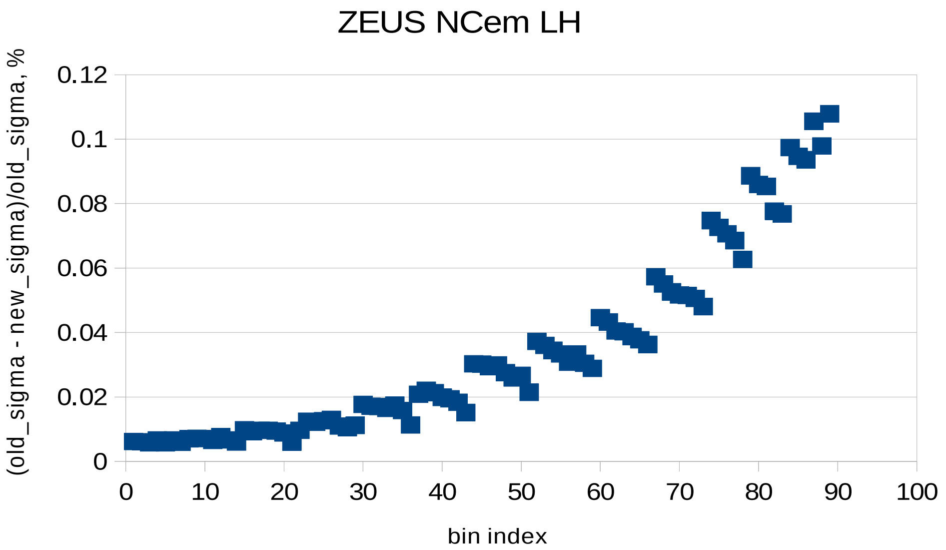
- Free parameters: PDF parameters + couplings of Z^0 to quarks (a_u, a_d, v_u, v_d) or M_W.
- Optimal M_c and M_b and α_S inherited from HERAPDF2.0.
- Model and parametrisation uncertainty estimation → HERAPDF2.0 strategy.
- Correction calculated using EPRC code: Δr^{QCD} order α_S. No QED corrections.

Polarisation update

- Correction from QCD predictions (PDF → HERAPDF2.0)

$$\sigma_{pol}^{\pm NEW} = \frac{\sigma_{NEW\,P_e}^{pred}}{\sigma_{OLD\,P_e}^{pred}} \sigma_{pol}^{\pm OLD}$$





- Very tiny effect on the cross sections.

- Uncertainties due to polarisation were also estimated (treated as correlated in the analysis).

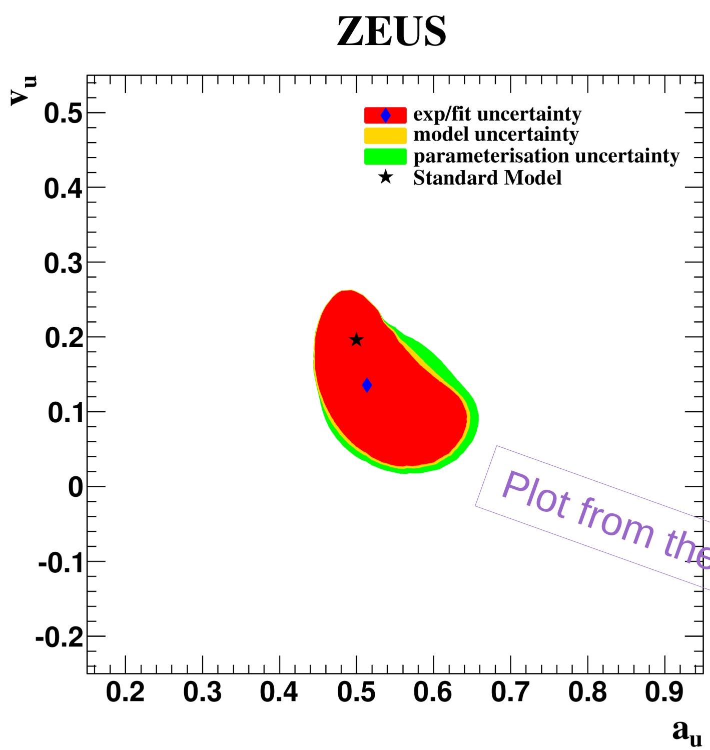
More details in dedicated talk on 07.10.2015

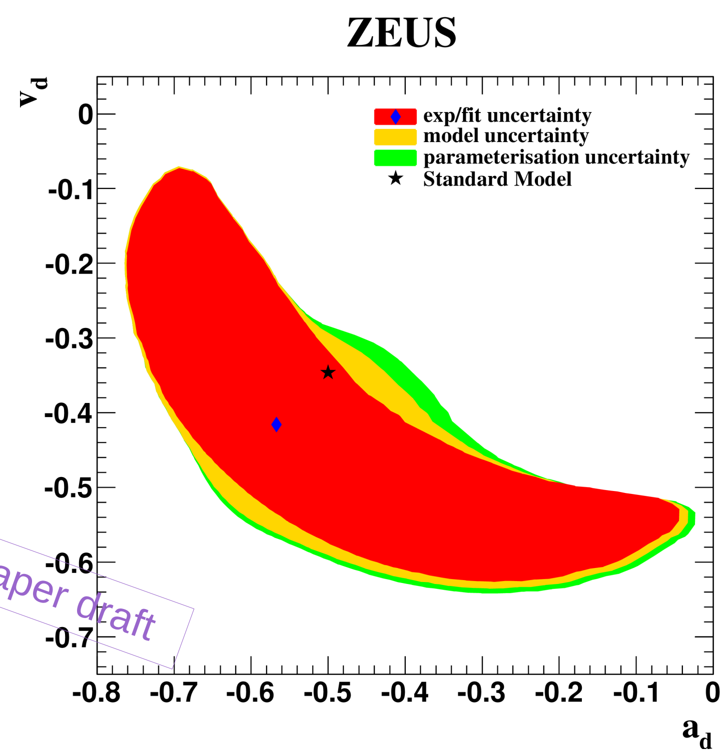
Couplings of light quarks to Z boson

- Couplings were determined simultaneously with PDFs (**ZEUS-EW-Z**)

	SM
$a_u = +0.514\ ^{+0.088}_{-0.049}(\mathrm{exp})\ ^{+0.036}_{-0.017}(\mathrm{model})\ ^{+0.061}_{-0.006}(\mathrm{param})$	**0.5**
$a_d = -0.567\ ^{+0.345}_{-0.148}(\mathrm{exp})\ ^{+0.115}_{-0.051}(\mathrm{model})\ ^{+0.106}_{-0.005}(\mathrm{param})$	**-0.5**
$v_u = +0.136\ ^{+0.093}_{-0.078}(\mathrm{exp})\ ^{+0.015}_{-0.027}(\mathrm{model})\ ^{+0.000}_{-0.039}(\mathrm{param})$	**0.196**
$v_d = -0.416\ ^{+0.249}_{-0.168}(\mathrm{exp})\ ^{+0.042}_{-0.083}(\mathrm{model})\ ^{+0.000}_{-0.044}(\mathrm{param})$	**-0.346**

- 2D uncertainties were also evaluated.



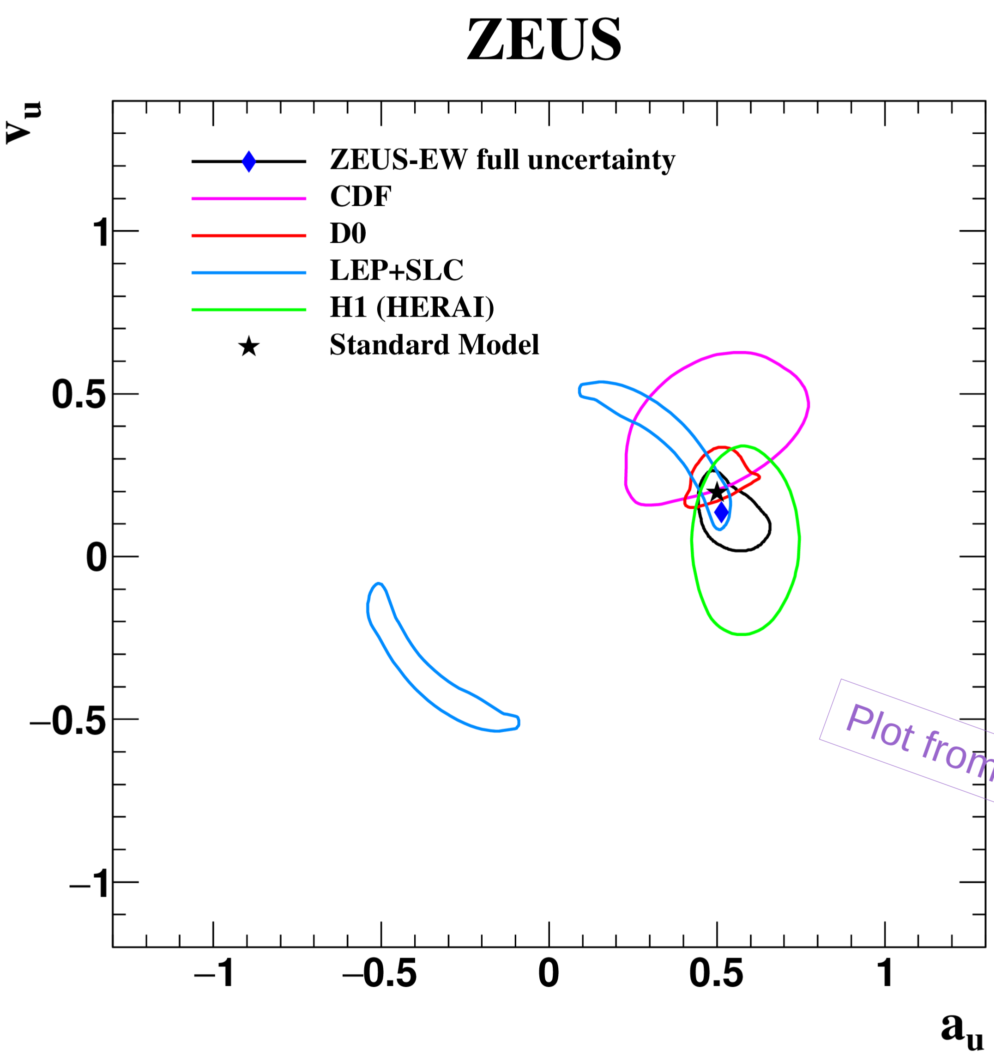


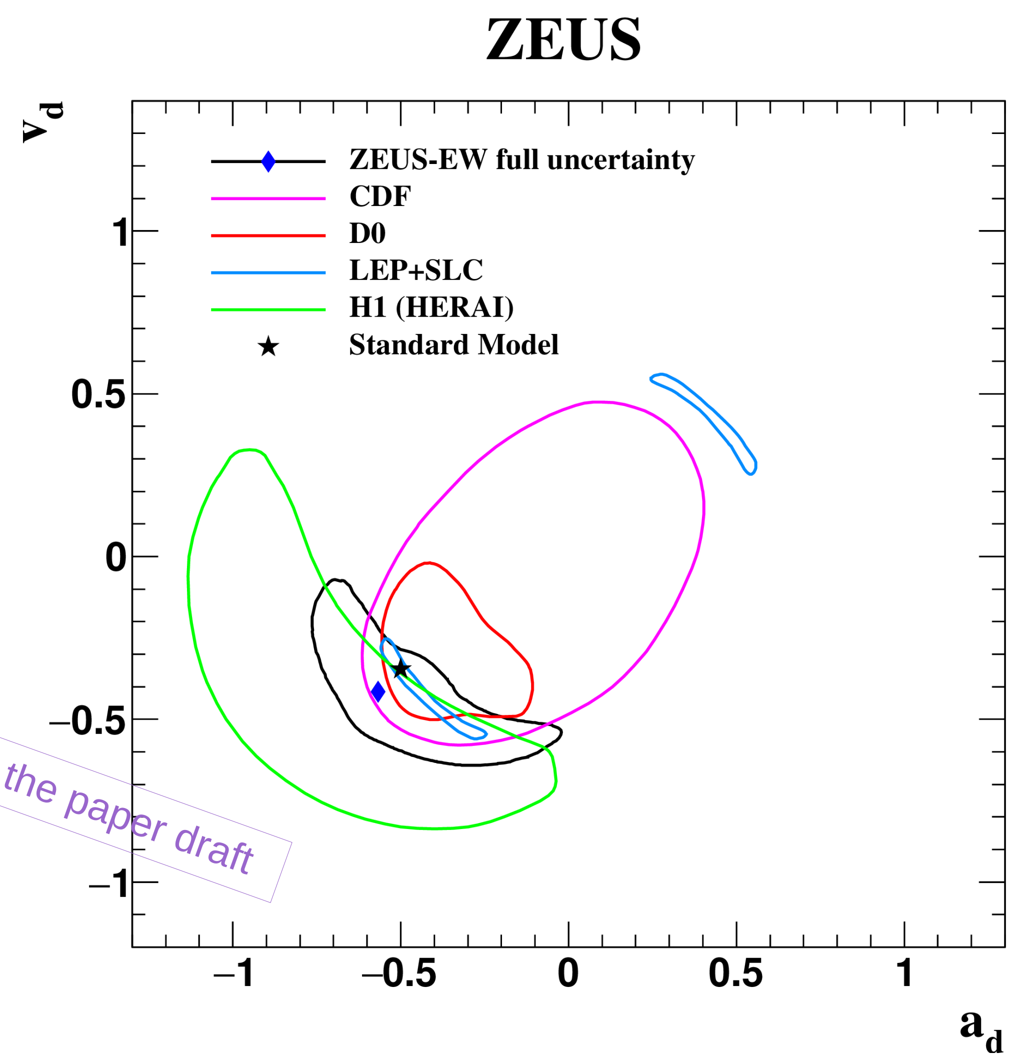
Plot from the paper draft

Mod/par variations in backup

Couplings of light quarks to Z boson

- ZEUS-EW-Z results are compatible with previous measurements



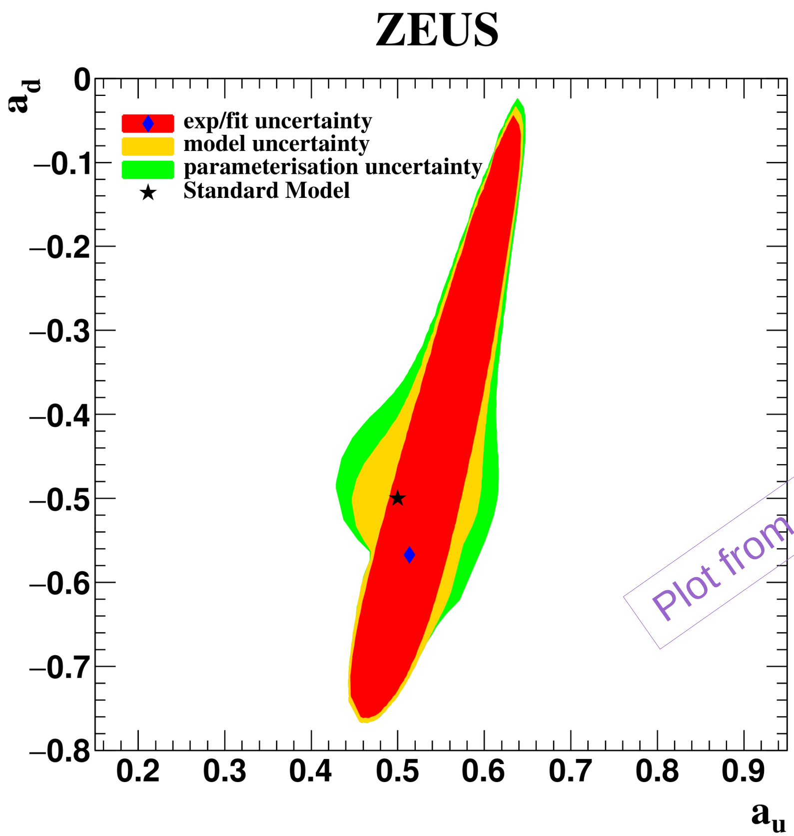


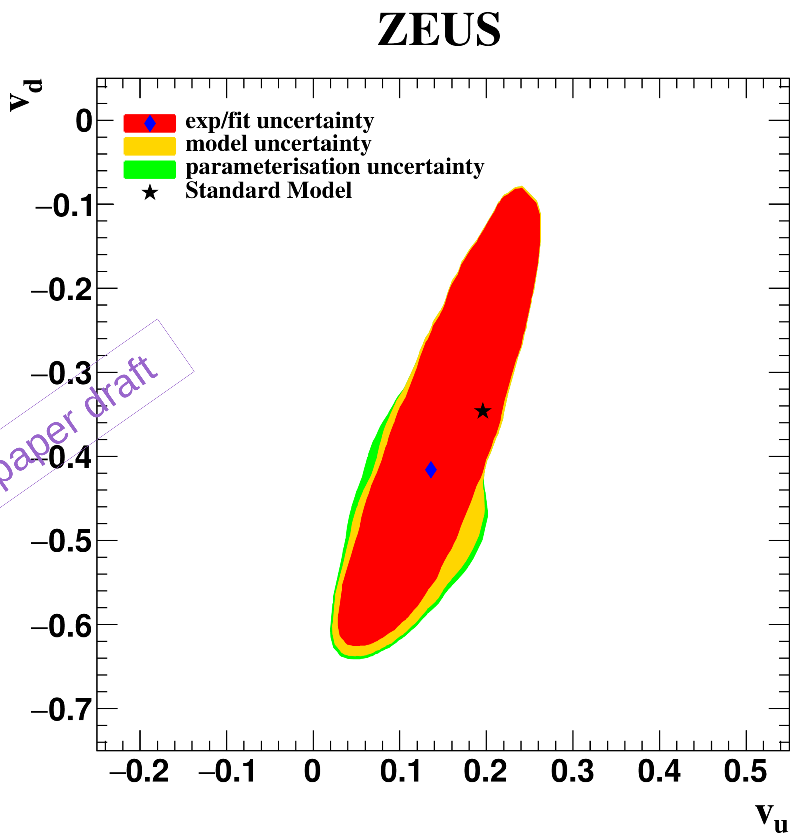
Plot from the paper draft

Comparison of numerical values in backup

Couplings of light quarks to Z boson

- Couplings in the fit show pretty high correlation
- Correlation of couplings to PDF parameters is weak (see also slides 9 and 10)

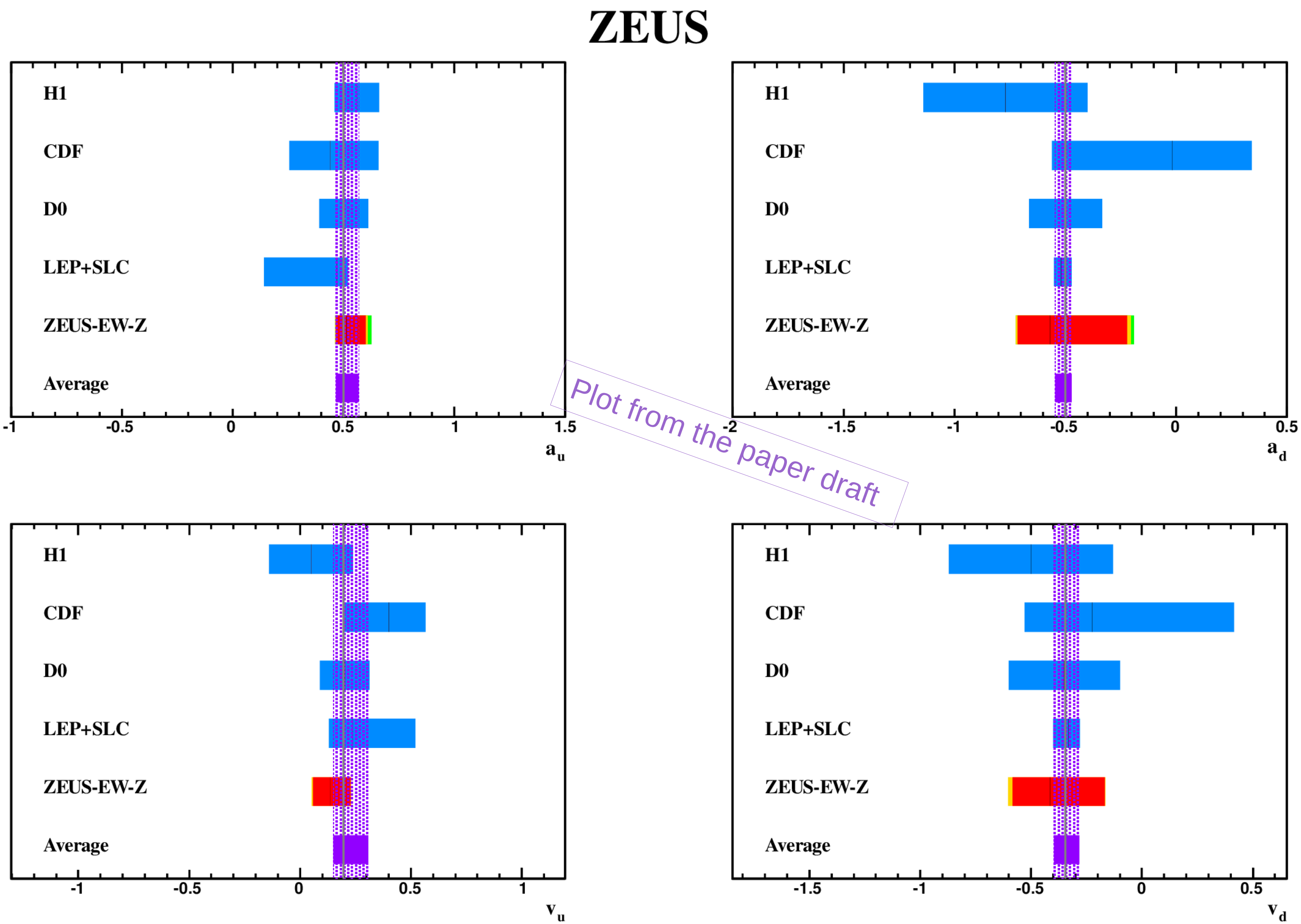




	a_u	a_d	v_u	v_d
a_u	1.000	0.879	−0.604	−0.753
a_d	0.879	1.000	−0.692	−0.900
v_u	−0.604	−0.692	1.000	0.871
v_d	−0.753	−0.900	0.871	1.000

Full correlation table in backup

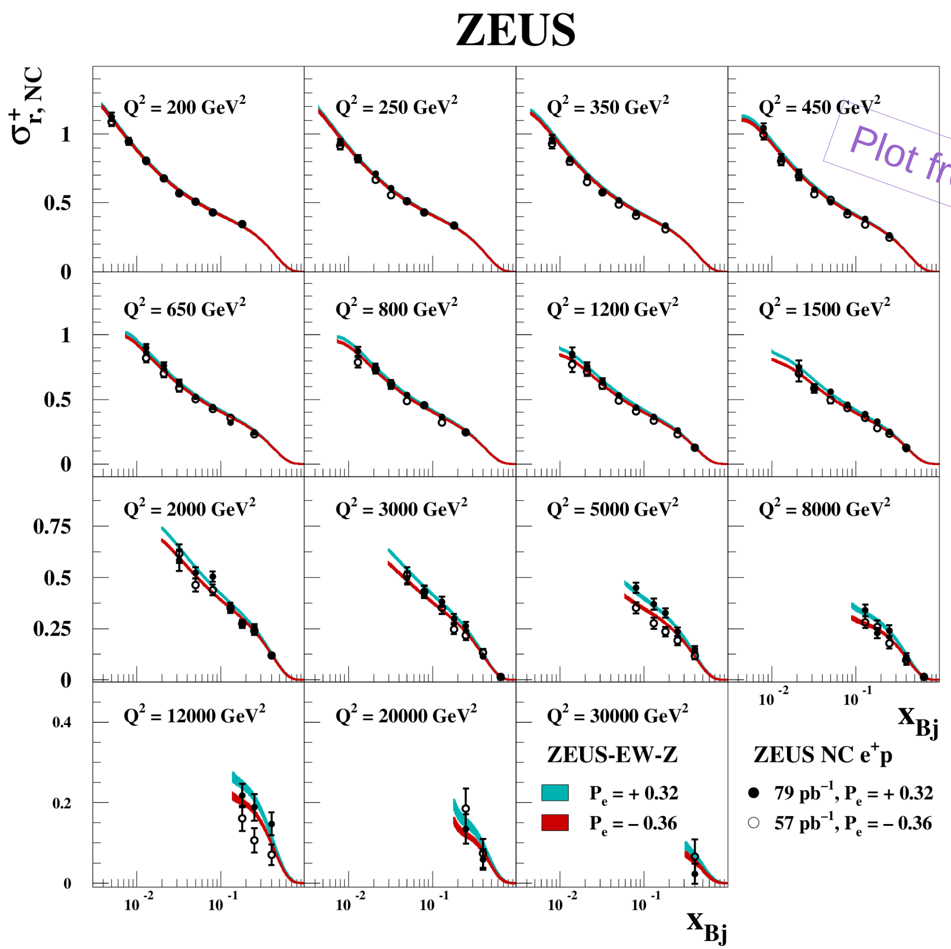
Couplings of light quarks to Z boson

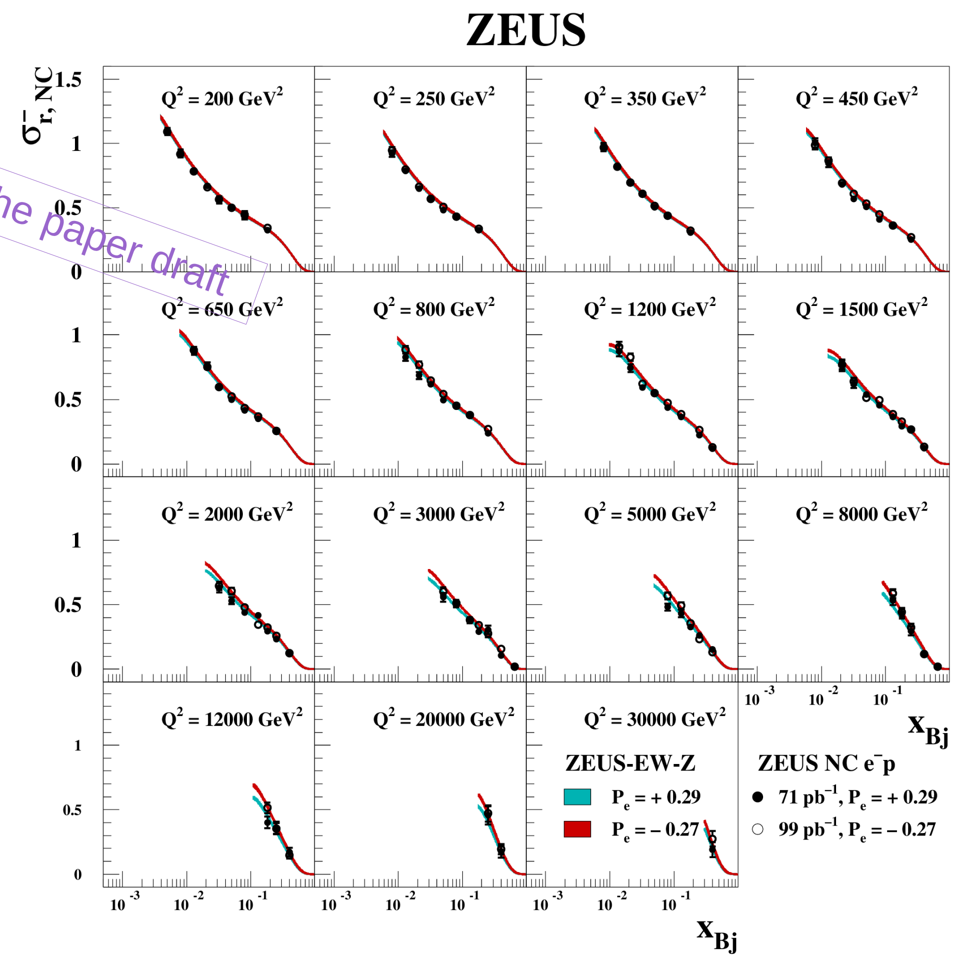


- Naive averaging shows, ZEUS-EW-Z measurements are so far the most precise for u-quarks.

Data description (ZEUS-EW-Z)

- Fitted predictions describe data very well.

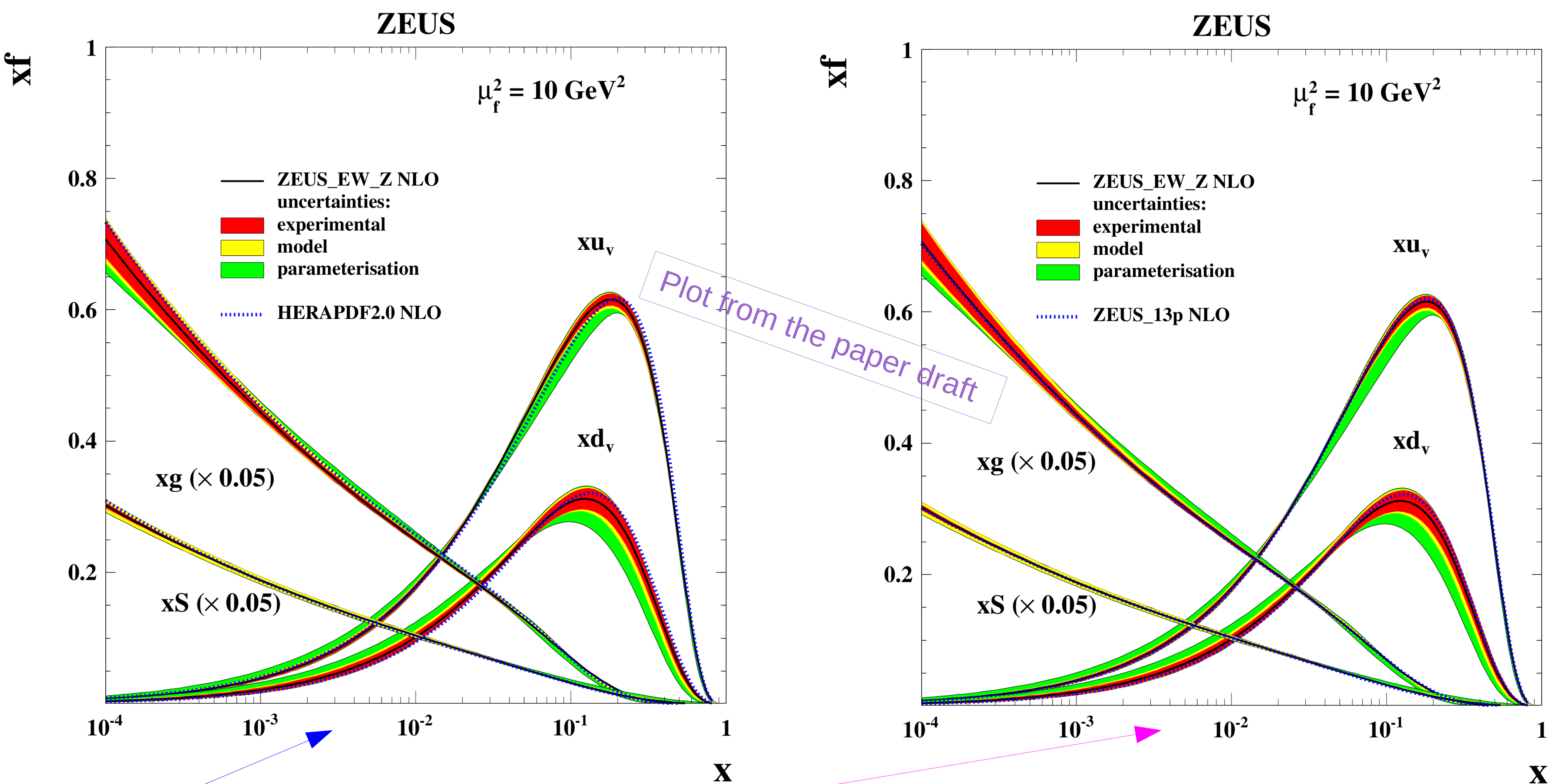




Plot from the paper draft

- χ^2 = 3269 / 2925 = 1.118

Effect of coupling determination on PDFs



- HERAPDF2.0 and ZEUS-13p PDFs with couplings set to SM agree with ZEUS-EW-Z PDFs.
- PDFs do not absorb any non-SM effects which could show up in EW couplings.

Effect of PDFs determination on couplings

- Couplings, fitted at fixed PDFs are well compatible with those from ZEUS-EW-Z fit.

	a_u	exp	tot	a_d	exp	tot	v_u	exp	tot	v_d	exp	tot
EW-Z	$+.514$	$^{+.088}_{-.049}$	$^{+.113}_{-.052}$	$-.567$	$^{+.345}_{-.148}$	$^{+.379}_{-.157}$	$+.136$	$^{+.093}_{-.078}$	$^{+.094}_{-.091}$	$-.416$	$^{+.249}_{-.168}$	$^{+.252}_{-.193}$
13p+Z	$+.497$	$^{+.075}_{-.034}$		$-.582$	$^{+.303}_{-.110}$		$+.138$	$^{+.081}_{-.078}$		$-.407$	$^{+.221}_{-.176}$	
HPDF+Z	$+.486$	$^{+.061}_{-.034}$		$-.634$	$^{+.239}_{-.110}$		$+.149$	$^{+.078}_{-.078}$		$-.357$	$^{+.220}_{-.194}$	
SM	$+.500$			$-.500$			$+.196$			$-.346$		

- Differences in the experimental uncertainties can give a rough estimate of PDF uncertainties in the measurement.

Cross-checks: HERAFitter vs ZEUSFitter

Parameter	HF Volodymyr	HF Katarzyna	ZF Amanda
'Bg'	-0.068 ± 0.074	-0.068 ± 0.085	-0.07 ± 0.13
'Cg'	8.50 ± 0.84	8.50 ± 0.84	8.5 ± 1.1
'Aprig'	1.41 ± 0.60	1.41 ± 0.62	1.35 ± 0.53
'Bprig'	-0.158 ± 0.058	-0.158 ± 0.064	-0.16 ± 0.12
'Cprig'	25.00	25.00	25.00
'Buv'	0.742 ± 0.026	0.742 ± 0.026	0.737 ± 0.026
'Cuv'	4.698 ± 0.089	4.698 ± 0.089	4.675 ± 0.088
'Euv'	9.2 ± 1.3	9.2 ± 1.3	9.2 ± 1.2
'Bdv'	0.763 ± 0.077	0.763 ± 0.077	0.741 ± 0.076
'Cdv'	4.38 ± 0.33	4.38 ± 0.33	4.34 ± 0.35
'CUbar'	3.56 ± 0.48	3.56 ± 0.48	3.61 ± 0.50
'ADbar'	0.1976 ± 0.0088	0.1976 ± 0.0088	0.1959 ± 0.0091
'BDbar'	-0.1583 ± 0.0054	-0.1583 ± 0.0054	-0.1586 ± 0.0055
'CDbar'	4.1 ± 1.1	4.1 ± 1.1	3.6 ± 1.1
'alphas'	0.1180	0.1180	0.1180
'fs'	0.4000	0.4000	0.4000
'auEW'	0.514 ± 0.057	0.514 ± 0.057	0.520 ± 0.064
'adEW'	-0.57 ± 0.21	-0.57 ± 0.21	-0.55 ± 0.23
'vuEW'	0.136 ± 0.084	0.136 ± 0.084	0.136 ± 0.087
'vdEW'	-0.42 ± 0.21	-0.42 ± 0.21	-0.41 ± 0.23
Fit status	converged	converged	undefined
Uncertainties	migrad-hesse	migrad-hesse	migrad-hesse
Total χ^2 / dof	3270 / 2925	3270 / 2925	3269 / 2925

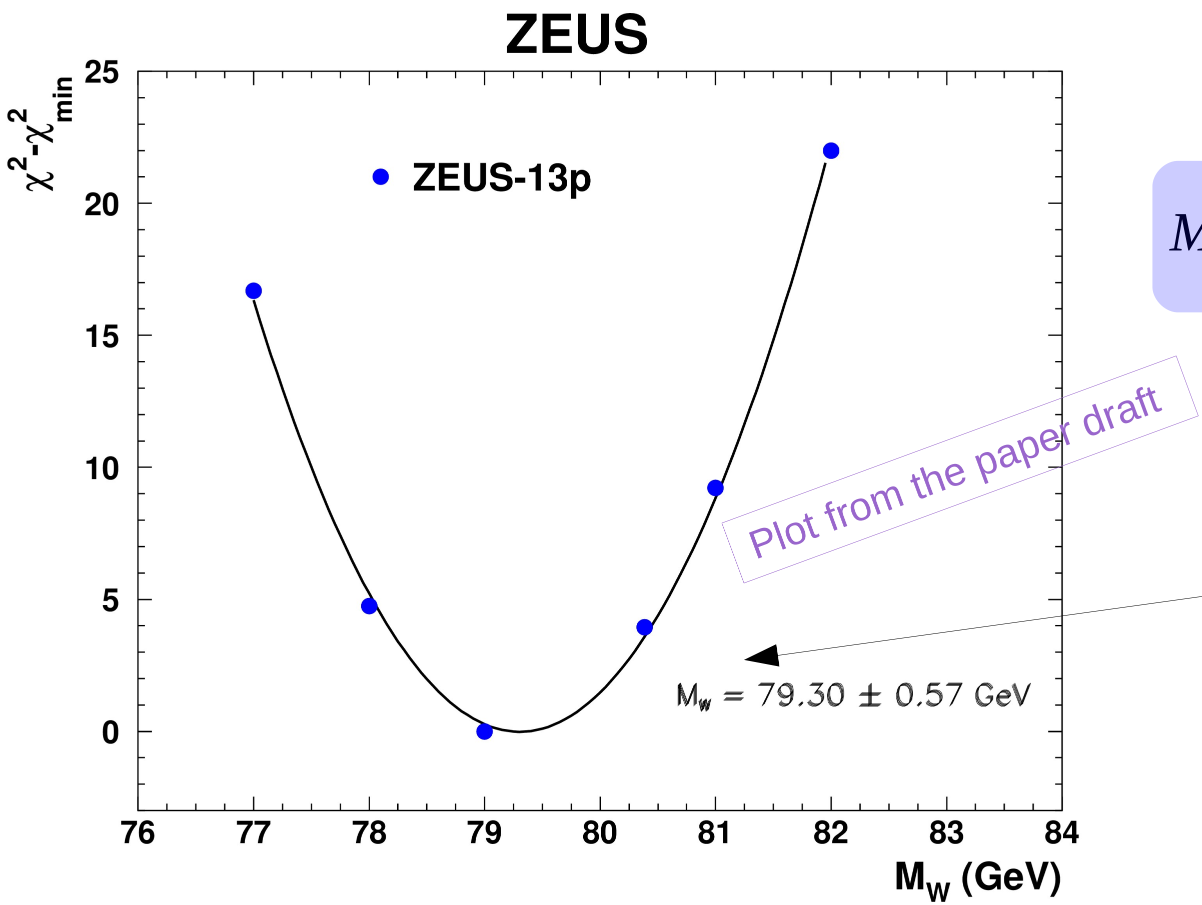
- Very close results from different codes.

PDF comparison @ 1.9GeV^2 in backup

Mass of W boson

- Mass of W boson was determined simultaneously with PDFs (**ZEUS-EW-W**)

$$M_W = 79.20 \pm 0.56(\mathrm{exp})\ ^{+0.06}_{-0.18}(\mathrm{model})\ ^{+0.02}_{-0.60}(\mathrm{param})\ \mathrm{GeV}$$



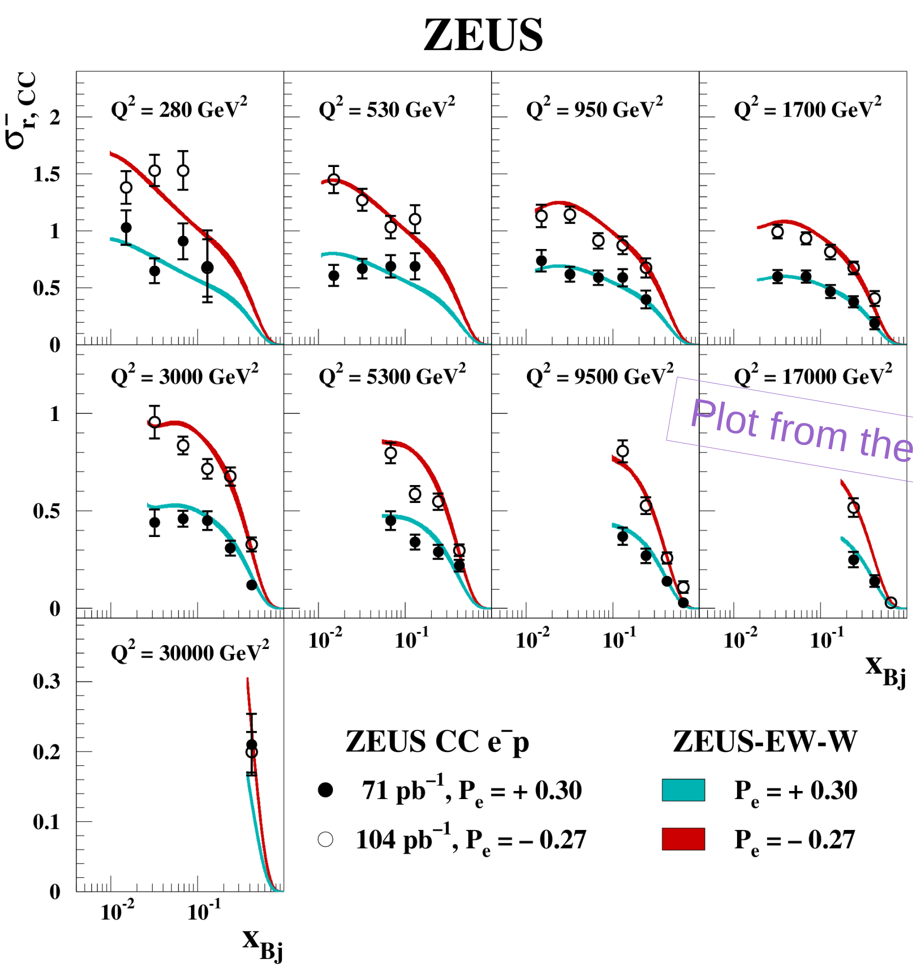
$$M_W^{World\ average} = 80.385 \pm 0.015\, GeV$$

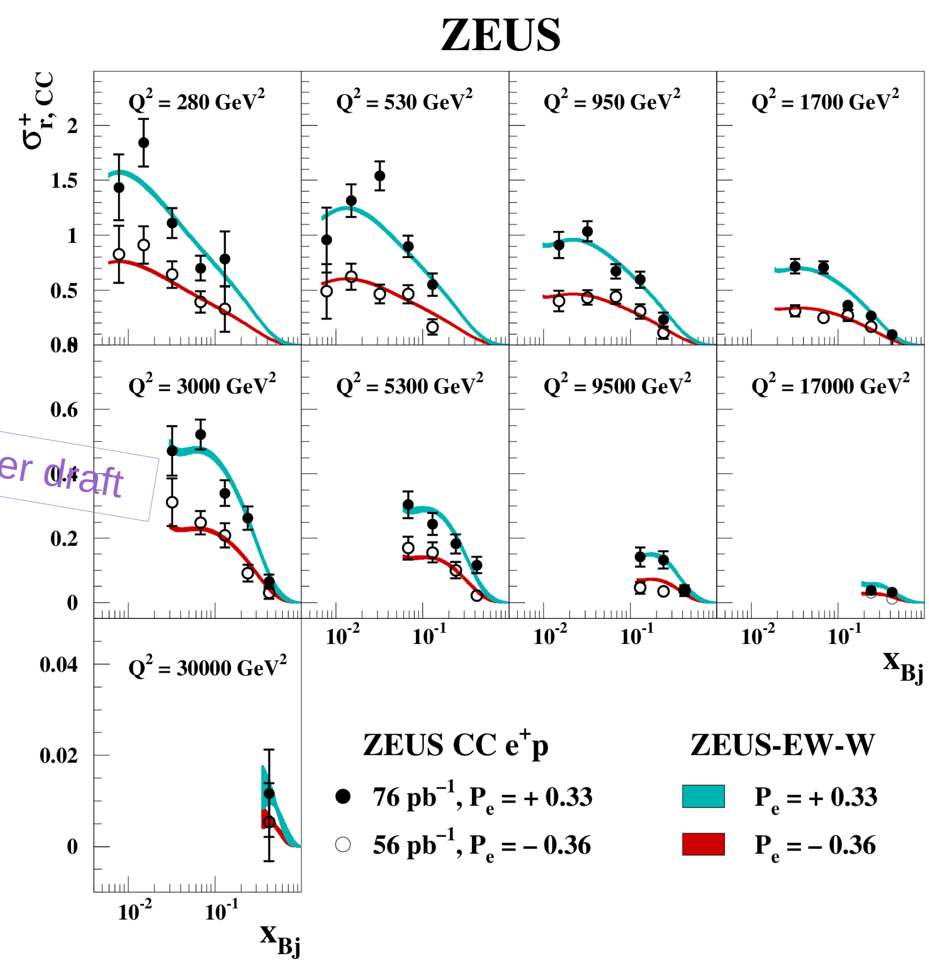
Gaussian extrapolation

- M_W form ZEUS-EW-W is consistent with current world average.

Data description (ZEUS-EW-W)

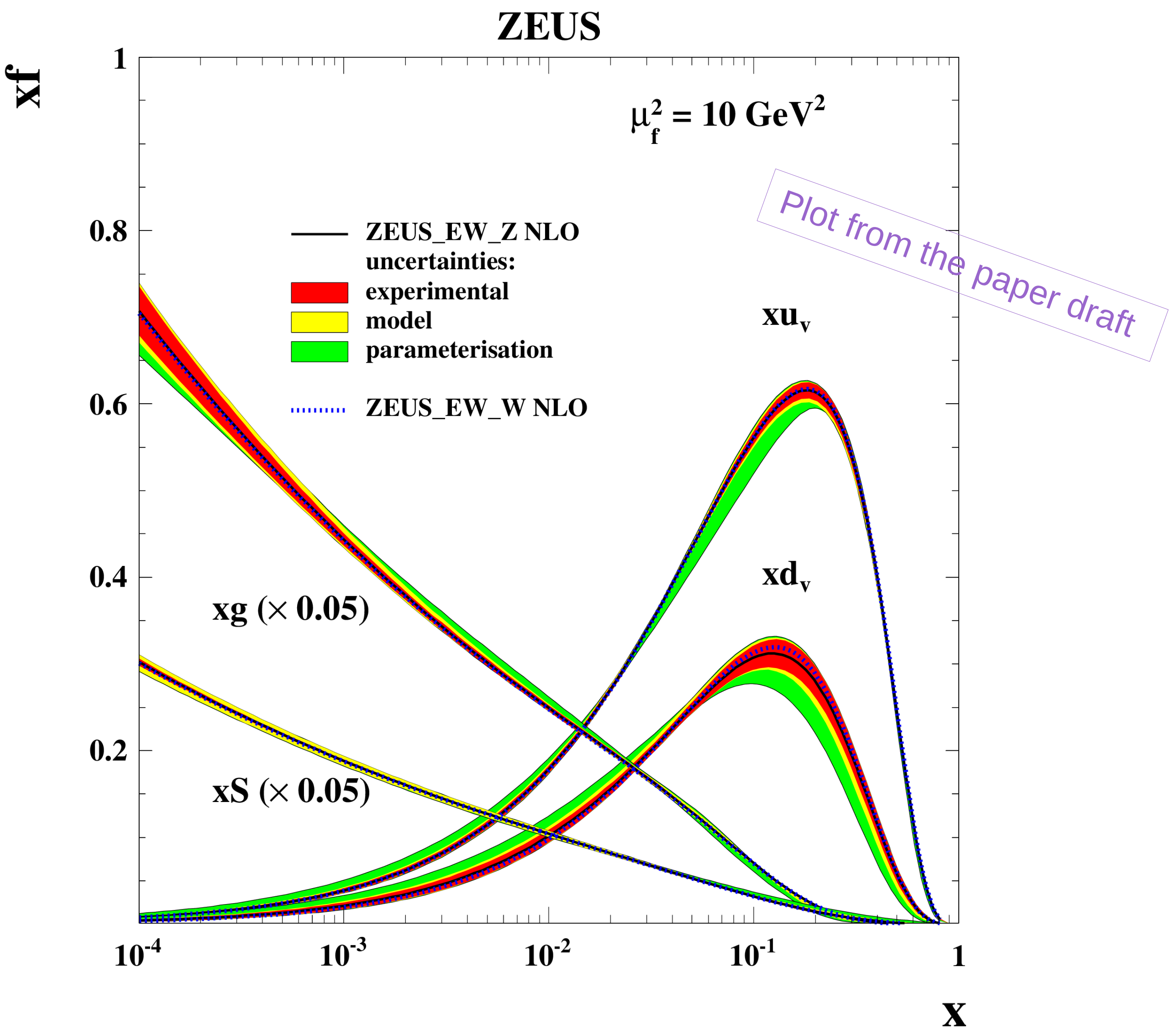
- Fitted predictions describe data very well.





- χ^2 = 3268 / 2928 = 1.118

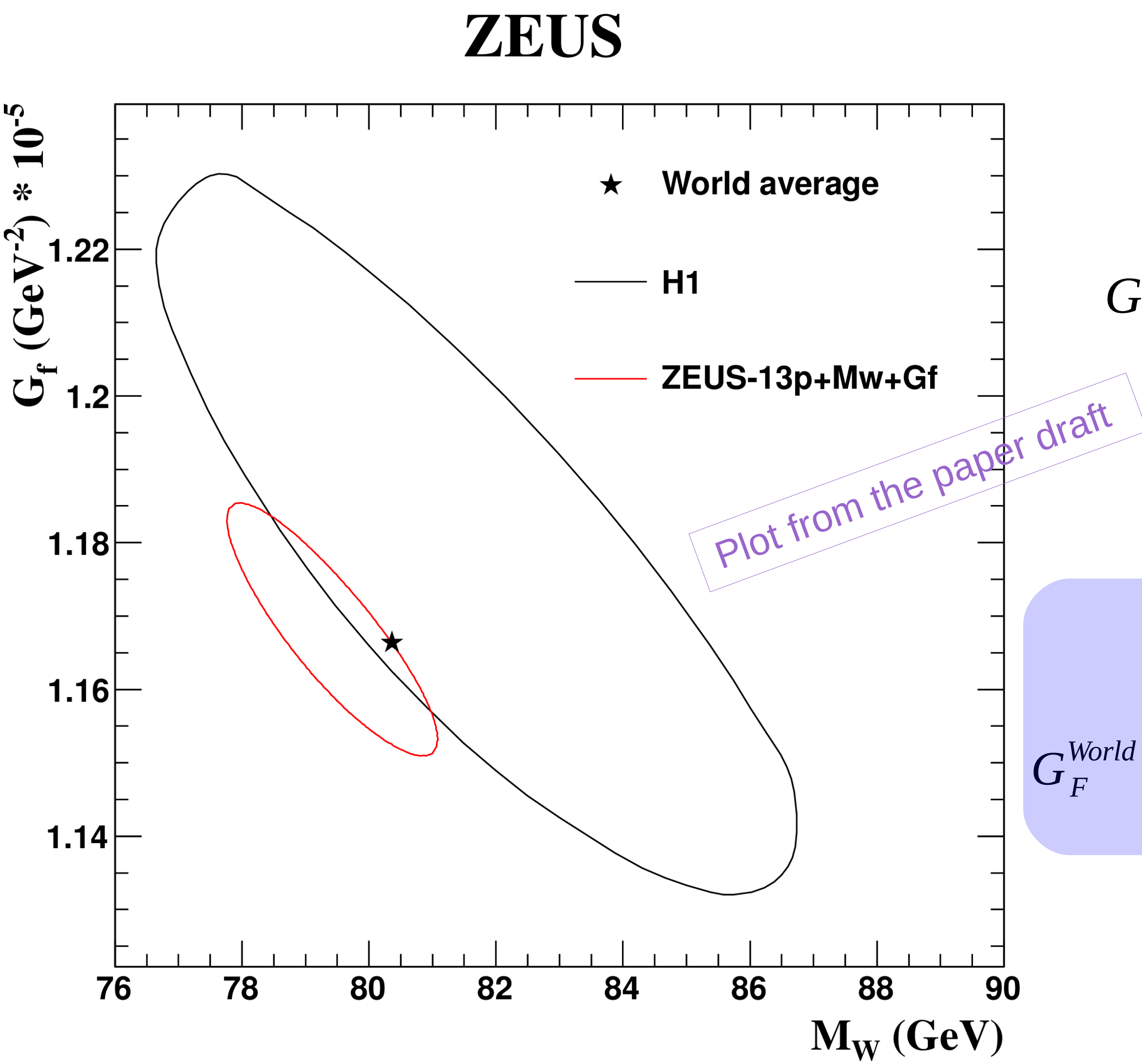
ZEUS-EW-Z vs ZEUS-EW-W



- PDFs from ZEUS-EW-Z and ZEUS-EW-W are very similar.

G_F and mass of W boson

- G_F and mass of W boson were also determined simultaneously with PDFs



$$M_W = 79.43 \pm 1.15\,(\exp)\,GeV$$

$$G_F = 1.1680 * 10^{-5} \pm 0.0118\,(\exp)\,GeV^{-2}$$

$$corr\,(M_W, G_F) = -0.87$$

$$M_W^{World\ average} = 80.385 \pm 0.015\,GeV$$

$$G_F^{World\ average} = 1.1663787 * 10^{-5} \pm 6 * 10^{-12}\,GeV^{-2}$$

- Fitter G_F and M_W are consistent with current world average values.

Summary

- QCD and EW analysis of HERA data was performed.
- Couplings of light quarks to Z boson were determined (ZEUS-EW-Z).
  - Fitted couplings are consistent with SM predictions;
  - Results are compatible with those frome other measurements;
  - Couplings of u-quark are constrained significantly better than those of d-quarks.
- Mass of W boson was determined (ZEUS-EW-W).
  - Fitted value of M_W is consistent with current world average;
- Mass of W boson and Fermi constant G_F were determined.
  - Fitted value of M_W and G_F are consistent with current world average values;

- Paper draft of the analysis can be found at:

http://www.desy.de/~myronv/ZEUSEW/

Questions / answers

Misha

0) l. 67-75 Do I understand correctly, that in fact we measure a_U, v_U and a_D, v_D, as we do to distinguish between flavours in the see?

Yes, we can separate flavours (not in the sea though).

1) why don't we consider NNLO fit? This would be interesting at least as a cross check.

	a_u	a_b	v_u	v_d	chi2
ZEUS-EW-Z (NNLO)	0.454	-0.609	0.128	-0.452	3283
ZEUS-EW-Z	$0.514^{+0.113}_{-0.052}$	$-0.567^{+0.379}_{-0.157}$	$0.136^{+0.094}_{-0.091}$	$-0.416^{+0.252}_{-0.193}$	3269
SM	0.5	-0.5	0.196	-0.346	

NNLO fits are very unstable. In the current cross-check HESSE did not converge.

2) I'm confused about the data sample used in the analysis. From the description it is unclear to me how the polarised ZEUS data samples were usedtogether with the HERAI+II combined data .

Data used: ZEUS and H1 HERAI data + H1 HERAII unpolarised data + ZEUS HERAII polarised data + H1 and ZEUS data from runs with reduced proton energy.

All the correlations are preserved as in the HERAPDF2.0 combination.

Misha

3) l.189: how the 68% CL is defined? Does it cover 68% of the 2D pdf? does it correspond to deltaChi2=1 criteria of the 2D chi2 (what are the values of other 2 couplings? are they frozen?)

> This is basically a MINOS approach: you shift two of your parameters away from the optimal values, fix them and refit all the other parameters in the fit. In such a way one can probe the contour, alone which you have (chi2 - chi2_min) = 2.3 (CL = 68% for 2D case).

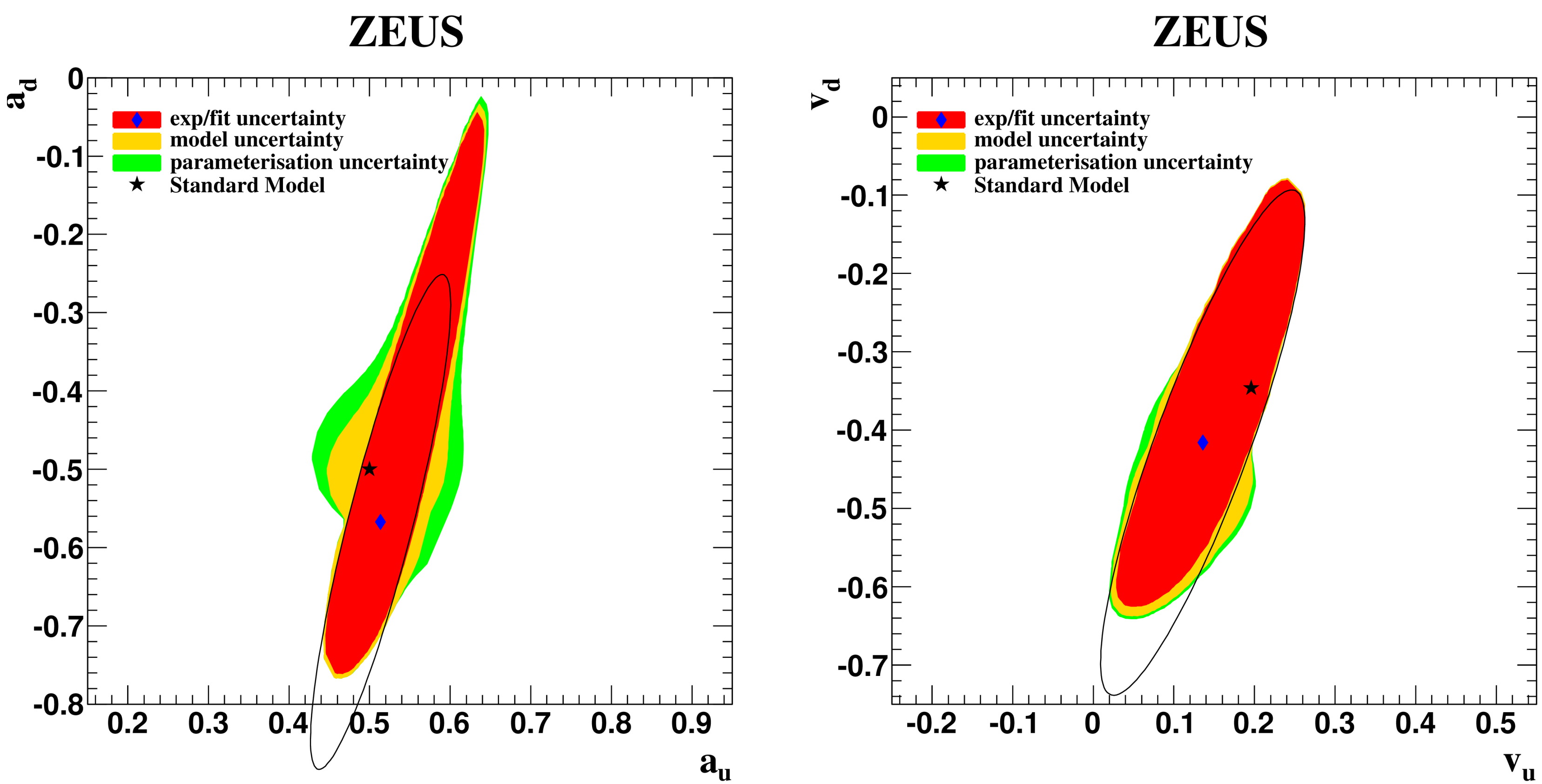
4) Fig. 7: I think we should remove the average. We know the values are correlated with each other within each other and very significantly (for us and LEP at least) and we neglect this significant correlation. We also see that some values have very asymmetric uncertainties (e.g. LEP a_u and v_u) and we had to make some symmetrisation assumptions to use some simple average most likely.

> I symmetrised measurements before averaging. however, for the u-quarks our result, as one can see is not that asummetric, and it strongly dominates the average value. in the d-quark case it is LEP who dominates in the average and there it is also not that asymmetric. So symmetrisation here is not so significant, I guess. In addition, neglecting possible correlations between the experiments means overestimating the uncertainty of average result. This plot has just an illustrative purpose

Misha

5) Fig. 8: please check these plots as the correlation seems to be not very significant on this plots (tilt is far from ~pi/4), whereas the correlation table quotes coefficients ~0.9. Is it due to funny model + param. uncertainties? Can we get stat-only correlation coefficient for a visual check (not to include in the draft)?

Checked. All fine.



Quark couplings to Z

Now consider fits to electroweak NC couplings as well as PDF parameters

The total cross-section : $\sigma = \sigma^0 + P\,\sigma^P$

The unpolarised cross-section is given by $\sigma^0 = Y_+ F_2^0 + Y_- xF_3^0$

$$F_2^0 = \Sigma_i\, A_i^0(Q^2)\,[xq_i(x,Q^2) + x\bar{q}_i(x,Q^2)]$$

$$xF_3^0 = \Sigma_i\, B_i^0(Q^2)\,[xq_i(x,Q^2) - x\bar{q}_i(x,Q^2)]$$

$$A_i^0(Q^2) = e_i^2 - 2 e_i \mathbf{v_i}\, \mathbf{v_e}\, P_Z + (v_e^2+a_e^2)(\mathbf{v_i}^2+\mathbf{a_i}^2)\, P_Z^2$$

$$B_i^0(Q^2) = -2 e_i\, \mathbf{a_i}\, a_e\, P_Z + 4\mathbf{a_i}\, a_e\, \mathbf{v_i}\, v_e\, P_Z^2$$

$$P_Z = \frac{1}{\sin^2 2\theta}\frac{Q^2}{(M_Z^2+Q^2)}$$

The polarised cross-section is given by $\sigma^P = Y_+ F_2^P + Y_- xF_3^P$

$$F_2^P = \Sigma_i\, A_i^P(Q^2)\,[xq_i(x,Q^2) + x\bar{q}_i(x,Q^2)]$$

$$xF_3^P = \Sigma_i\, B_i^P(Q^2)\,[xq_i(x,Q^2) - x\bar{q}_i(x,Q^2)]$$

$$A_i^P(Q2) = 2 e_i\, \mathbf{v_i}\, a_e\, P_Z - 2 v_e\, a_e\, (\mathbf{v_i}^2+\mathbf{a_i}^2)\, P_Z^2$$

$$B_i^P(Q2) = 2 e_i\, \mathbf{a_i}\, \mathbf{v_e}\, P_Z - 2\, \mathbf{a_i}\, \mathbf{v_i}\, (v_e^2+a_e^2)\, P_Z^2$$

$P_Z >> P_Z^2$ (γZ interference is dominant)
$\mathbf{v_e}$ is very small (~0.04).

→

unpolarized xF_3 → a_i,
polarized F_2 → v_i

Ewald

1) I have a problem with the statement that we improve the precision of a_u and v_u by our results. Of course, as shown in fig. 7, we improve these parameters with respect to other collider experiments. However, having lookedinto the PDG tables I saw that the uncertainties quoted for the world averages of a_uand v_u are by a factor 2 smaller than shown in fig.7. This I would like to understand. I wonder what neutrino experiments contribute.

	a_u	a_b	v_u	v_d
PDG (average)	$0.5^{+0.04}_{-0.06}$	$-0.523^{+0.050}_{-0.029}$	$0.25^{+0.07}_{-0.06}$	$-0.33^{+0.05}_{-0.06}$
ZEUS-EW-Z	$0.514^{+0.113}_{-0.052}$	$-0.567^{+0.379}_{-0.157}$	$0.136^{+0.094}_{-0.091}$	$-0.416^{+0.252}_{-0.193}$
SM	0.5	-0.5	0.196	-0.346

Checked. No neutrino results on this.

PDG does its own FIT using separate measurements. Meaning our current precision CAN contribute significantly to the PDG average.

2) The electroweak coupling constants of u and d on one side and the W mass with the Fermi constant on the other have been fitted on different data sets

Both couplings of light quarks to Z-boson and mass of W-boson were fitted on the same data collection. It was ZEUS and H1 HERAI data + H1 HERAII unpolarised data + ZEUS HERAII polarised data + H1 and ZEUS data from runs with reduced proton energy.

Erich

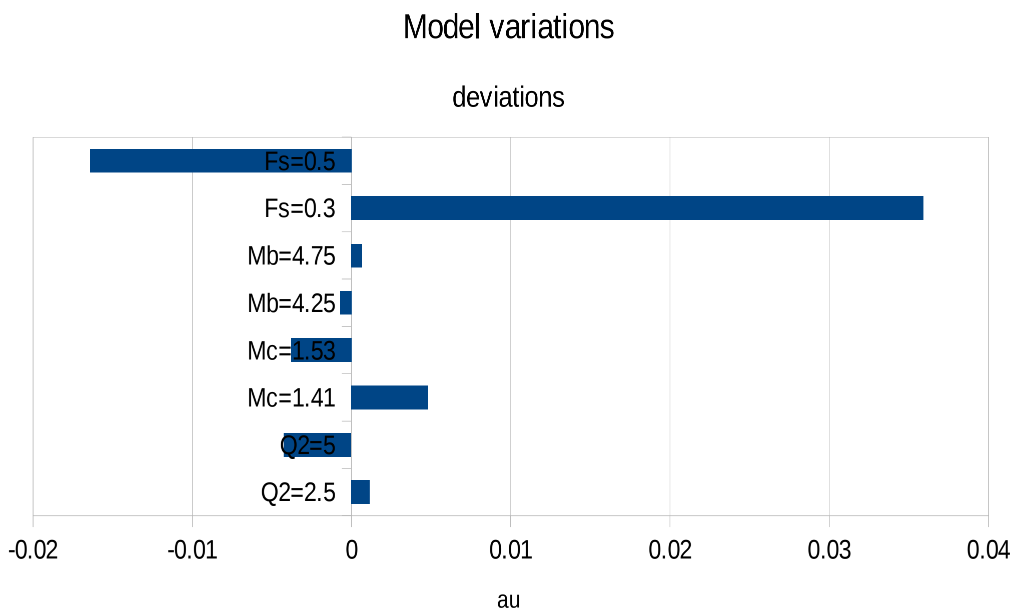
1)Whereas we contribute something new to the quark ew couplings, this is not the case for the W mass and G. Here our accuracy is far worse than the PDG values and our measurements have more the meaning of a consistency check. I therefore suggest to shorten this chapter fittingly.

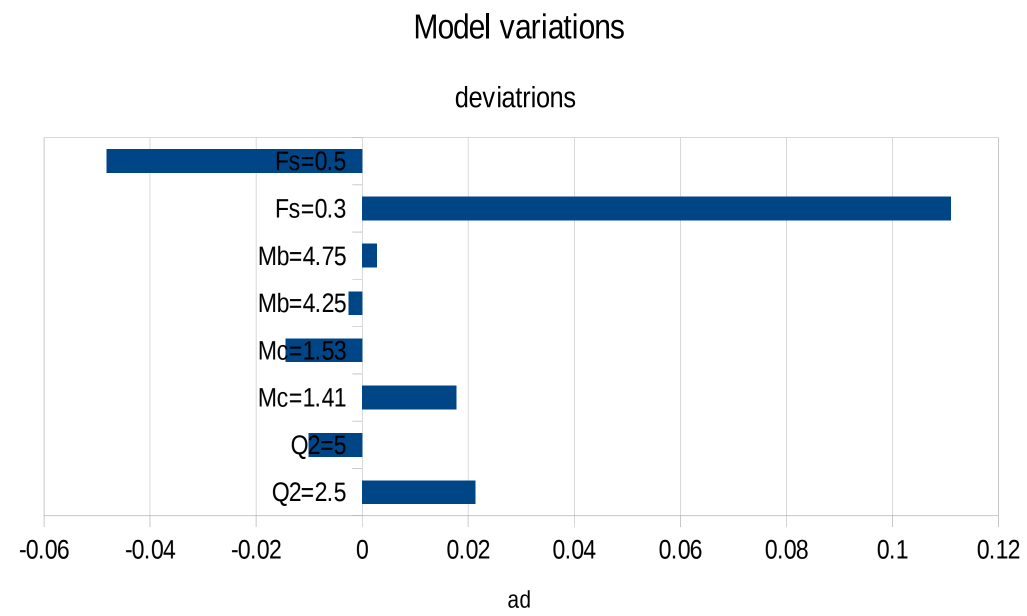
Backup

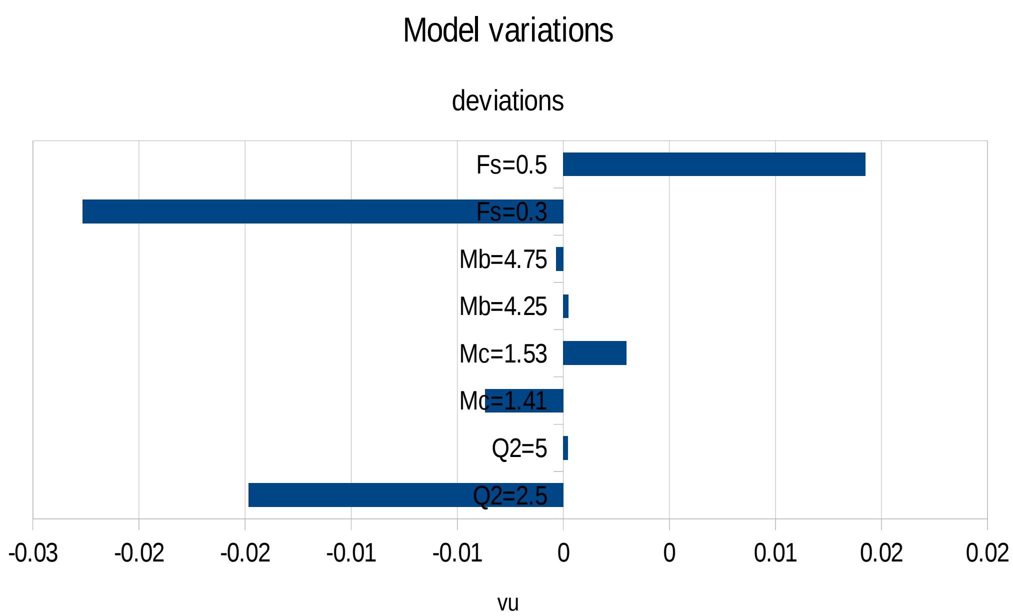
World results (full uncertainties)

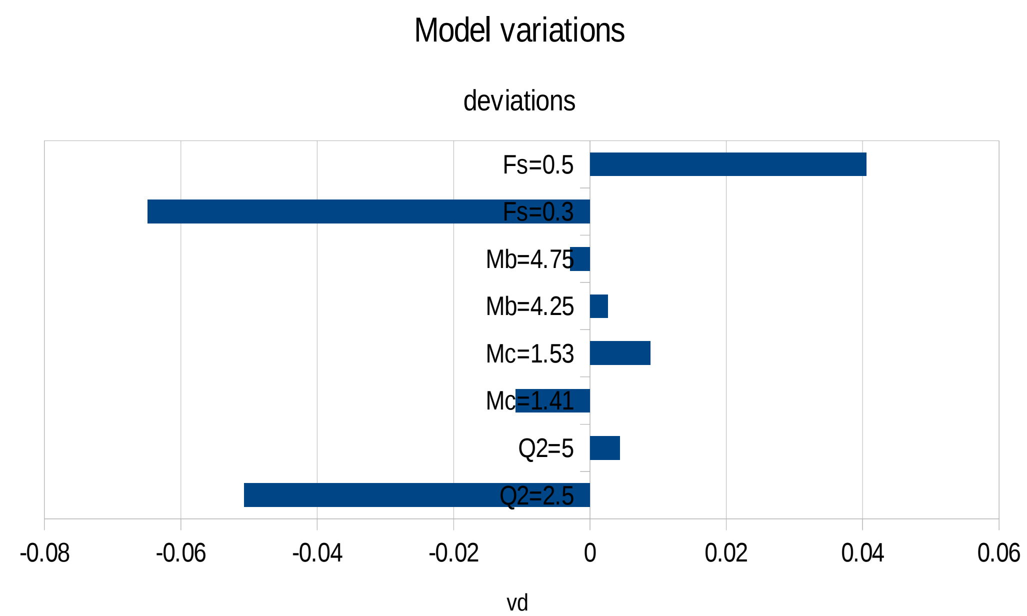
	a_u	a_b	v_u	v_d
LEP	$0.47\,^{+0.05}_{-0.33}$	$-0.52\,^{+0.05}_{-0.03}$	$0.24\,^{+0.28}_{-0.11}$	$-0.33\,^{+0.05}_{-0.07}$
D0	0.50±0.11	-0.50±0.17	0.20±0.11	0.35±0.25
CDF	$0.44\,^{+0.22}_{-0.19}$	$-0.02\,^{+0.36}_{-0.54}$	$0.40\,^{+0.17}_{-0.20}$	$-0.23\,^{+0.64}_{-0.30}$
H1: HERA1 (publ.)	0.56±0.10	-0.77±-0.37	0.05±0.19	-0.50±0.37
ZEUS: HERA1+2 (prel.)	0.51±0.20	-0.54±0.37	0.05±0.10	-0.64±0.24
ZEUS-EW-Z	$0.514\,^{+0.113}_{-0.052}$	$-0.567\,^{+0.379}_{-0.157}$	$0.136\,^{+0.094}_{-0.091}$	$-0.416\,^{+0.252}_{-0.193}$
SM	0.5	-0.5	0.196	-0.346

Model variations

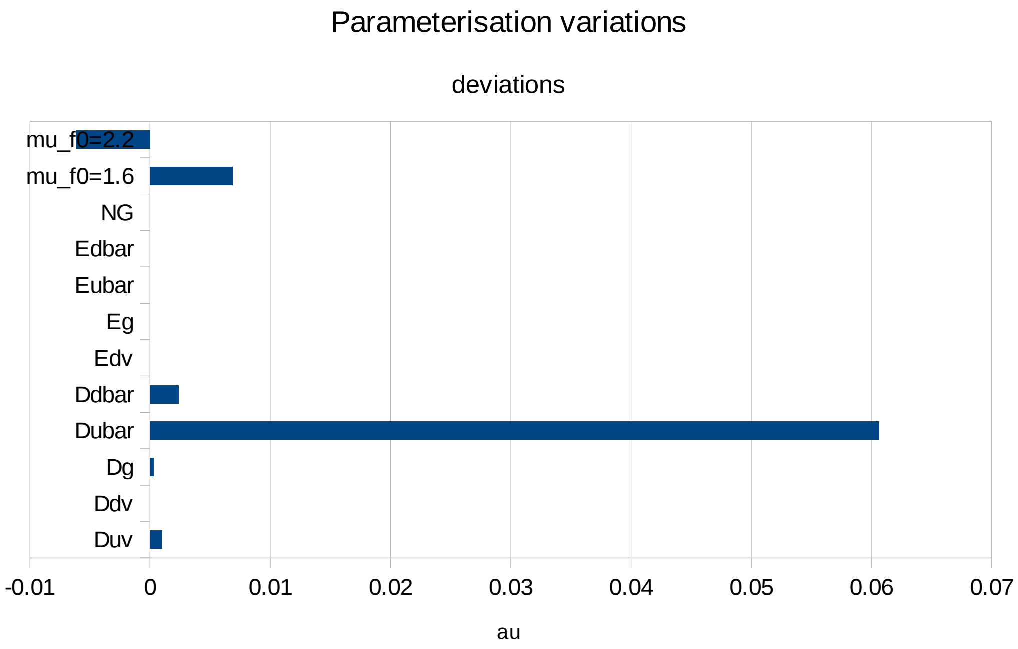


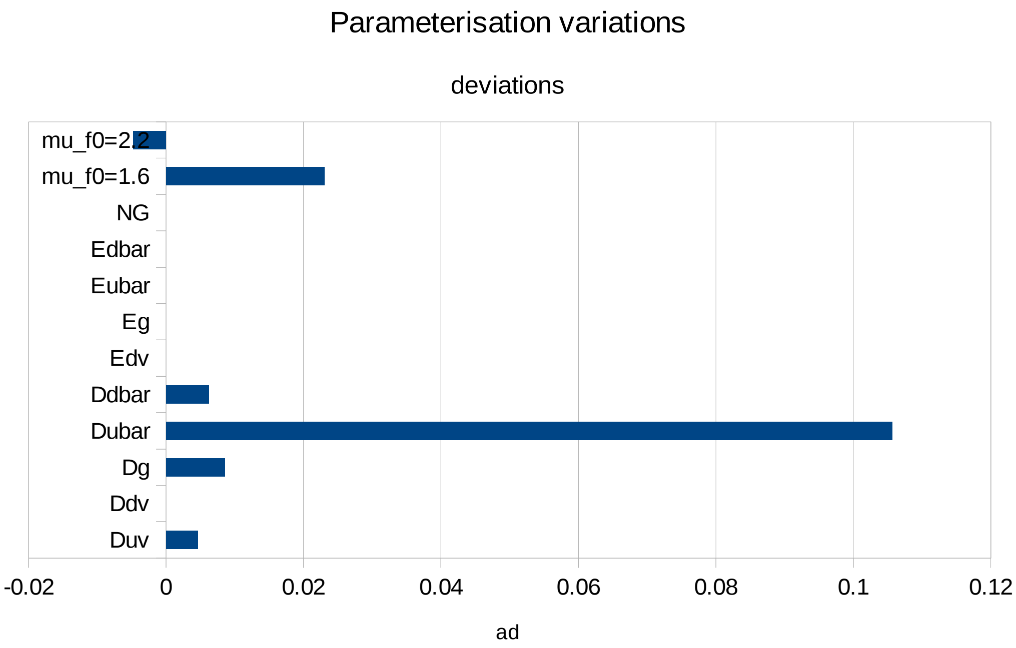


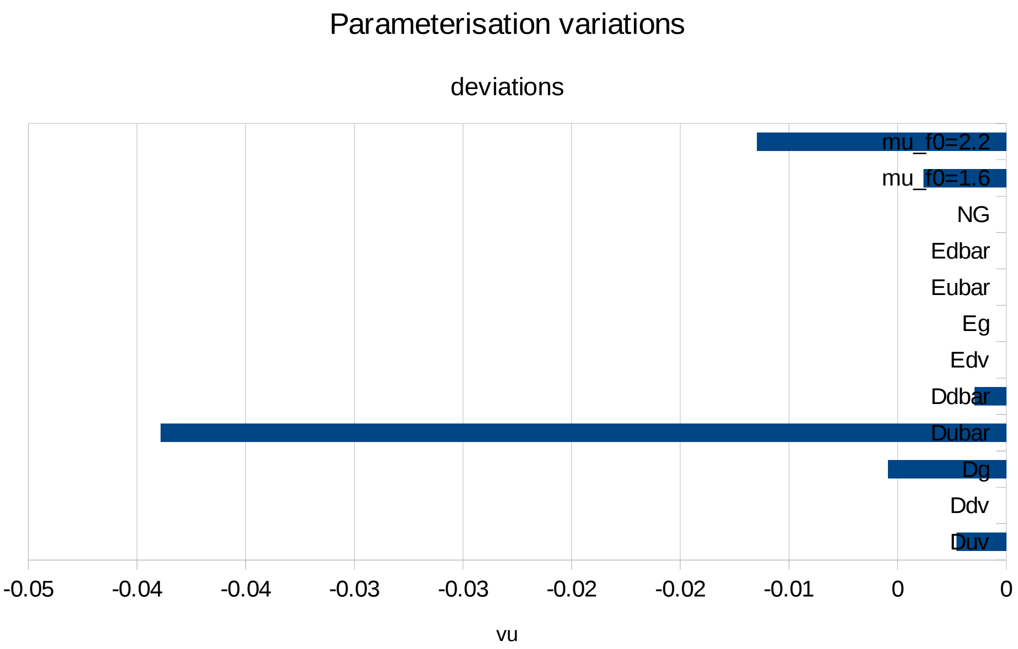


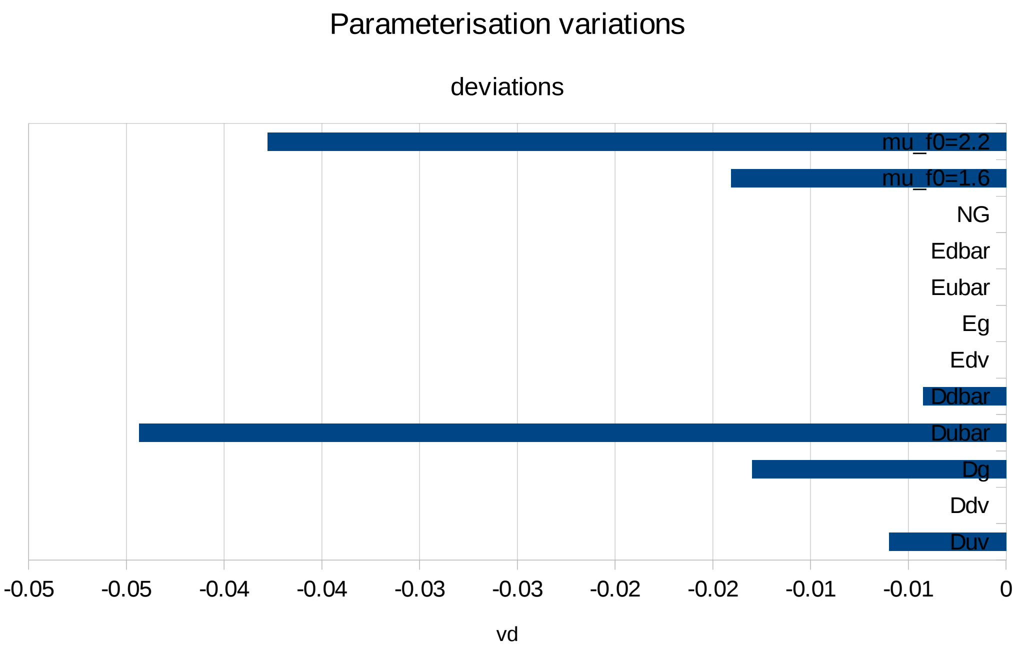


Parametrisation variations variations

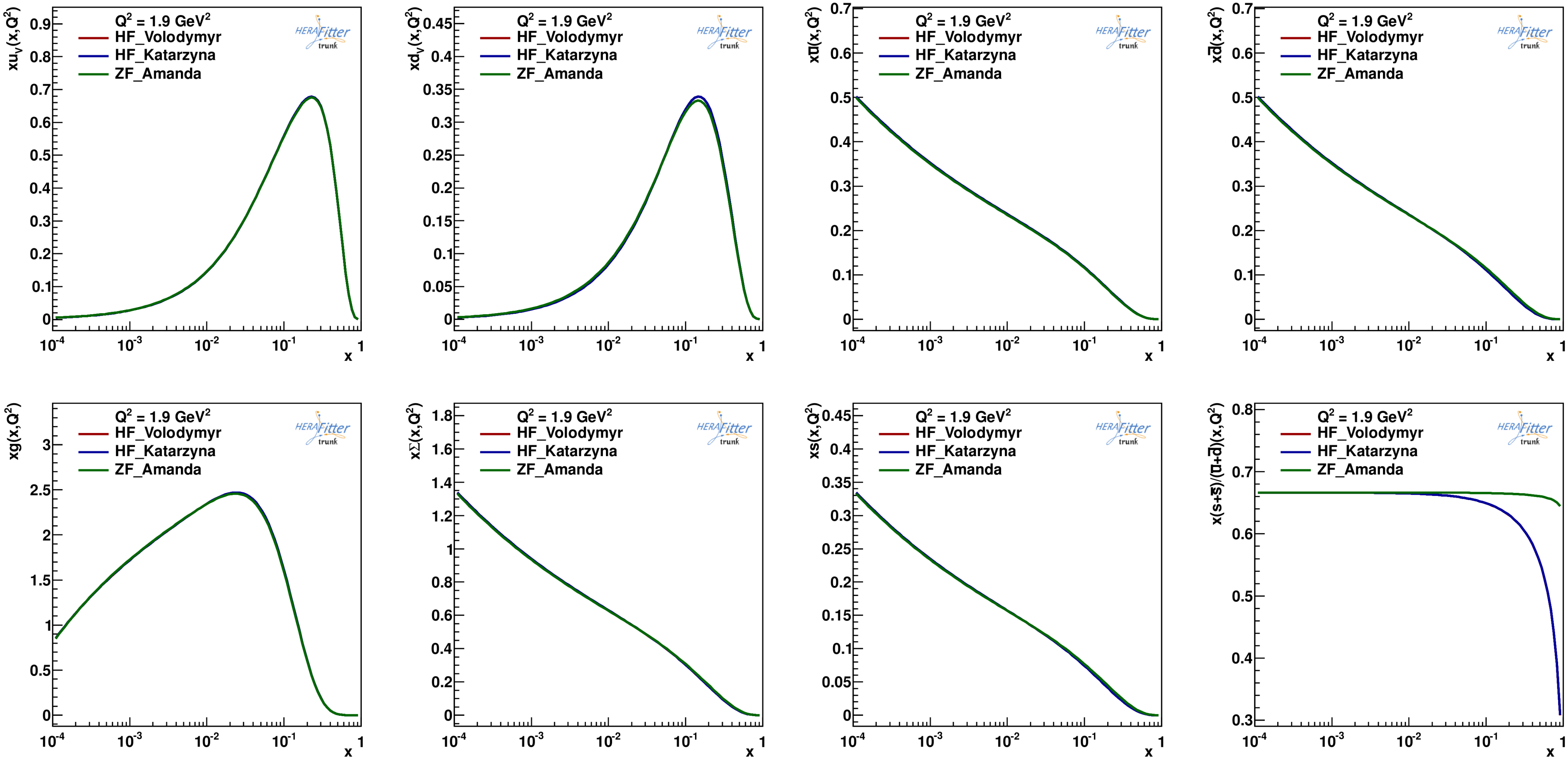








Cross-checks: HERAFitter vs ZEUSFitter



Correlation matrix for the fit parameters

NO.	Bg	Cg	Aprig	Bprig	Buv	Cuv	Euv	Bdv	Cdv	CUbar	ADbar	BDbar	CDbar	auEW	adEW	vuEW	vdEW
Bg	1.000	-0.017	-0.451	0.823	-0.217	0.173	0.251	-0.084	-0.085	-0.098	-0.107	-0.136	0.047	0.025	0.003	0.015	0.018
Cg	-0.017	1.000	0.831	0.456	0.338	-0.372	-0.549	0.007	0.297	-0.020	-0.084	-0.104	-0.437	0.108	0.097	-0.099	-0.112
Aprig	-0.451	0.831	1.000	0.119	0.547	-0.404	-0.629	0.231	0.275	0.159	0.080	0.071	-0.150	-0.051	0.001	-0.044	-0.054
Bprig	0.823	0.456	0.119	1.000	0.106	-0.037	-0.082	0.074	0.047	0.043	0.011	-0.014	0.012	-0.029	-0.011	-0.001	-0.002
Buv	-0.217	0.338	0.547	0.106	1.000	-0.408	-0.774	0.466	-0.087	0.690	0.477	0.396	0.440	-0.361	-0.179	0.079	0.071
Cuv	0.173	-0.372	-0.404	-0.037	-0.408	1.000	0.828	-0.296	-0.235	-0.187	-0.095	-0.069	-0.039	0.109	0.029	0.040	0.028
Euv	0.251	-0.549	-0.629	-0.082	-0.774	0.828	1.000	-0.296	-0.066	-0.363	-0.170	-0.117	-0.091	0.192	0.087	-0.023	-0.017
Bdv	-0.084	0.007	0.231	0.074	0.466	-0.296	-0.296	1.000	0.516	0.406	0.352	0.293	0.675	-0.336	-0.135	0.038	0.022
Cdv	-0.085	0.297	0.275	0.047	-0.087	-0.235	-0.066	0.516	1.000	-0.137	-0.187	-0.194	-0.140	0.111	0.129	-0.101	-0.128
CUbar	-0.098	-0.020	0.159	0.043	0.690	-0.187	-0.363	0.406	-0.137	1.000	0.674	0.636	0.329	-0.321	-0.138	0.055	0.052
ADbar	-0.107	-0.084	0.080	0.011	0.477	-0.095	-0.170	0.352	-0.187	0.674	1.000	0.959	0.478	-0.273	-0.138	0.057	0.060
BDbar	-0.136	-0.104	0.071	-0.014	0.396	-0.069	-0.117	0.293	-0.194	0.636	0.959	1.000	0.416	-0.240	-0.120	0.048	0.053
CDbar	0.047	-0.437	-0.150	0.012	0.440	-0.039	-0.091	0.675	-0.140	0.329	0.478	0.416	1.000	-0.450	-0.272	0.149	0.154
auEW	0.025	0.108	-0.051	-0.029	-0.361	0.109	0.192	-0.336	0.111	-0.321	-0.273	-0.240	-0.450	1.000	0.879	-0.604	-0.753
adEW	0.003	0.097	0.001	-0.011	-0.179	0.029	0.087	-0.135	0.129	-0.138	-0.138	-0.120	-0.272	0.879	1.000	-0.692	-0.900
vuEW	0.015	-0.099	-0.044	-0.001	0.079	0.040	-0.023	0.038	-0.101	0.055	0.057	0.048	0.149	-0.604	-0.692	1.000	0.871
vdEW	0.018	-0.112	-0.054	-0.002	0.071	0.028	-0.017	0.022	-0.128	0.052	0.060	0.053	0.154	-0.753	-0.900	0.871	1.000

Trying various Q^2_{min} and calc. orders.

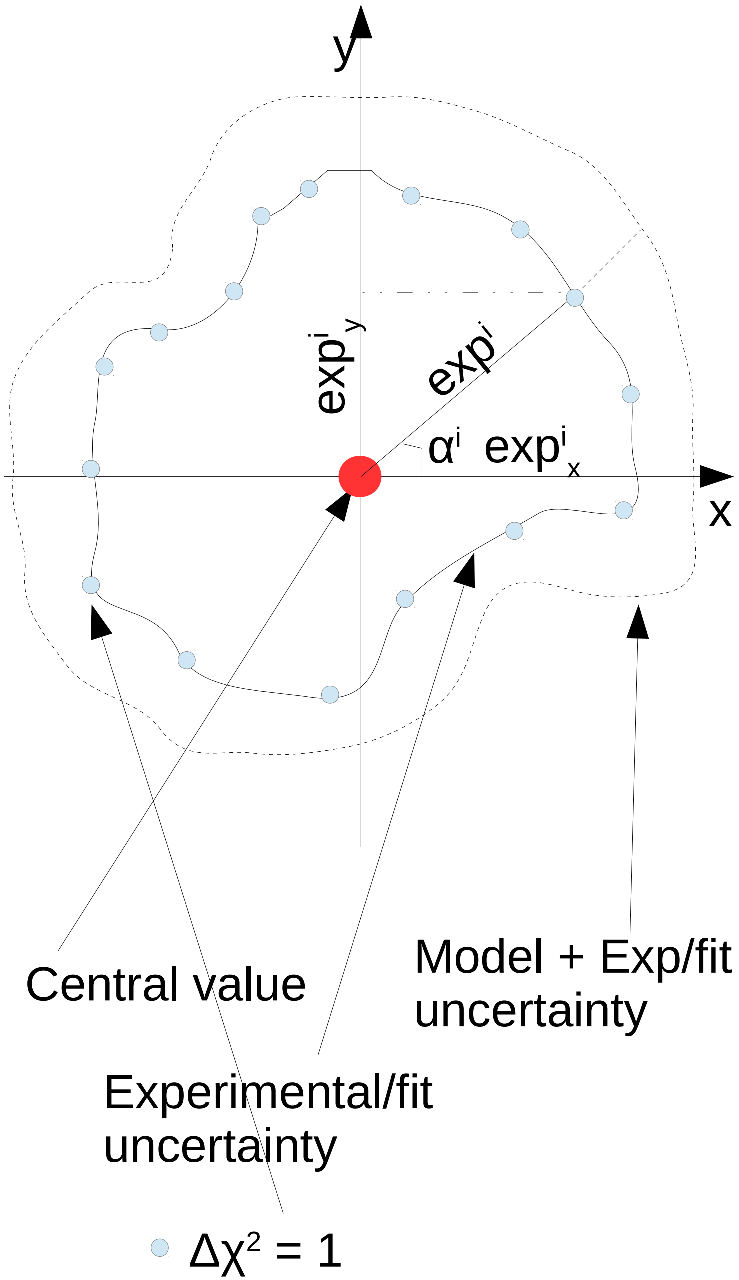
	13p+4EW					14p+4EW					Number of data points
	a_u	a_d	v_u	v_d	χ^2	a_u	a_d	v_u	v_d	χ^2	
NLO 3.5 GeV²	0.516 ±0.062	-0.523 ±0.227	0.148 ±0.071	-0.442 ±0.187	3589	0.601 ±0.061	-0.303 ±0.253	0.102 ±0.049	-0.533 ±0.085	3571	3248
NLO 10 GeV²	0.499 ±0.054	-0.559 ±0.184	0.149 ±0.065	-0.432 ±0.172	3161	0.619 ±0.055	-0.266 ±0.240	0.114 ±0.048	-0.509 ±0.084	3145	3006
NNLO 3.5 GeV²	-	-	-	-	-	-	-	-	-	-	3248
NNLO 10 GeV²	0.501 ±0.051	-0.554 ±0.175	0.146 ±0.061	-0.441 ±0.158	3154	-	-	-	-	-	3006
SM	0.5	-0.5	0.196	-0.346		0.5	-0.5	0.196	-0.346		

Both MIGRAD and HESSE failed

only MIGRAD has converged

- 14p+EW is VERY unstable.
- $Q^2_{min} = 3.5\ GeV^2 \rightarrow Q^2_{min} = 10\ GeV^2$: reduction of uncertainty (but not too stable).

Contours with exp + other uncertainty



$$exp^i = \sqrt{exp_x^{i\,2} + exp_y^{i\,2}}$$

$$mod^i = \sqrt{(\cos\alpha\, mod_x)^2 + (\sin\alpha\, mod_y)^2}$$

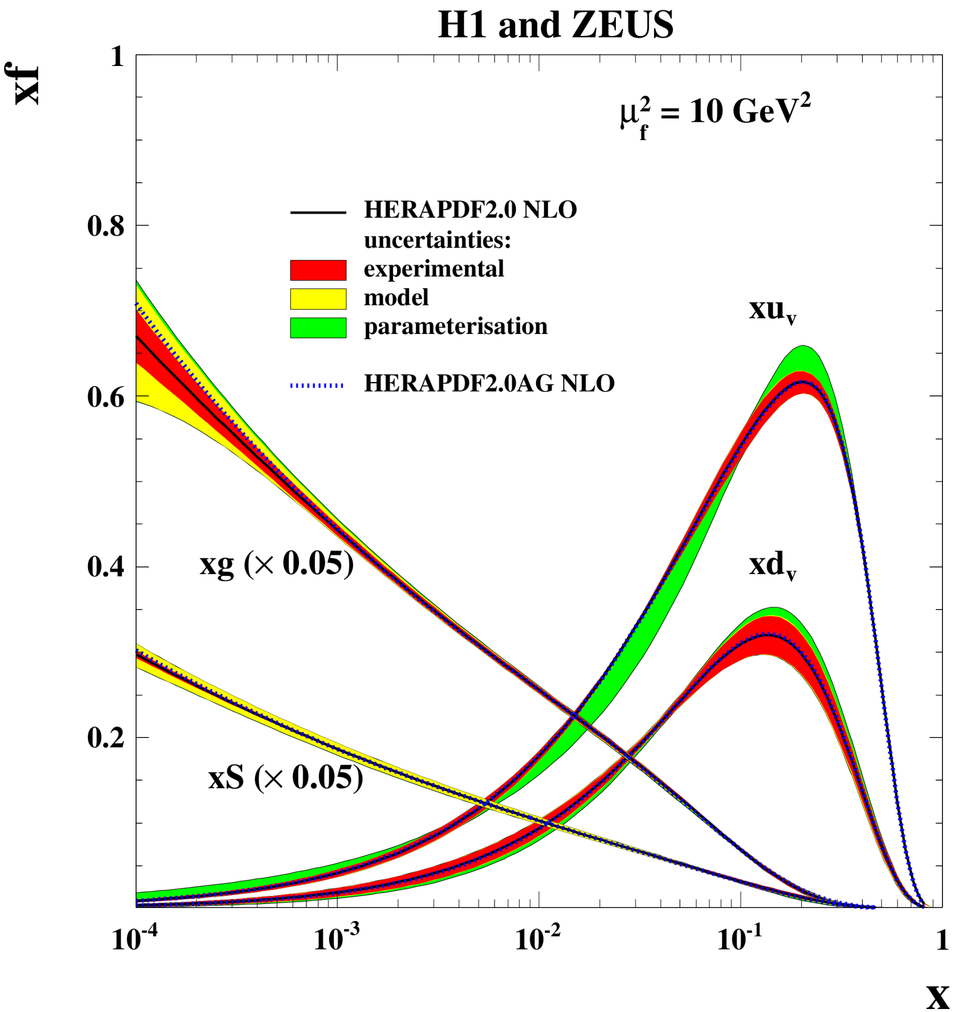
$$\cos\alpha \frac{exp_x^i}{exp\, i} \qquad \sin\alpha \frac{exp_y^i}{exp\, i}$$

$$total^i = \sqrt{exp^{i\,2} + mod^{i\,2}}$$

$$\boxed{total_x^i = \cos\alpha\, total^i}$$

$$\boxed{total_y^i = \sin\alpha\, total^i}$$

HERAPDF2.0: errors estimation



- Full systematic correlation treatment.
- Experimental uncertainties:
  - Hessian method used: full second-derivative matrix calculated
  - Conventional $\Delta\chi^2 = 1$ => 68% CL
- Model uncertainties:
  - All variations are added in quadratures, separately positive and negative.

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

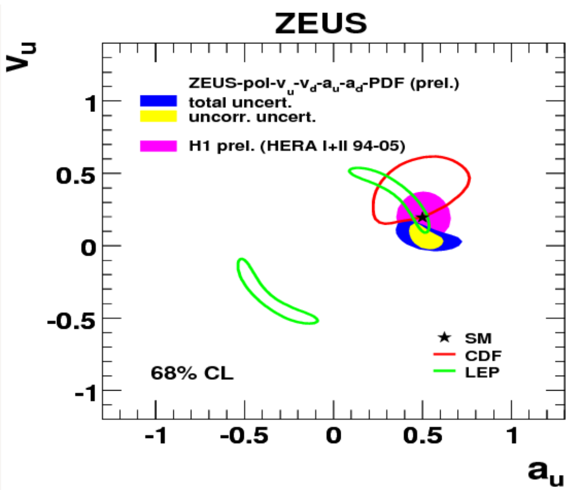
Adding D and E parameters to each PDF

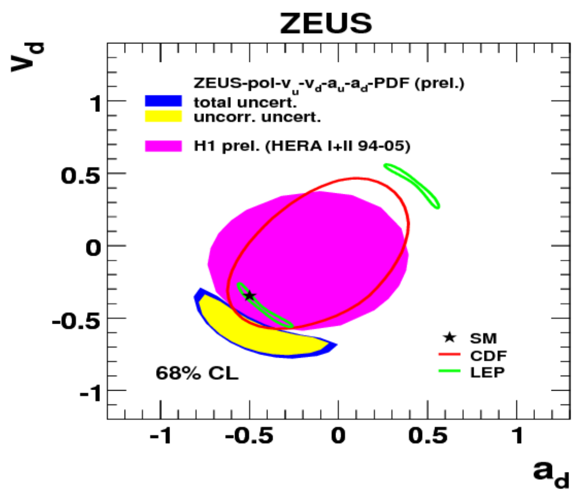
- Parametrisation uncertainties:
  - The largest deviation taken.

$$\bar{x} = \frac{\sum_i \frac{x_i}{\sigma_i^2}}{\sum_i \frac{1}{\sigma_i^2}}$$

$$\sigma_{\bar{x}} = \frac{1}{\sqrt{\sum_i \frac{1}{\sigma_i^2}}}$$

Previous analysis

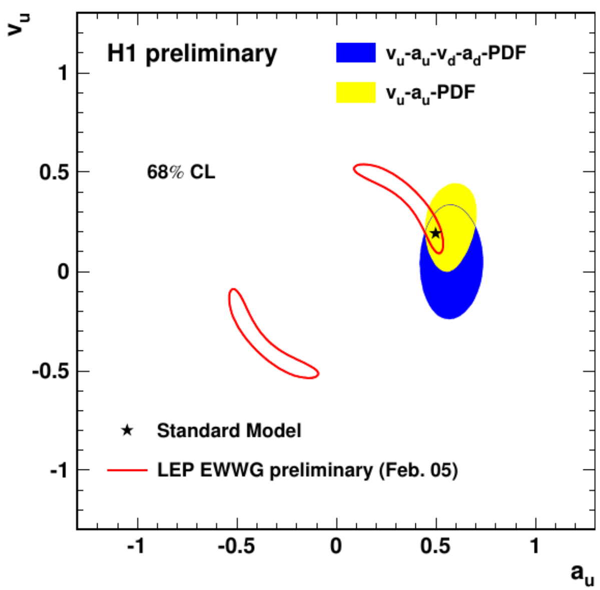


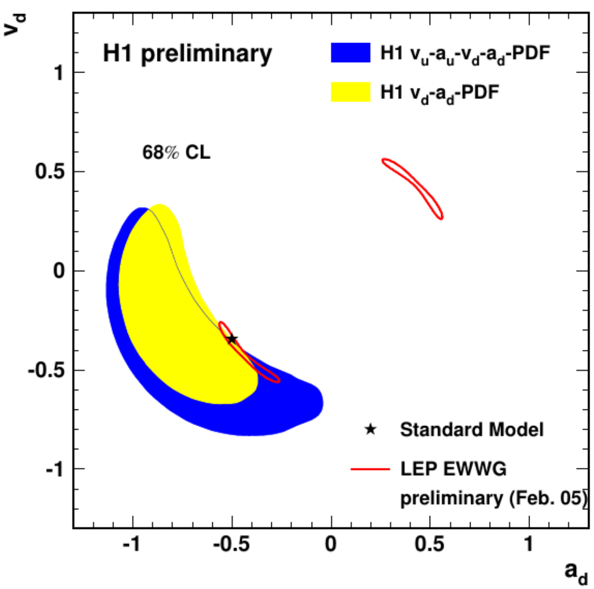


- Determination of EW par. by ZEUS

  ZEUS HERA I + HERA II e⁻p (pol)

- ZEUS-prel-07-027





- Determination of EW par. by H1

  H1 HERA I (unpolarized)

- Phys. Lett. **B632**, 35, (2006)

- All H1 and ZEUS HERA I unpolarized and HERA II polarized data are now available

$$\tilde{F}_2^{\pm} = F_2 + k_Z(-v_e \mp Pa_e) \cdot F_2^{\gamma Z} + k_Z^2(v_e^2 + a_e^2 \pm 2Pv_e a_e) \cdot F_2^Z$$

$$x\tilde{F}_3^{\pm} = k_Z(\pm a_e + Pv_e) \cdot xF_3^{\gamma Z} + k_Z^2(\mp 2v_e a_e - P(v_e^2 + a_e^2)) \cdot xF_3^Z$$

$$(F_2, F_2^{\gamma Z}, F_2^Z) = x\sum(e_q^2, 2e_q v_q, v_q^2 + a_q^2)(q + \bar{q}) \qquad (xF_3^{\gamma Z}, xF_3^Z) = 2x\sum(e_q a_q, v_q a_q)(q - \bar{q})$$

Plots from paper draft

Fig. 1

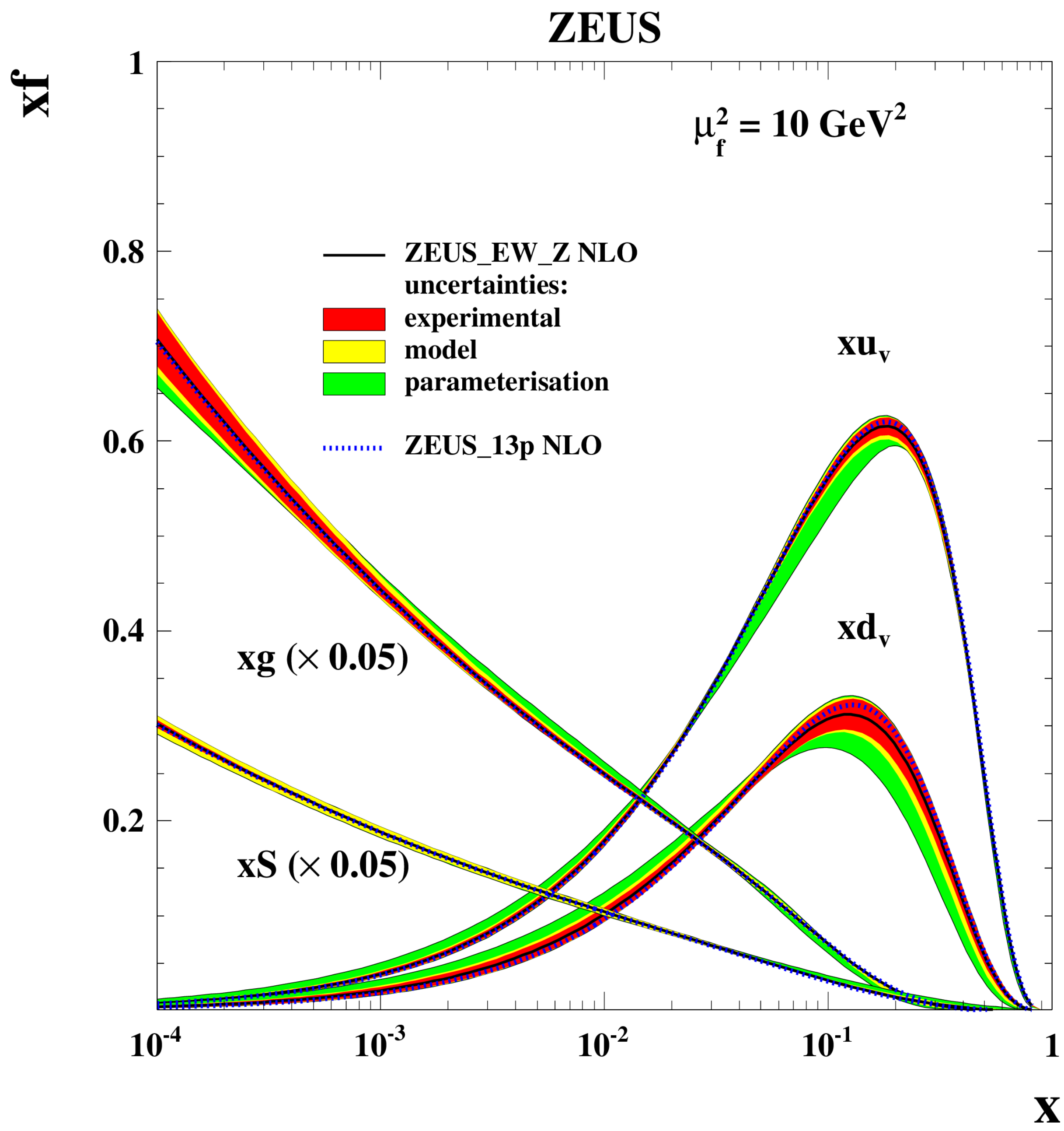
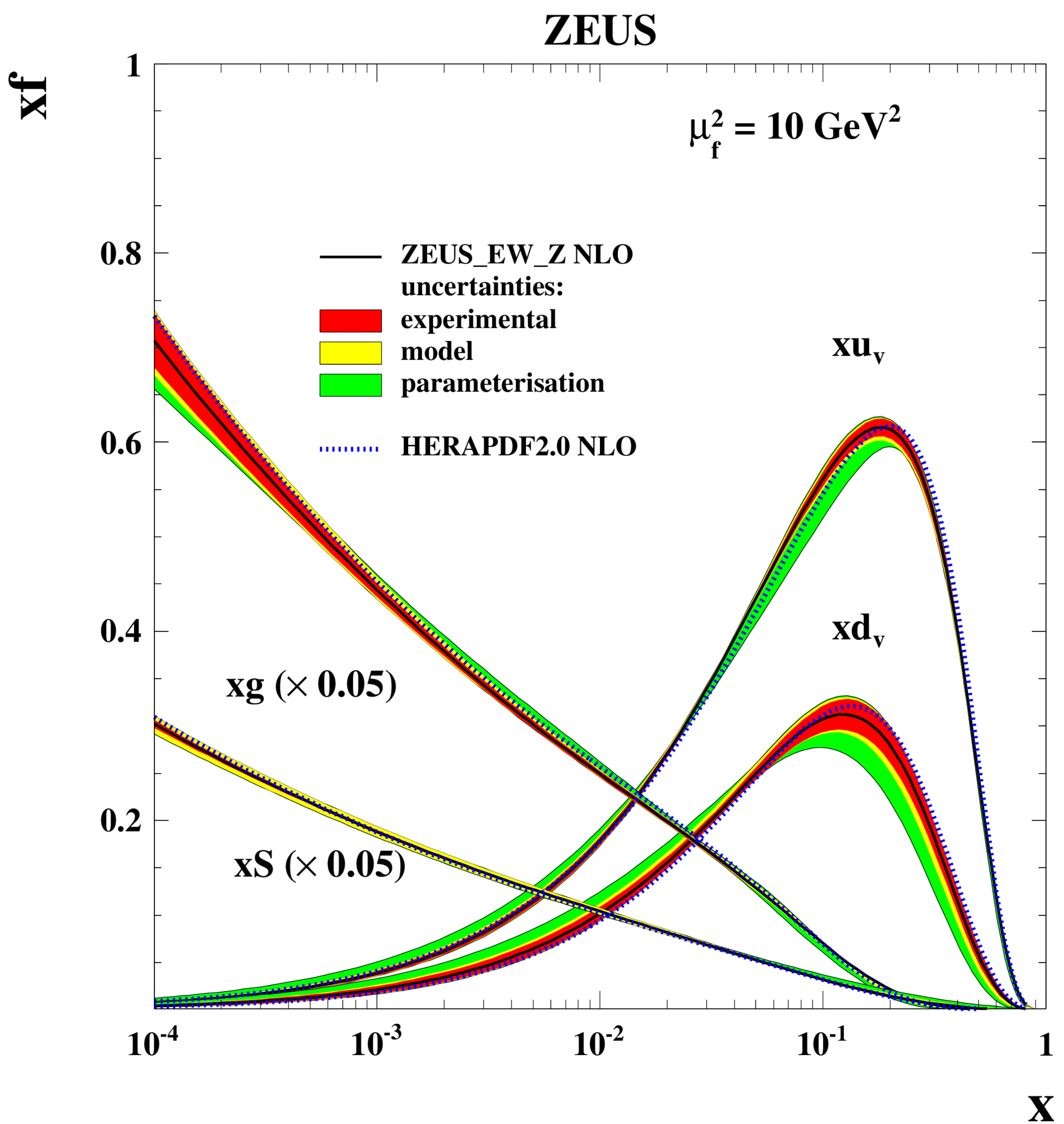
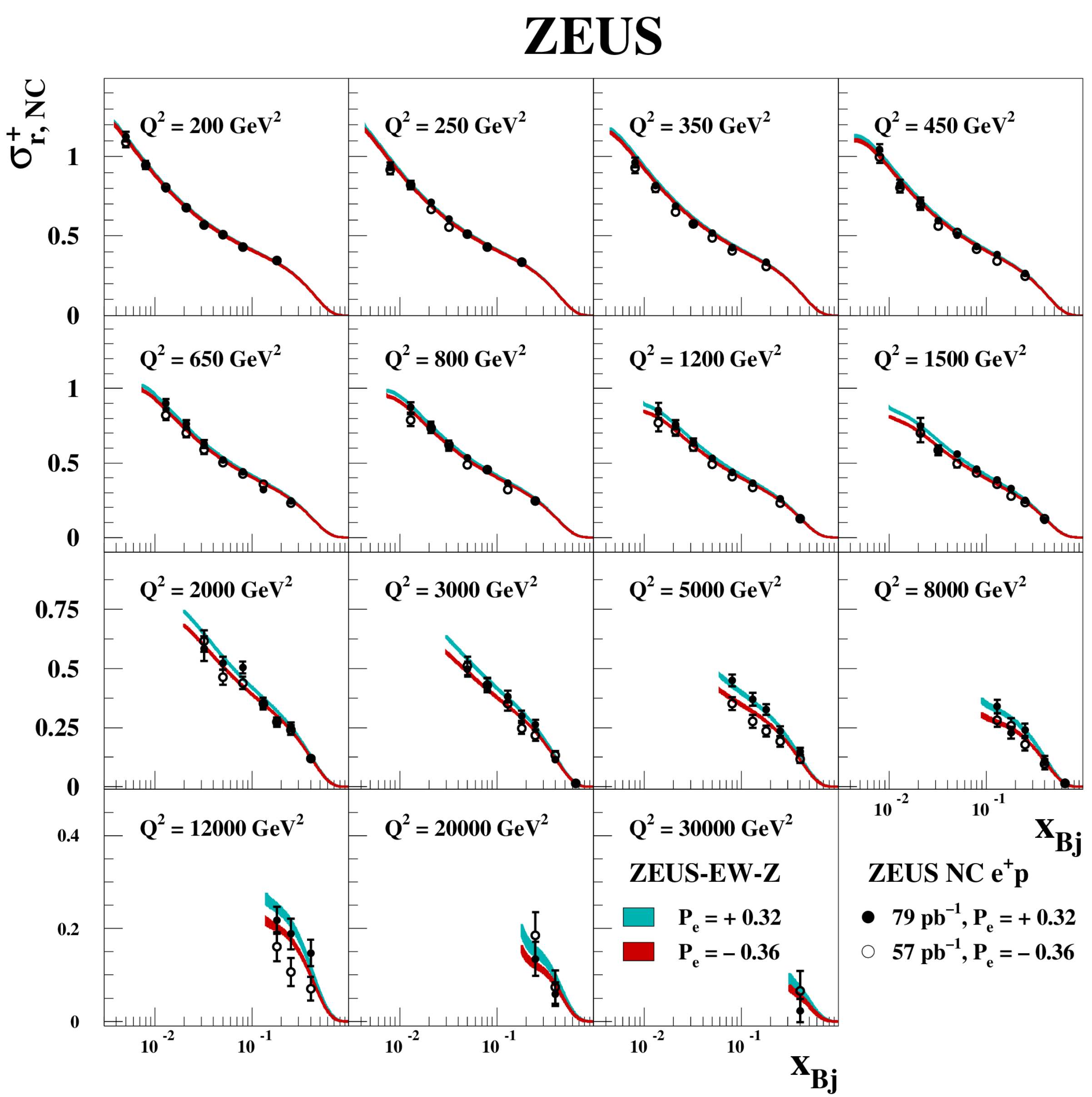

ZEUS
xf
μ_f^2 = 10 GeV^2
ZEUS_EW_Z NLO
uncertainties:
experimental
model
parameterisation
ZEUS_13p NLO
xu_v
xd_v
xg (× 0.05)
xS (× 0.05)
1
0.8
0.6
0.4
0.2
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x

Fig. 2



ZEUS
xf
μ_f^2 = 10 GeV^2
ZEUS_EW_Z NLO
uncertainties:
experimental
model
parameterisation
HERAPDF2.0 NLO
xu_v
xd_v
xg (× 0.05)
xS (× 0.05)
1
0.8
0.6
0.4
0.2
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x

Fig. 3



ZEUS
$\sigma^+_{r,NC}$
Q² = 200 GeV²
Q² = 250 GeV²
Q² = 350 GeV²
Q² = 450 GeV²
Q² = 650 GeV²
Q² = 800 GeV²
Q² = 1200 GeV²
Q² = 1500 GeV²
Q² = 2000 GeV²
Q² = 3000 GeV²
Q² = 5000 GeV²
Q² = 8000 GeV²
Q² = 12000 GeV²
Q² = 20000 GeV²
Q² = 30000 GeV²
ZEUS-EW-Z
P_e = + 0.32
P_e = – 0.36
ZEUS NC e⁺p
79 pb⁻¹, P_e = + 0.32
57 pb⁻¹, P_e = – 0.36
x_Bj

Fig. 4

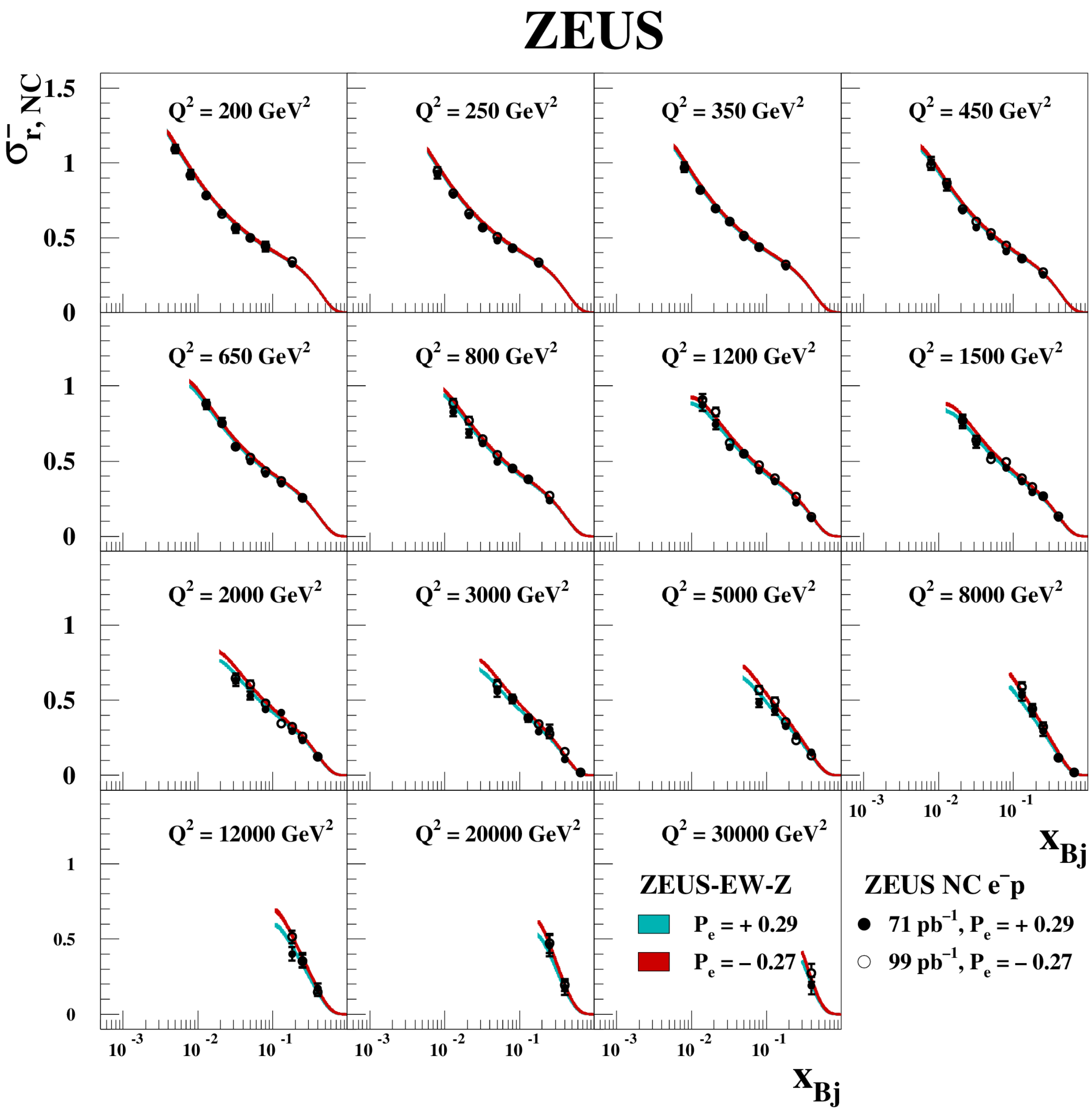

ZEUS
$\sigma^{-}_{r,NC}$
Q² = 200 GeV²
Q² = 250 GeV²
Q² = 350 GeV²
Q² = 450 GeV²
Q² = 650 GeV²
Q² = 800 GeV²
Q² = 1200 GeV²
Q² = 1500 GeV²
Q² = 2000 GeV²
Q² = 3000 GeV²
Q² = 5000 GeV²
Q² = 8000 GeV²
Q² = 12000 GeV²
Q² = 20000 GeV²
Q² = 30000 GeV²
ZEUS-EW-Z
Pe = + 0.29
Pe = – 0.27
ZEUS NC e⁻p
71 pb⁻¹, Pe = + 0.29
99 pb⁻¹, Pe = – 0.27
xBj

Fig. 5

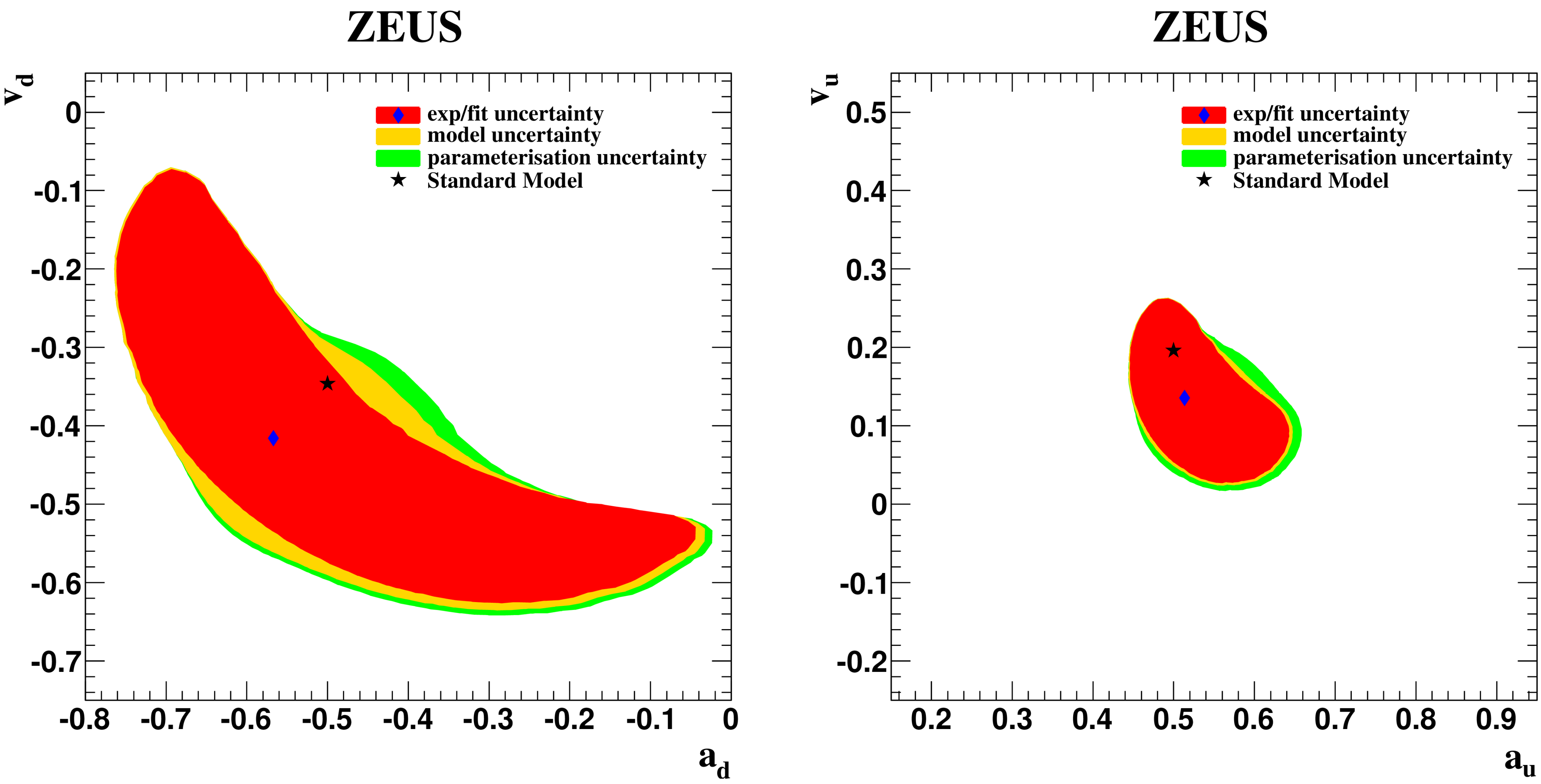

ZEUS
exp/fit uncertainty
model uncertainty
parameterisation uncertainty
Standard Model
v_d
a_d
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
ZEUS
exp/fit uncertainty
model uncertainty
parameterisation uncertainty
Standard Model
v_u
a_u
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0.9

Fig. 6

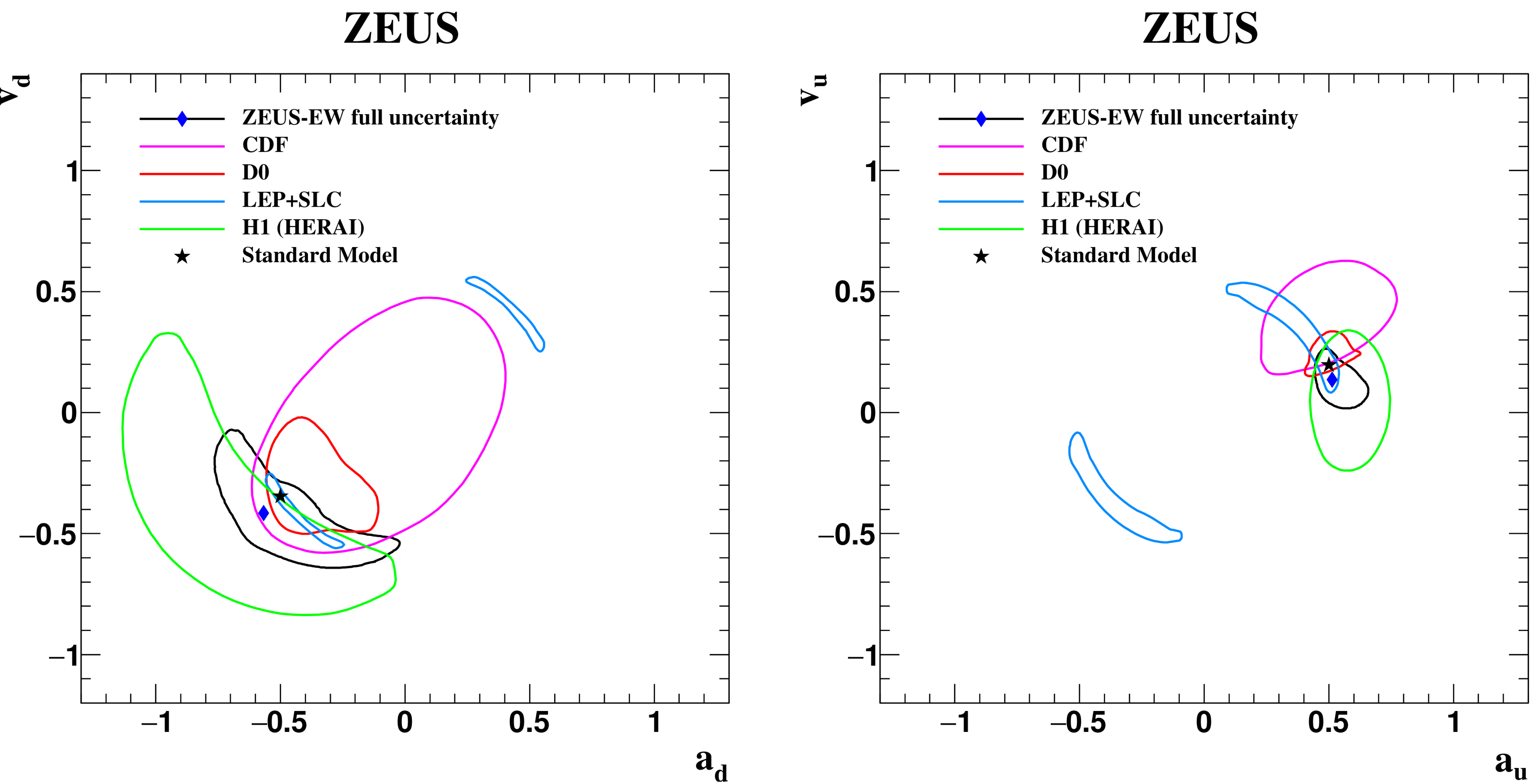

ZEUS
ZEUS-EW full uncertainty
CDF
D0
LEP+SLC
H1 (HERAI)
Standard Model
v_d
a_d
1
0.5
0
–0.5
–1
ZEUS
ZEUS-EW full uncertainty
CDF
D0
LEP+SLC
H1 (HERAI)
Standard Model
v_u
a_u

Fig. 7

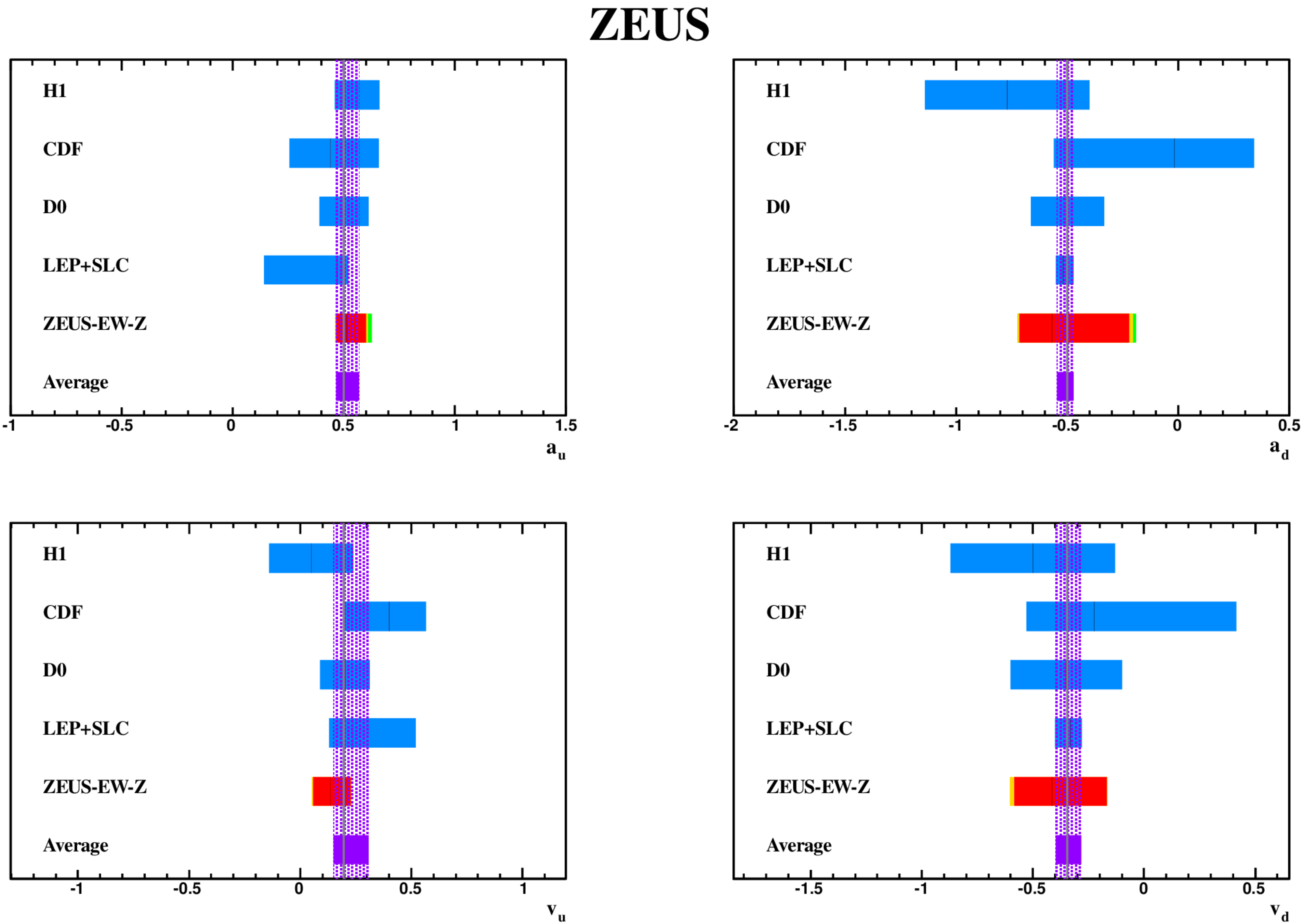
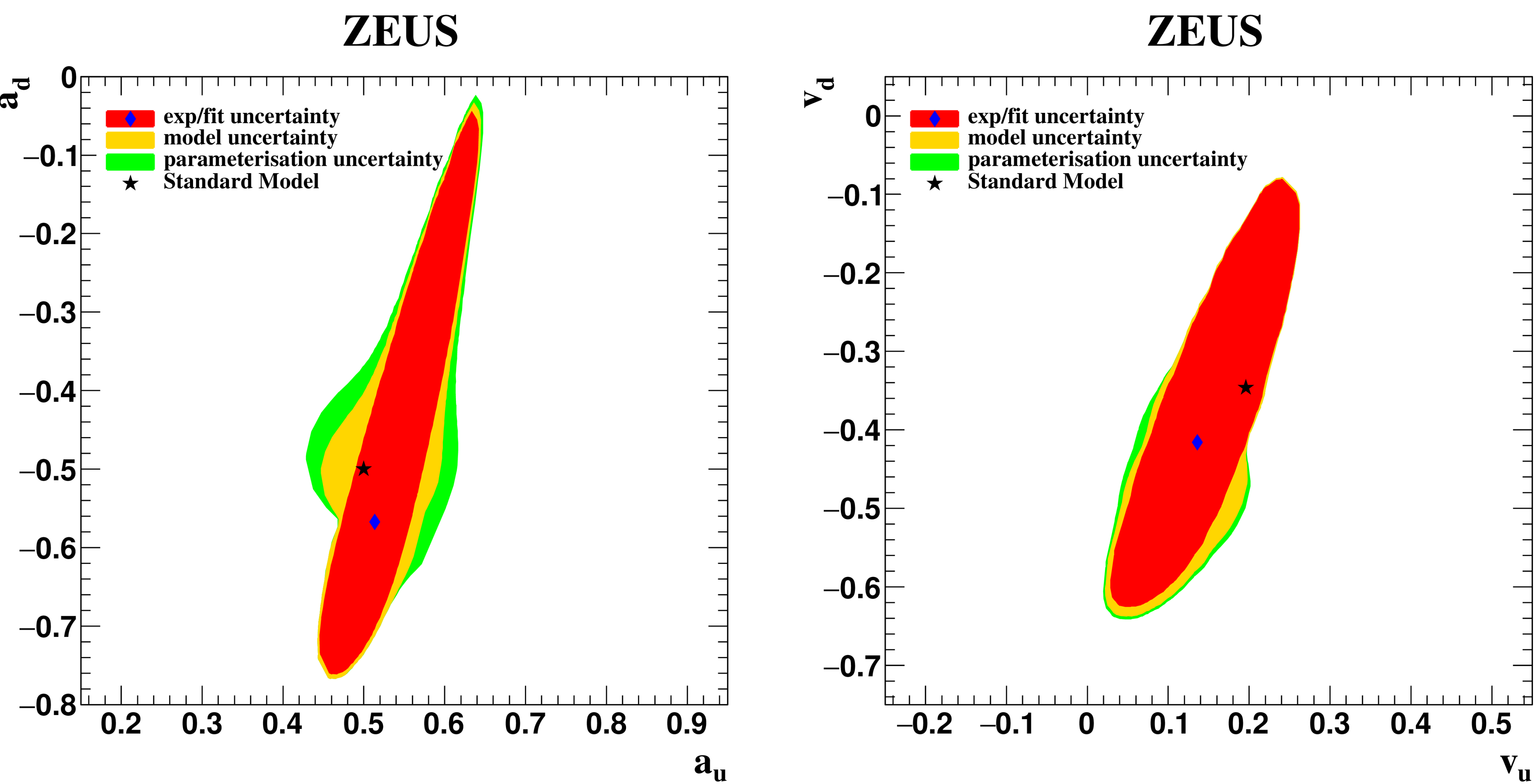
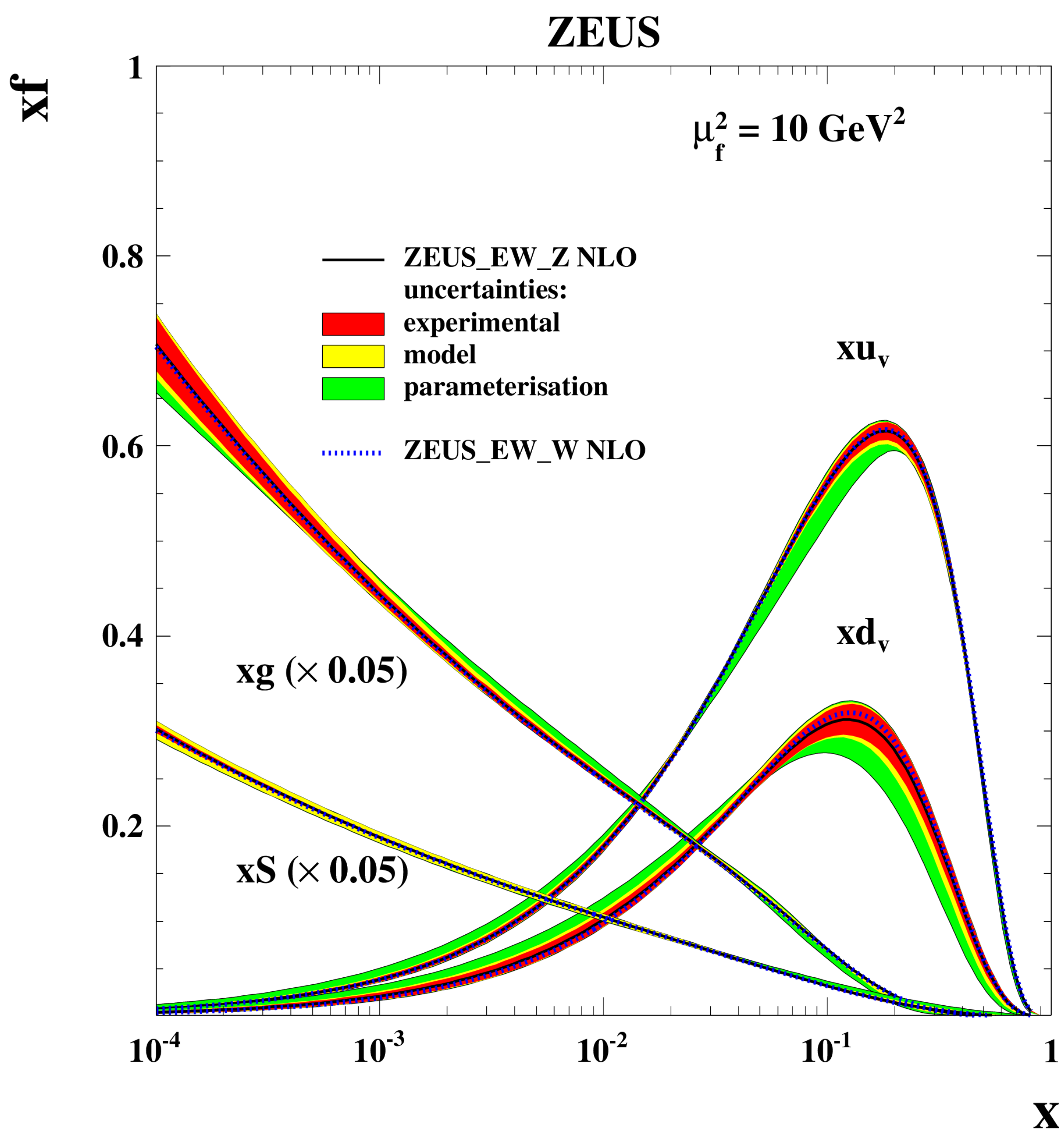

ZEUS
H1
CDF
D0
LEP+SLC
ZEUS-EW-Z
Average
-1
-0.5
0
0.5
1
1.5
a_u
-2
-1.5
-1
-0.5
0
0.5
a_d
-1
-0.5
0
0.5
1
v_u
-1.5
-1
-0.5
0
0.5
v_d

Fig. 8



ZEUS
exp/fit uncertainty
model uncertainty
parameterisation uncertainty
Standard Model
a_d
a_u
0
–0.1
–0.2
–0.3
–0.4
–0.5
–0.6
–0.7
–0.8
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
ZEUS
exp/fit uncertainty
model uncertainty
parameterisation uncertainty
Standard Model
v_d
v_u
0
–0.1
–0.2
–0.3
–0.4
–0.5
–0.6
–0.7
–0.2
–0.1
0
0.1
0.2
0.3
0.4
0.5

Fig. 9



ZEUS
xf
μ_f^2 = 10 GeV^2
ZEUS_EW_Z NLO
uncertainties:
experimental
model
parameterisation
ZEUS_EW_W NLO
xu_v
xd_v
xg (× 0.05)
xS (× 0.05)
1
0.8
0.6
0.4
0.2
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x

Fig. 10

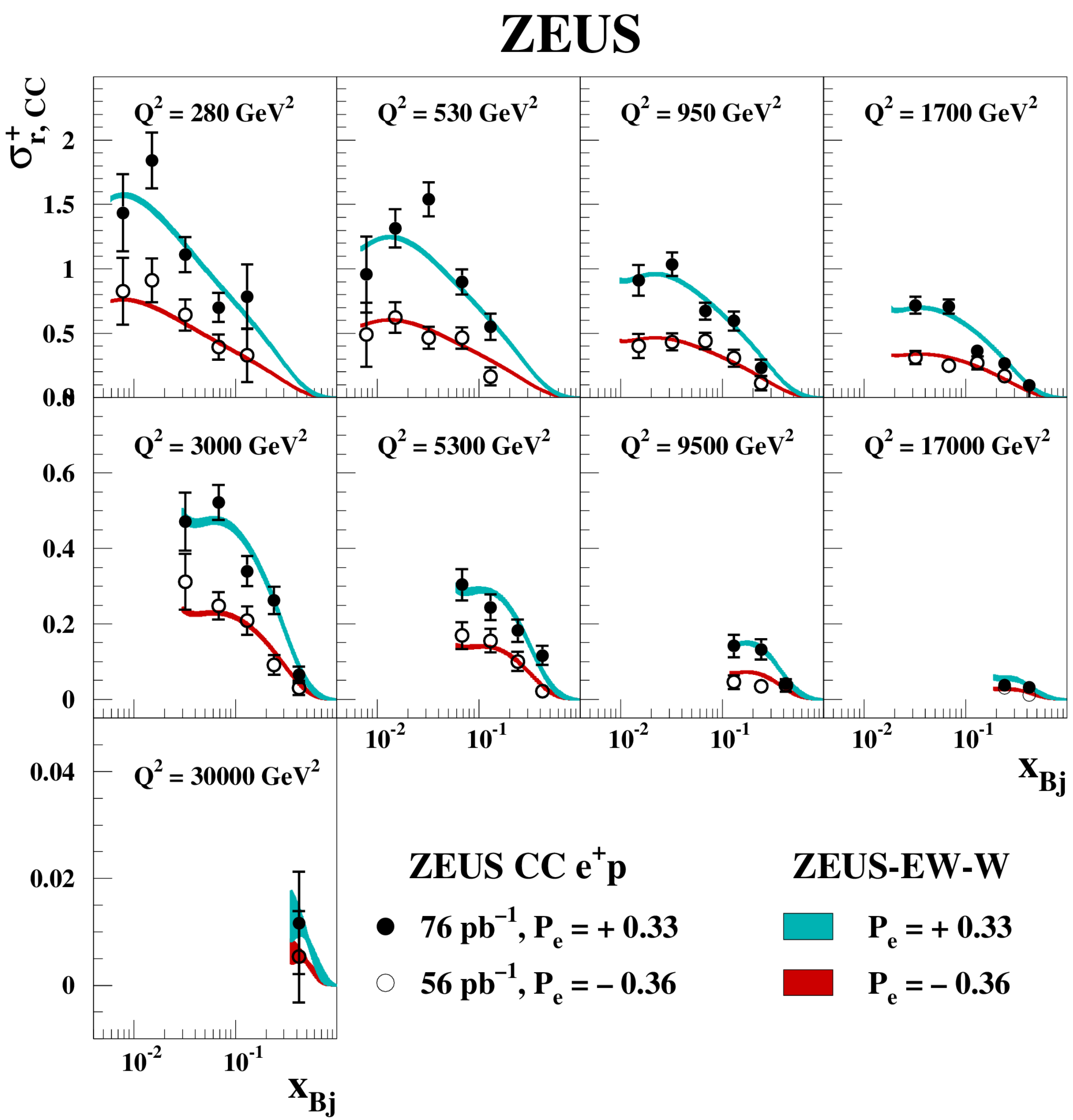
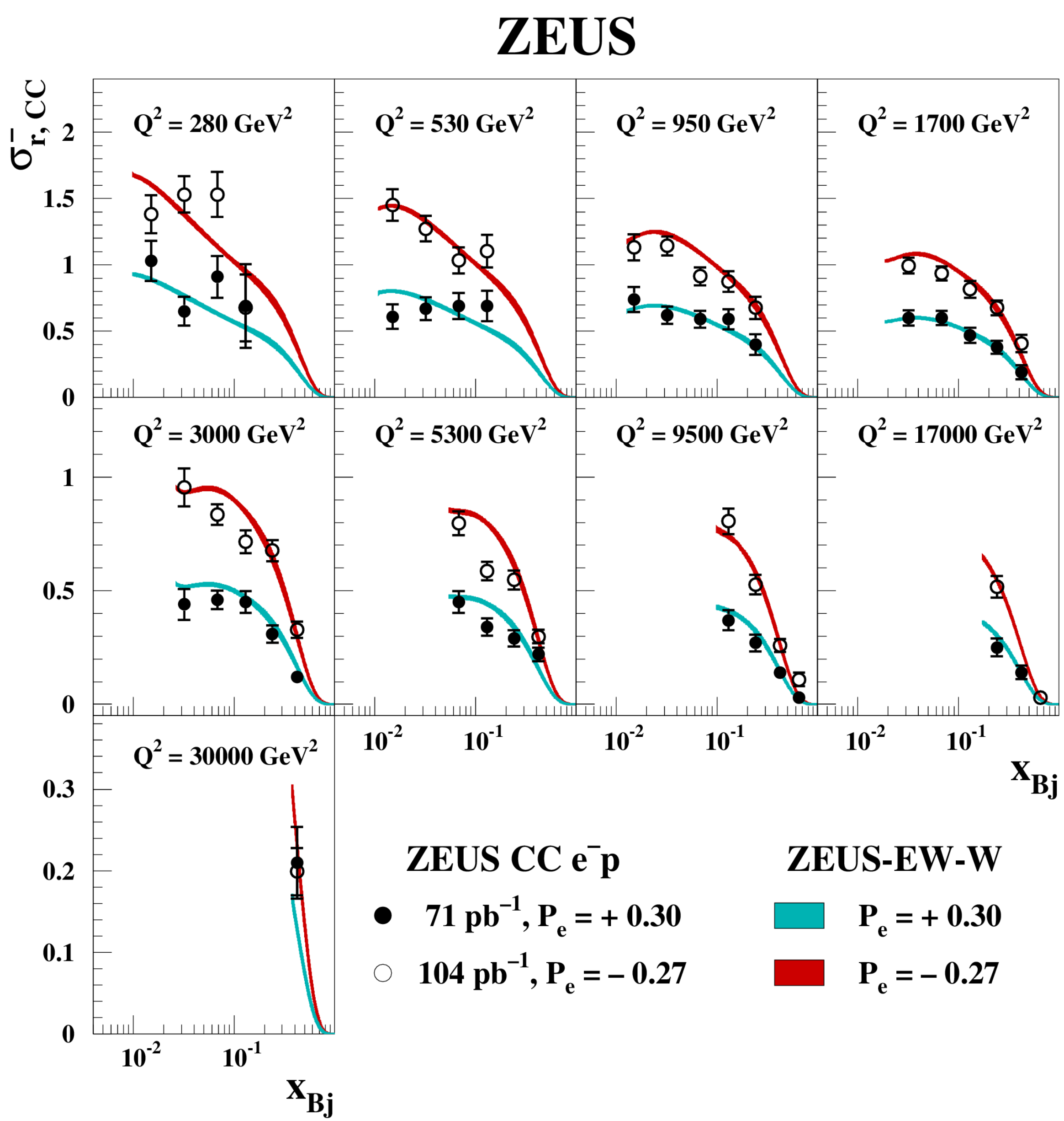

ZEUS
$\sigma^{+}_{r,CC}$
Q^2 = 280 GeV^2
Q^2 = 530 GeV^2
Q^2 = 950 GeV^2
Q^2 = 1700 GeV^2
Q^2 = 3000 GeV^2
Q^2 = 5300 GeV^2
Q^2 = 9500 GeV^2
Q^2 = 17000 GeV^2
Q^2 = 30000 GeV^2
x_{Bj}
ZEUS CC e^+p
76 pb^{-1}, P_e = + 0.33
56 pb^{-1}, P_e = – 0.36
ZEUS-EW-W
P_e = + 0.33
P_e = – 0.36

Fig. 11



ZEUS
$\sigma^-_{r,CC}$
Q^2 = 280 GeV^2
Q^2 = 530 GeV^2
Q^2 = 950 GeV^2
Q^2 = 1700 GeV^2
Q^2 = 3000 GeV^2
Q^2 = 5300 GeV^2
Q^2 = 9500 GeV^2
Q^2 = 17000 GeV^2
Q^2 = 30000 GeV^2
x_{Bj}
ZEUS CC e^-p
71 pb^{-1}, P_e = + 0.30
104 pb^{-1}, P_e = – 0.27
ZEUS-EW-W
P_e = + 0.30
P_e = – 0.27

Fig. 12

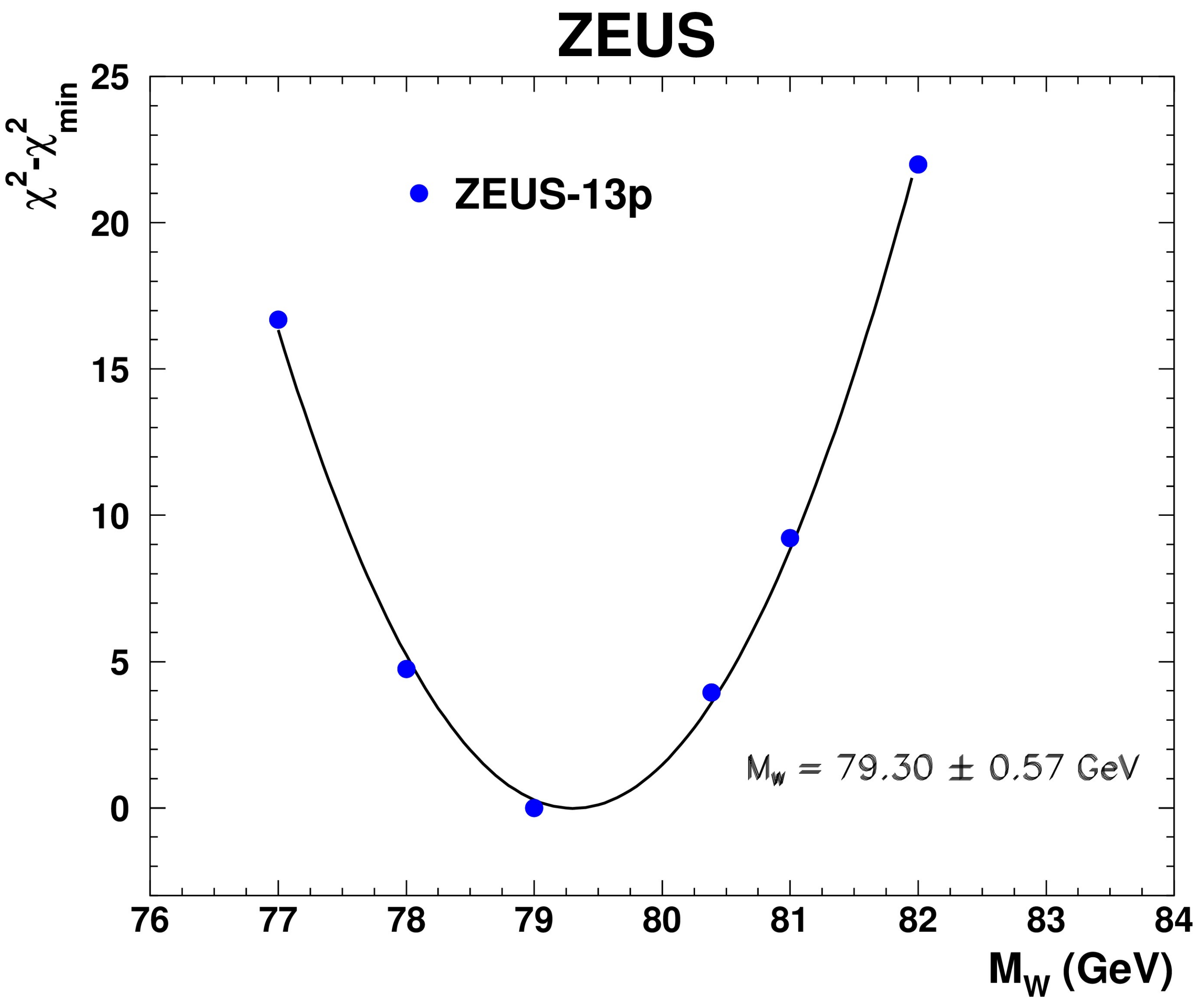
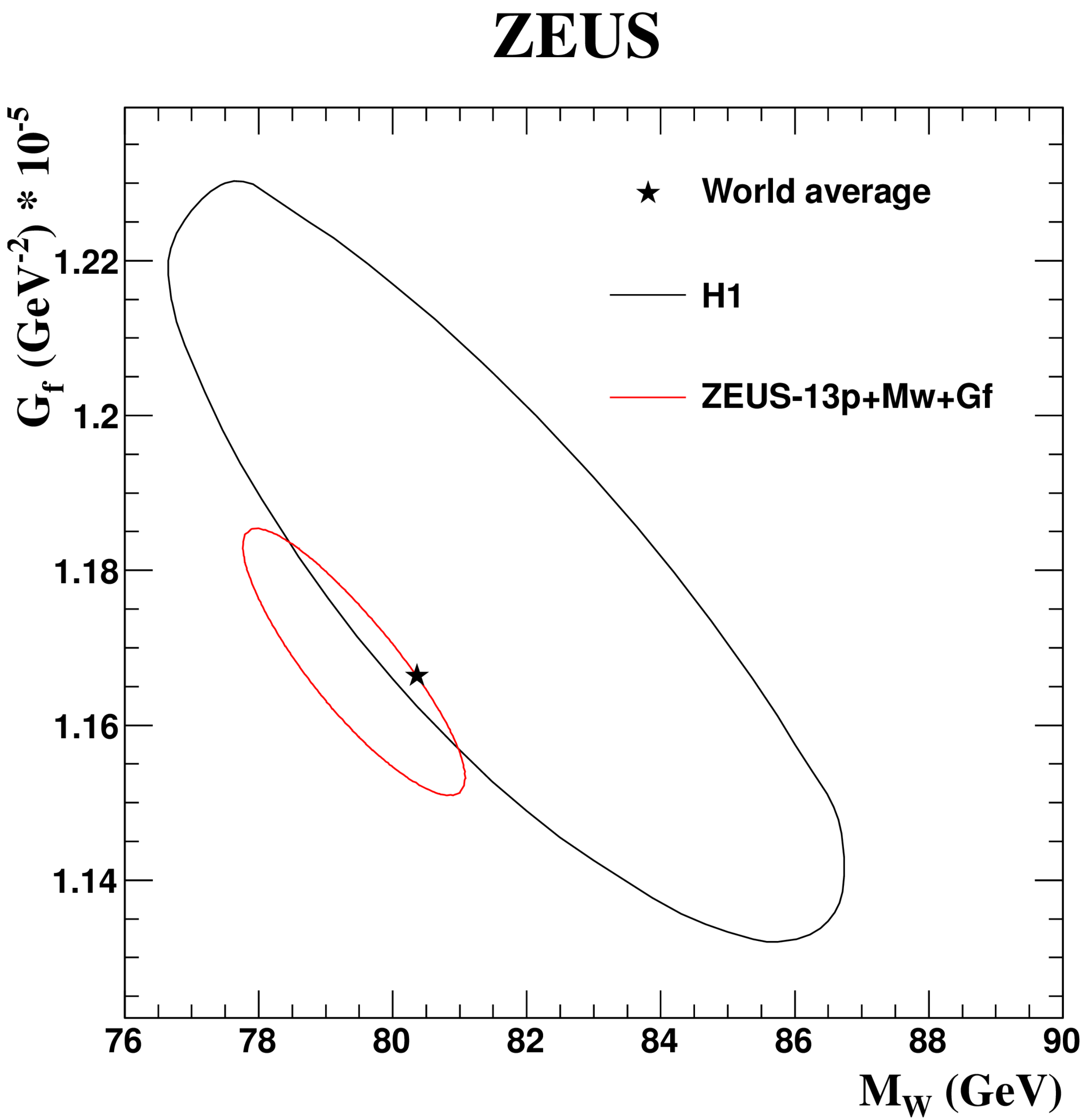

ZEUS
χ^2-χ^2_{min}
25
20
15
10
5
0
ZEUS-13p
M_W = 79.30 ± 0.57 GeV
76
77
78
79
80
81
82
83
84
M_W (GeV)

Fig. 13



ZEUS
World average
H1
ZEUS-13p+Mw+Gf
G_f (GeV^{-2}) * 10^{-5}
1.22
1.2
1.18
1.16
1.14
76
78
80
82
84
86
88
90
M_W (GeV)