H1 and ZEUS Combined PDF Fit

DIS08

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HERA Structure Function Working Group

NLO DGLAP PDF fit to the combined HERA data set presented in the talk of J. Feltesse

- Choice of parametrization
- Choice of error treatment
- Model assumptions
- Quality of fit to data
- PDFs
- Comparison to older H1/ZEUS fits, comparison to CTEQ, MRST
- Model Variations

Chosen form of the PDF parametrization at Q_0^2

$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2+Fx^3\ldots)$$

	A	B	C	D	E
gluon	sum rule	■	■		
u_v	sum rule	■	■	■	■
d_v	sum rule	$= B(u_v)$	■		
U_{bar}	Lim $x \to 0$ $\overline{u}/\overline{d} \to 1$	■	■		
D_{bar}	■	$= B(\overline{U})$	■		

The number of parameters for each parton has been optimized

Optimization means starting with only BLUE parameters and adding D, E,F parameters until there is no further χ2 advantage

PDFs fiited: gluon, u_v, d_v, $U_{bar}=u_{bar}+c_{bar}$, $D_{bar}=d_{bar}+s_{bar}+b_{bar}$

Sea flavour break-up at Q_0: s = fs*D, c=fc*U , $AU_{bar}=(1-fs)/(1-fc)AD_{bar}$

Lim $x \to 0$ $u_{bar}/d_{bar} \to 1$

fs = 0.33D (s=0.5d), fc = 0.15U consistent with dynamical generation

mc=1.4 GeV mass of charm quark mb=4.75 GeV mass of beauty quark
Zero-mass variable flavour number heavy quark scheme (for now)

Q_0^2 = 4 GeV^2 input scale Q^2_{min} = 3.5 GeV^2 minimum Q^2 of input data

$\alpha_s(Mz)$ = 0.1176 PDG2006 value

Renormalization and factorization scales = Q^2

$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2+Fx^3\ldots)$$

Alternative form of PDF parametrization: H1 style

	A	B	C	D	E	F
gluon	sum rule					
U	$\lim_{x\to 0}\bar{u}/\bar{d}\to 1$			sum rule		
D		$=B(U)$		sum rule		
U_{bar}	$=A(U)$	$=B(U)$				
D_{bar}	$=A(D)$	$=B(U)$				

PDFs: gluon, U=u+c, $U_{bar}=u_{bar}+c_{bar}$, D=d+s+b, $D_{bar}=d_{bar}+s_{bar}+b_{bar}$

Sea flavour break-up at Q_0: s = fs*D, c=fc*U   AU=(1-fs)/(1-fc)AD

Alternative form of PDF parametrization: ZEUS style

	A	B	C	D	E!
gluon	From Sum Rule				0.
u_v	From Sum Rule				
d_v	From Sum Rule	$= B_{uv}$			0.
u_{bar} - d_{bar}	from Z_S_11 fit	from Z_S_11 fit	from Z_S_11 fit	0.	0.
Sea				0.	0.

PDFs: gluon, u_v, d_v, Sea= $u_{sea}+u_{bar}+d_{sea}+d_{bar}+s+s_{bar}+c+c_{bar}$

Sea flavour break-up at Q_0: $s_{bar} = (d_{bar}+u_{bar})/4$, charm dynamically generated,

d_{bar}-u_{bar} fixed to fit E866 data

Choice of parameterization

All three forms have good $\chi 2$

our choice has the best

Further motivations are:

- Less model dependence on B parameters than in H1 param.
- No need for an additional input (ubar-dbar) x distribution as in ZEUS-Jet param
- Most conservative errors.
- It is inspired by both H1 and ZEUS parameterizations.

Choice of experimental error treatment

The data have already been combined taking full account of their correlated systematic errors, resulting in much reduced systematic uncertainties on the combined data set. Systematic uncertainties are now smaller than statistical uncertainties across the x, Q^2 plane.

We combine the 43 systematic uncertainties of the data with the statistical uncertainties in quadrature. Then we OFFSET the 4 systematic uncertainties which result from the combination procedure: $\chi 2$ = 476.7 for 562 degrees of freedom

For comparison treating all 47 systematic sources quadratically gives $\chi 2$= 428.0

treating all 47 systematic sources as still correlated gives $\chi 2$=553.1

All three methods give very similar central values for PDFs and very similar PDF uncertainties. Our choice is the most conservative.

The self-consistency of our data set and small systematics allows us to use $\Delta\chi 2$ = 1 to calculate the uncertainties.

Model uncertainties: to be added into the total PDF uncertainty

- mc 1.3 → 1.55 GeV variation of mass of c quark
- mb 4.3 → 5.0 GeV variation of mass of b quark
- fs 0.25→ 0.40 variation of strange sea fraction at Q_0
- fc 0.10→ 0.20 variation of charm sea fraction at Q_0
- Q_0^2 2.0 →6.0 GeV^2 variation of starting scale
- Q_{min}^2 2.5→5.0 GeV^2 variation of cuts on the data included

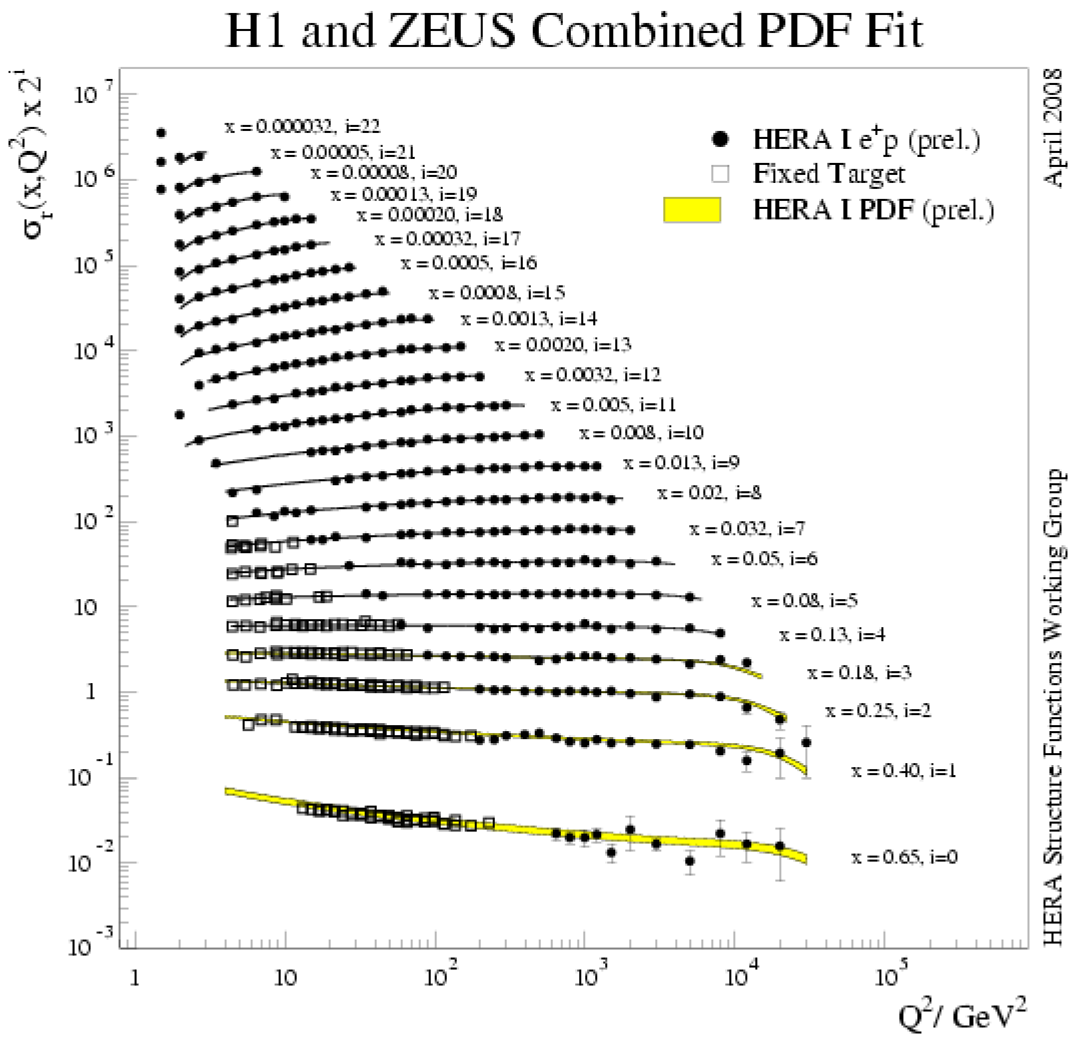
Model variations: to be compared with our results

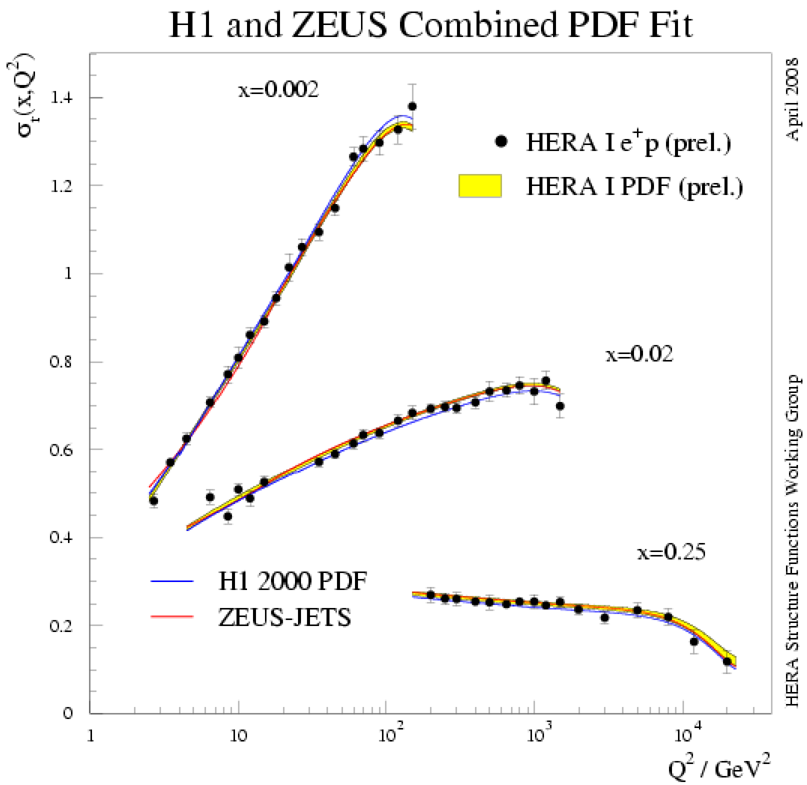
Variation of $\alpha_S(Mz)$ 0.1156 → 0.1196

Variation of form of parametrization

PDF fit RESULTS

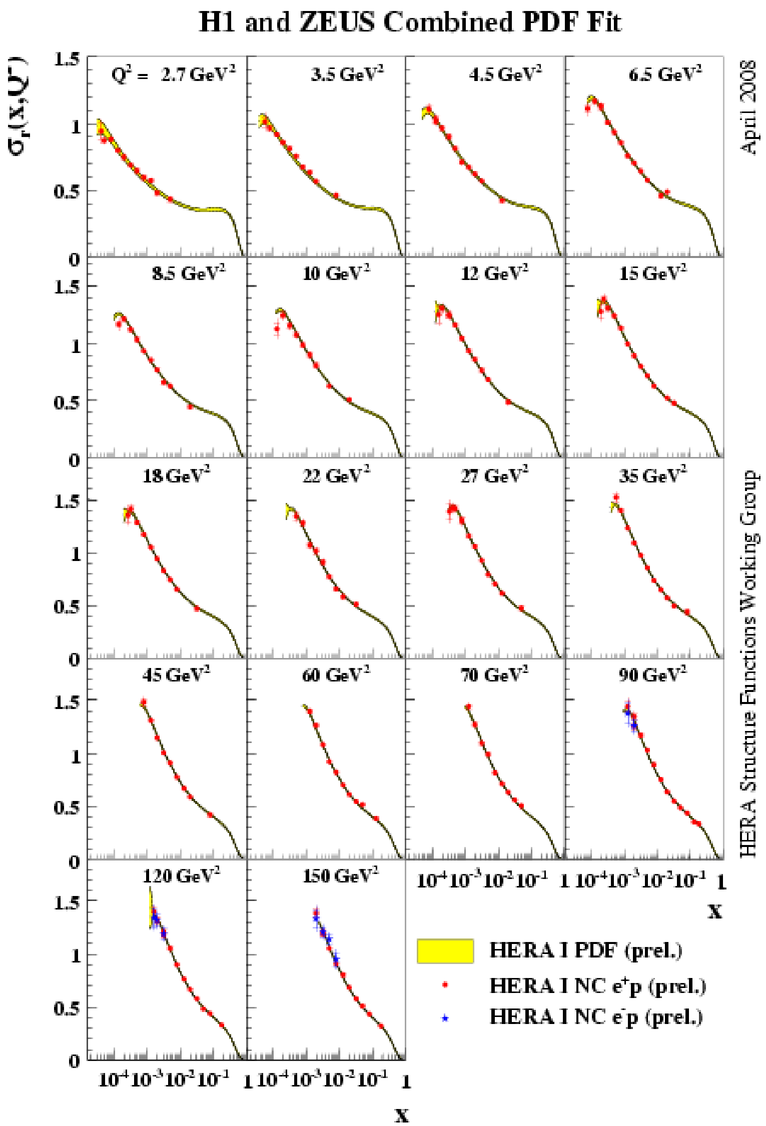
Comparison to HERA combined data



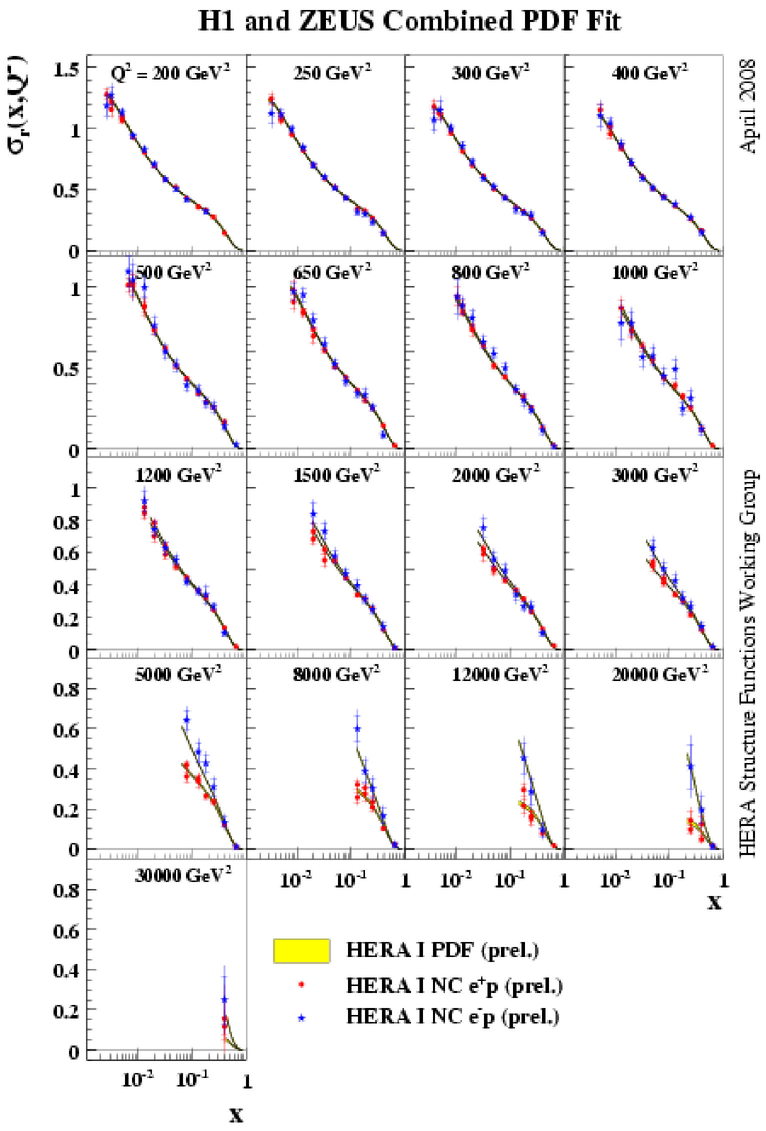


New HERA-I PDF fit predictions vs. H1/ZEUS combined data for NC e^+p. Total uncertainties on the PDF fit predictions are included but can barely be resolved.

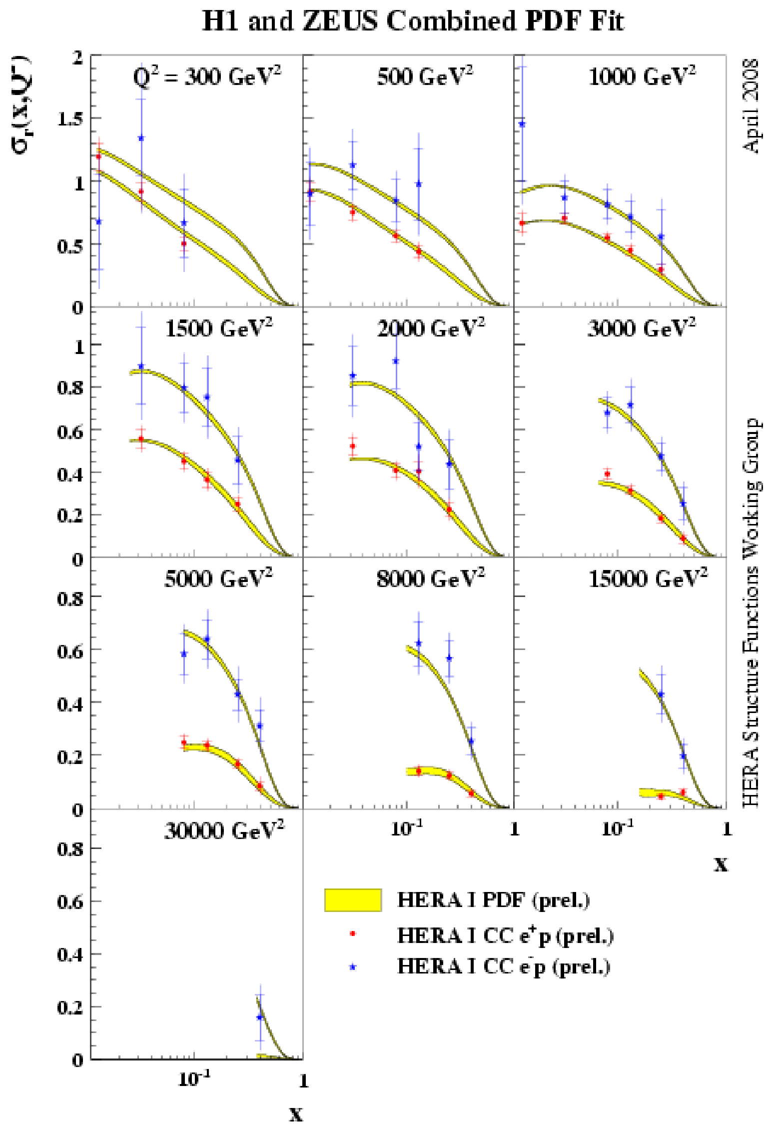
Blow up just three x values to see older ZEUS-JETS PDF and H12000 PDF plus new HERA-I PDF



New H1/ZEUS combined PDF fit predictions vs. H1/ZEUS combined data for NC e^+p and e^-p at low Q2. Total uncertainties on the PDF fit predictions are included but barely be resolved



New H1/ZEUS combined PDF fit predictions vs. H1/ZEUS combined data for NC e^+p and e^-p at high Q2. Total uncertainties on the PDF fit predictions are included but cannot be resolved



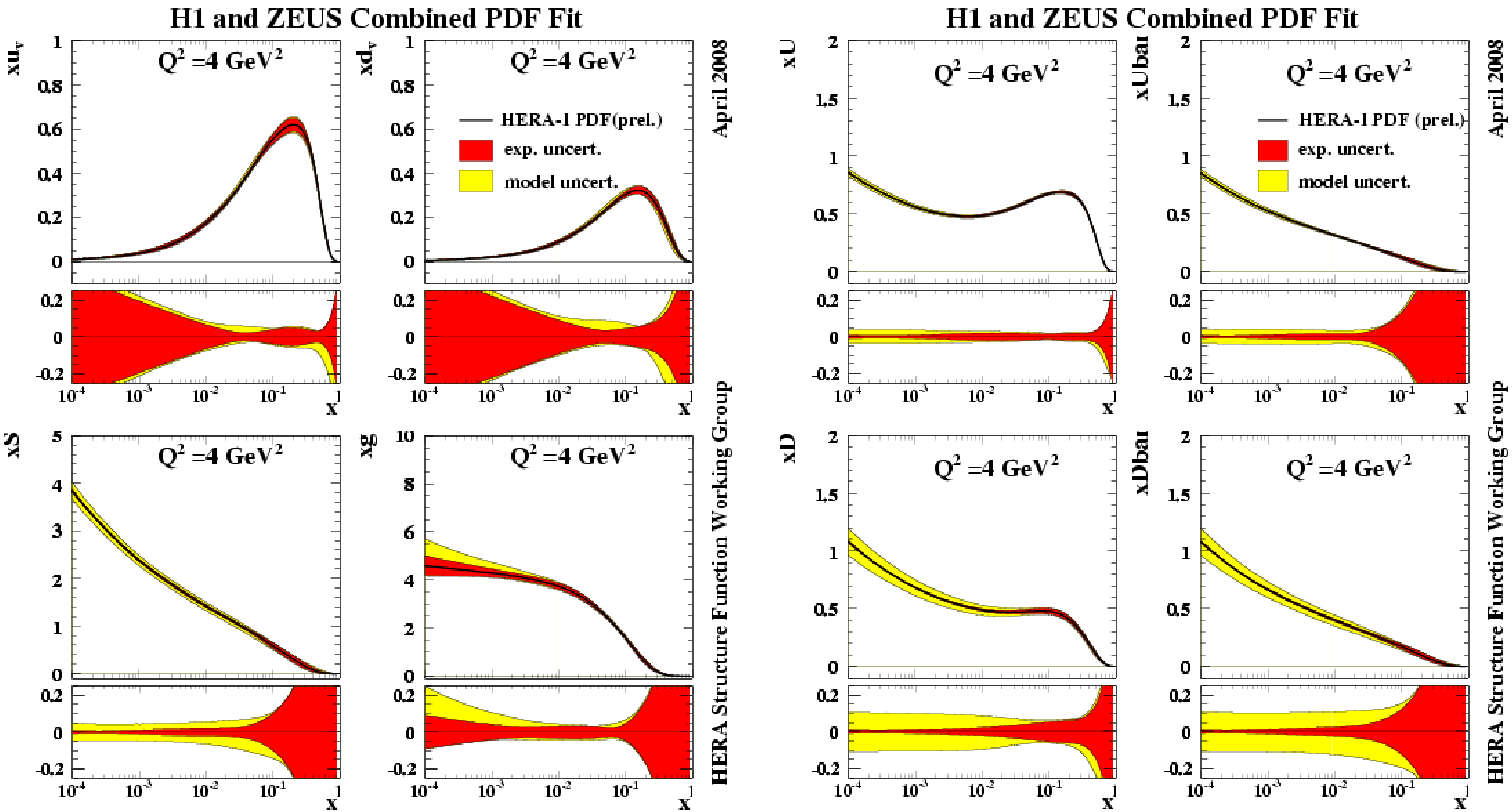
New H1/ZEUS combined PDF fit predictions vs. H1/ZEUS combined data for CC e^+p and e^-p at high Q2. Total uncertainties on the PDF fit predictions are included

PDF fit RESULTS

PDFs: experimental and model errors

Comparison to other PDFs

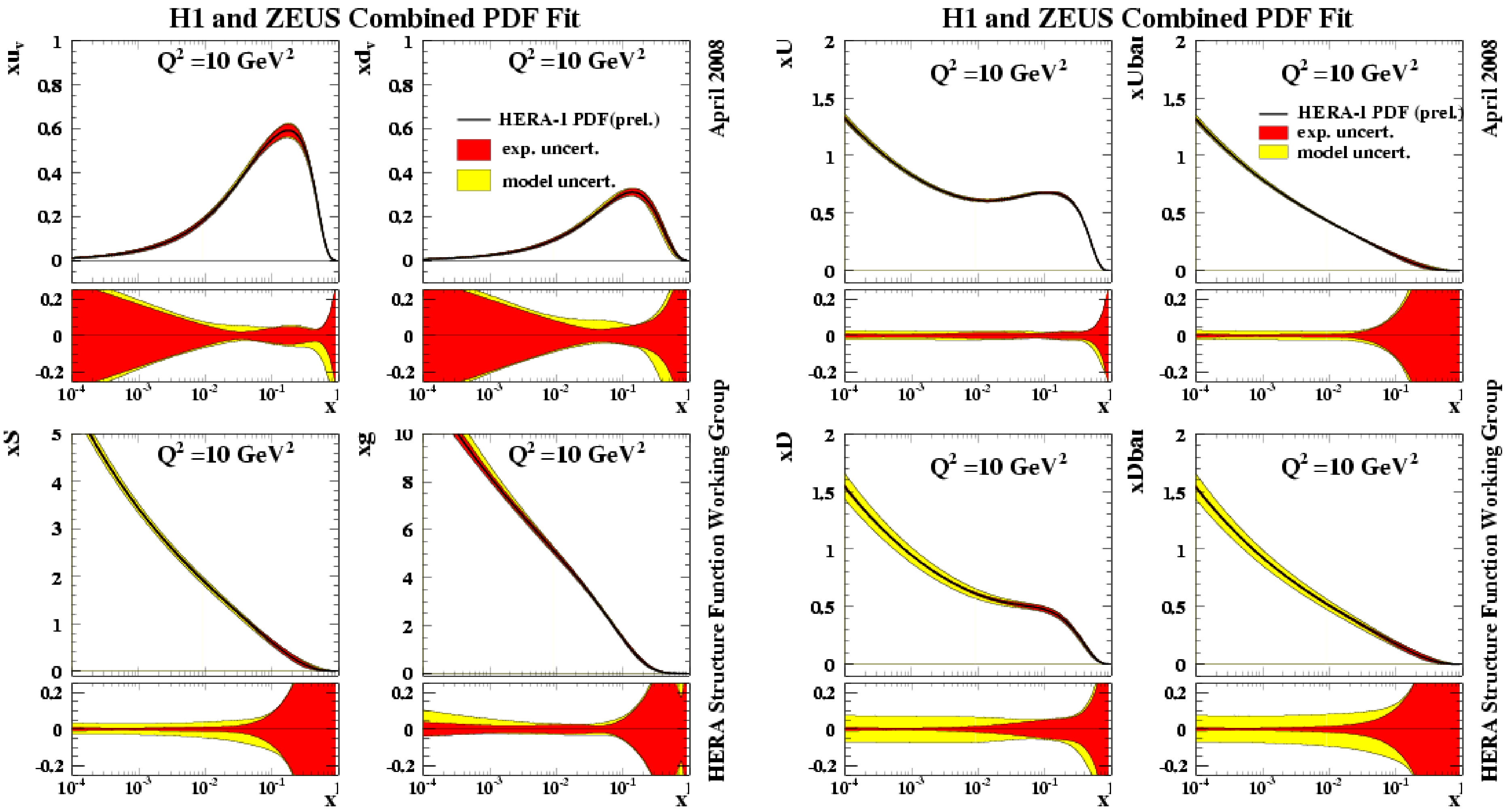
AT THE STARTING SCALE $Q^2_0 = 4\ GeV^2$



New H1/ZEUS combined PDFs with total experimental uncertainty bands plus model uncertainty bands

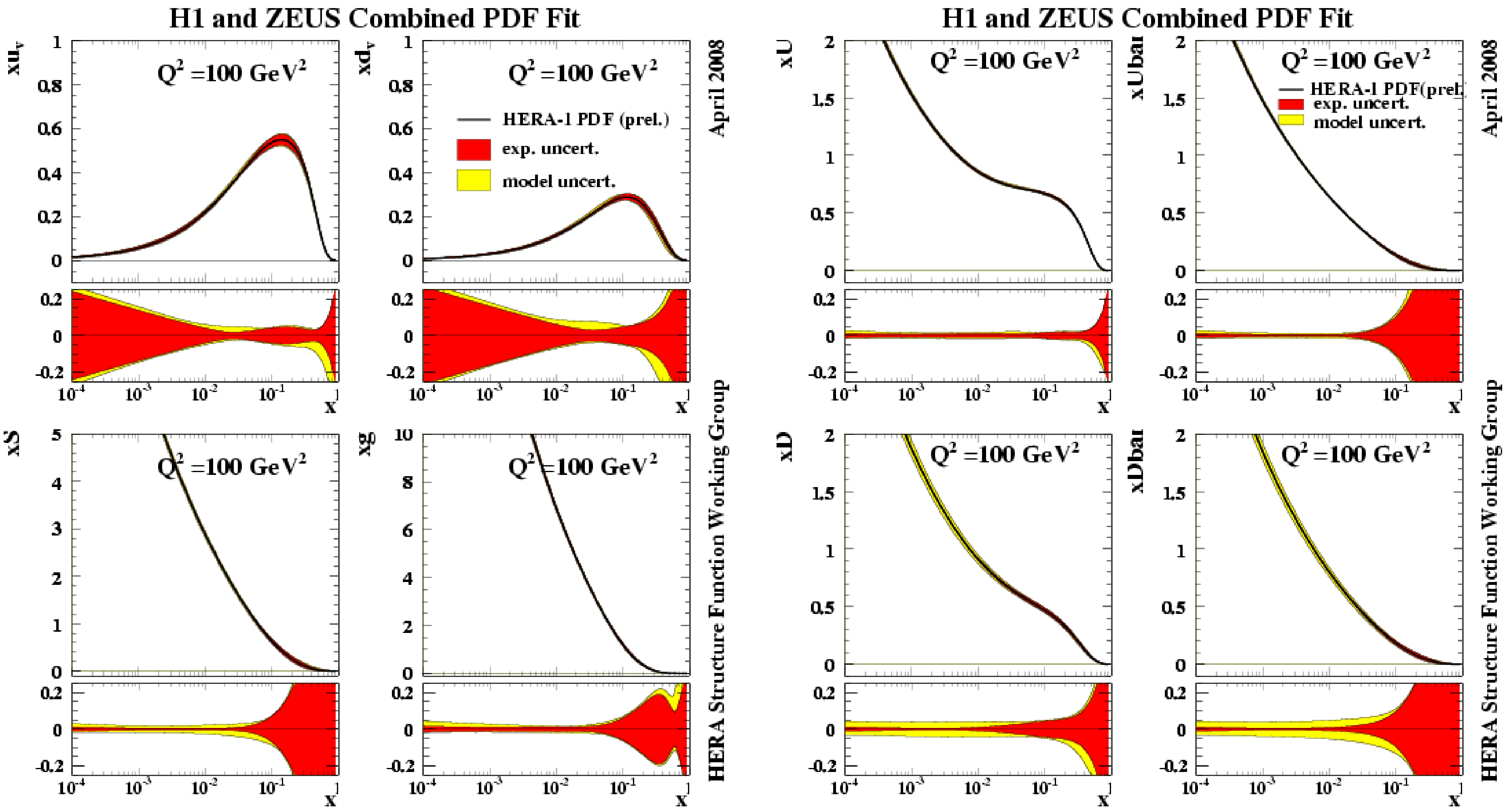
Strange fraction is the major contribution to model uncertainty on the sea
Choice of starting scale and Q2 cuts to the valence and gluon

At Q^2 =10 GeV^2



New H1/ZEUS combined PDFs with total experimental uncertainty bands plus model uncertainty bands

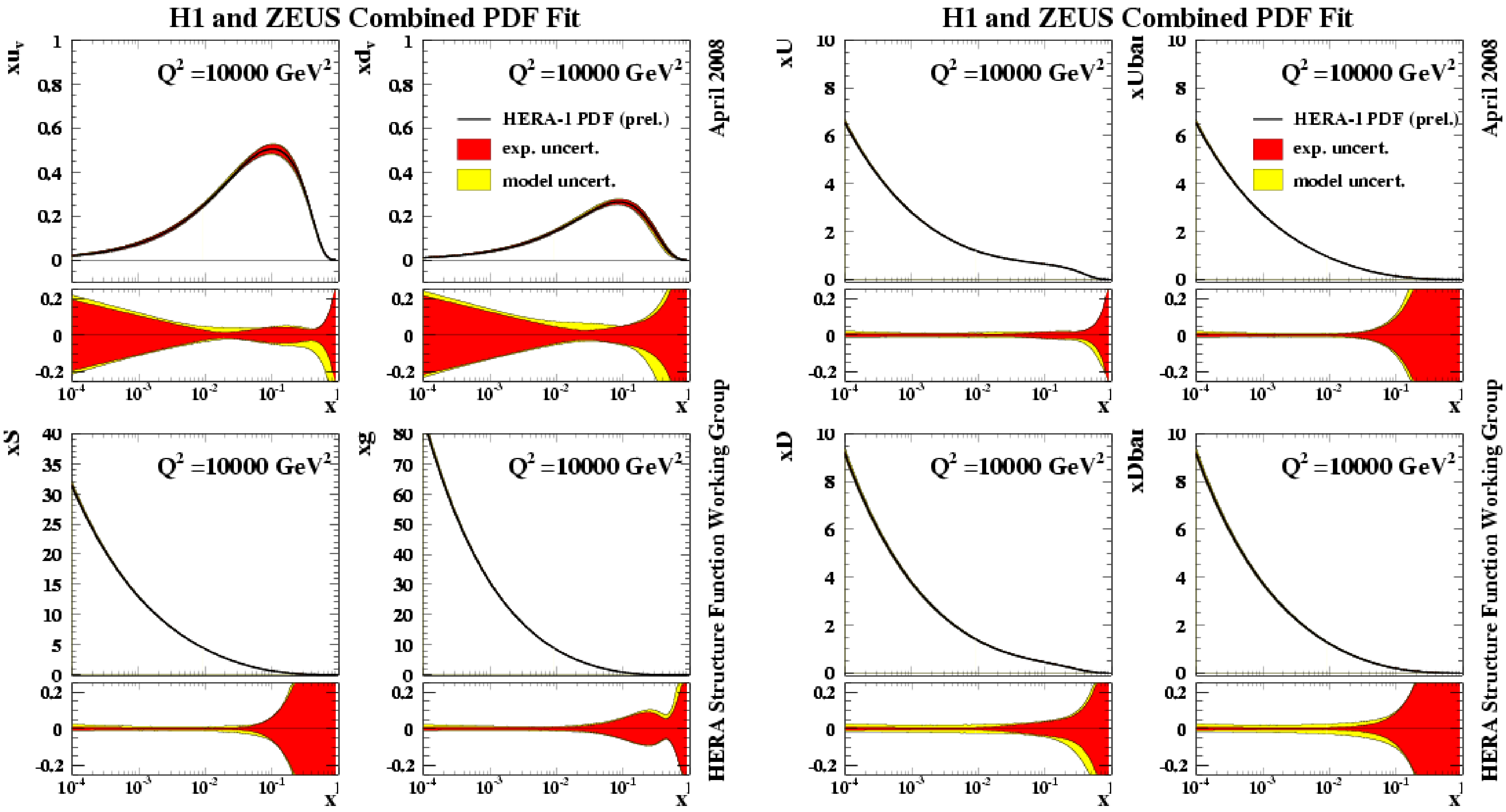
At $Q^2 = 100$ GeV^2



New H1/ZEUS combined PDFs with total experimental uncertainty bands plus model uncertainty bands from 6 sources of model variation:

Note how uncertainties are decreasing with Q^2

At Q^2 = 10000 GeV^2

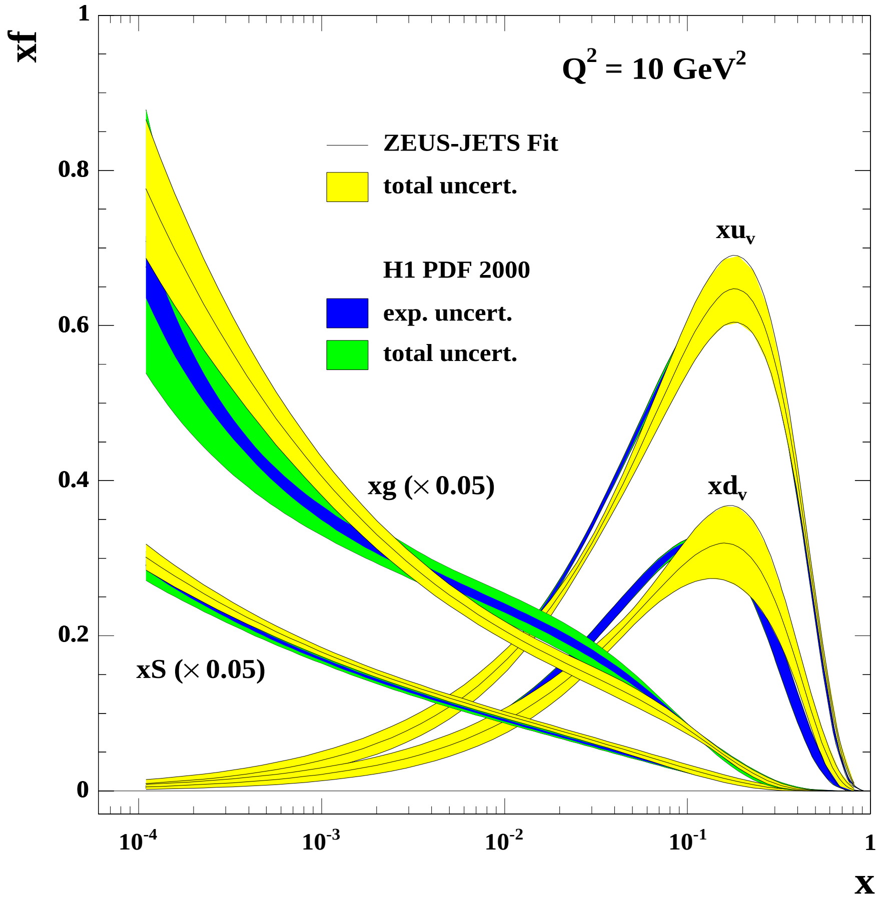


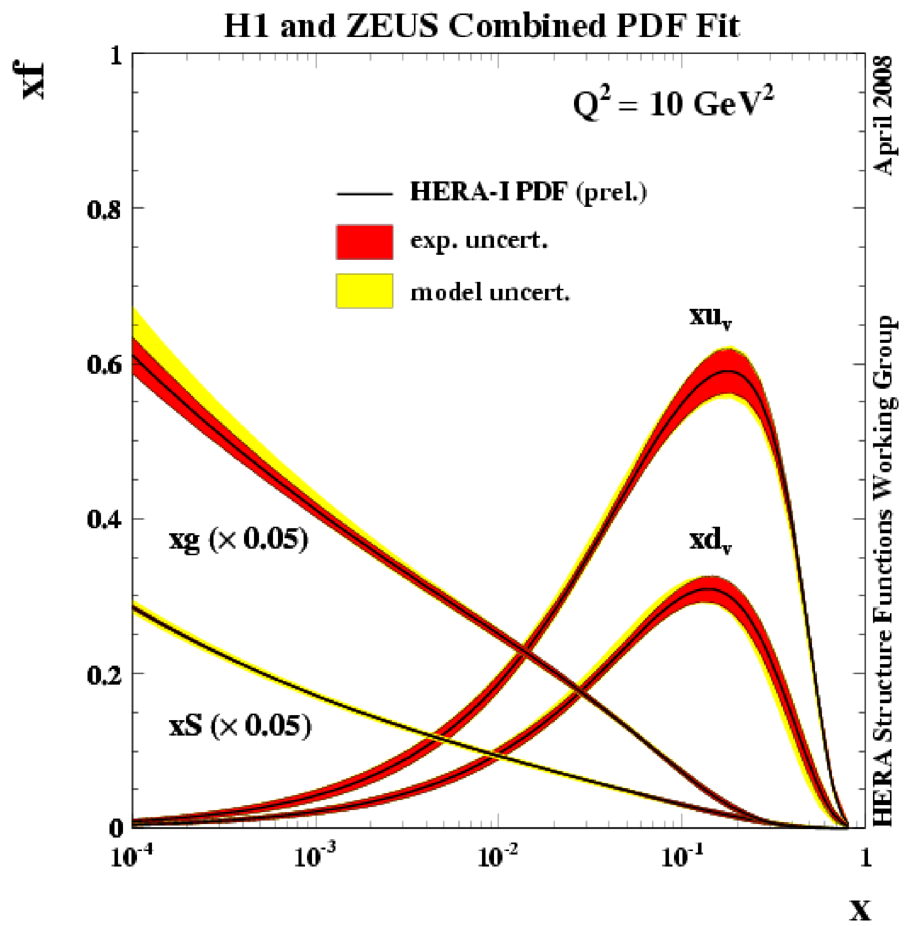
New H1/ZEUS combined PDFs with total experimental uncertainty bands plus model uncertainty bands from 6 sources of model variation:

At scales relevant to LHC physics uncertainties are impressively small.

Compare to published ZEUS/H1 results which also used only HERA data

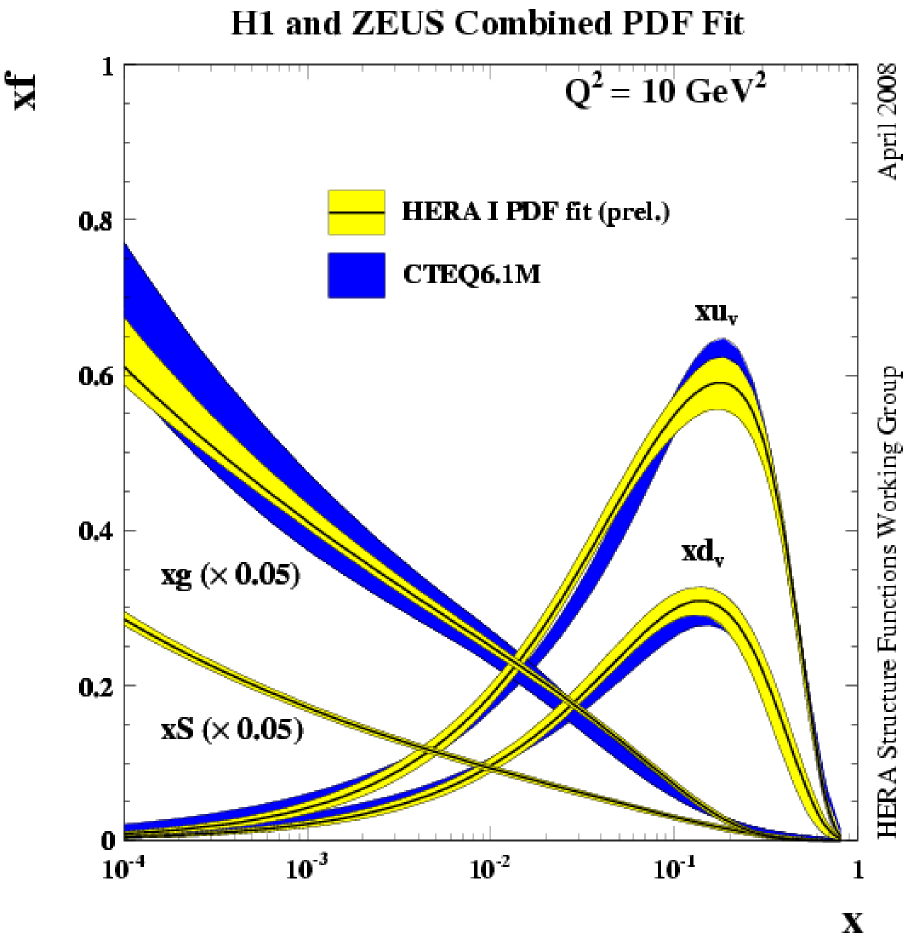
Note in published PDFs H1 has alphas variation included in model error, ZEUS does not.

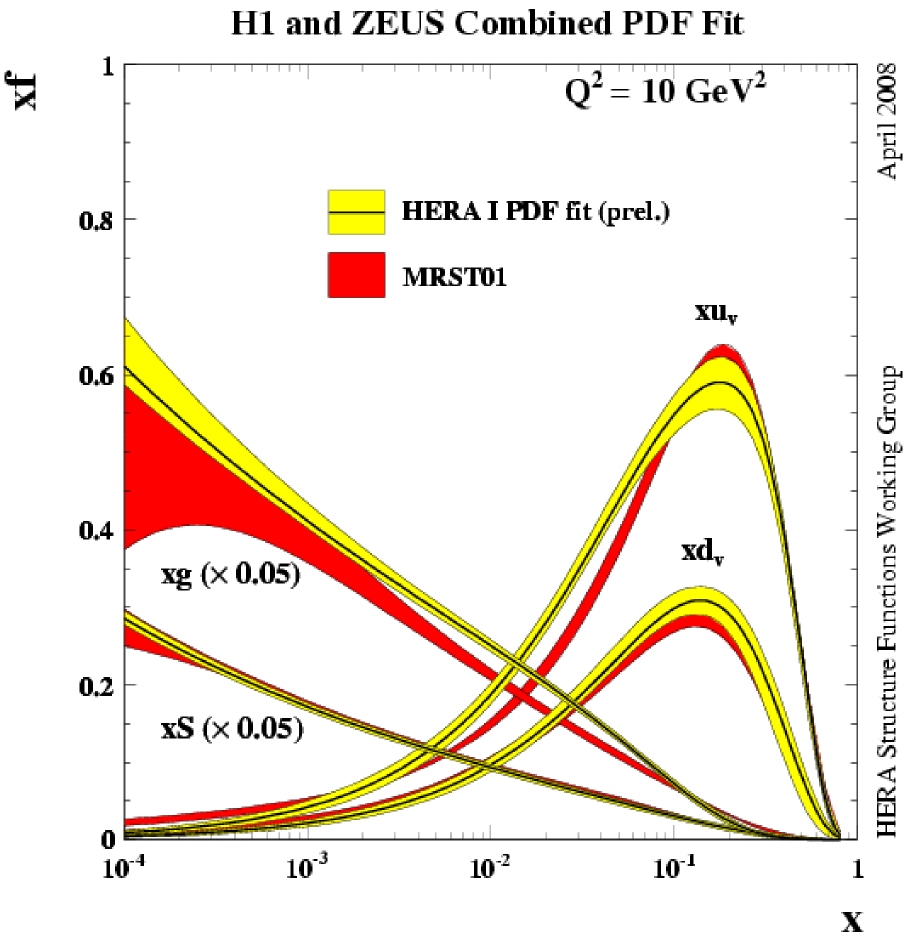




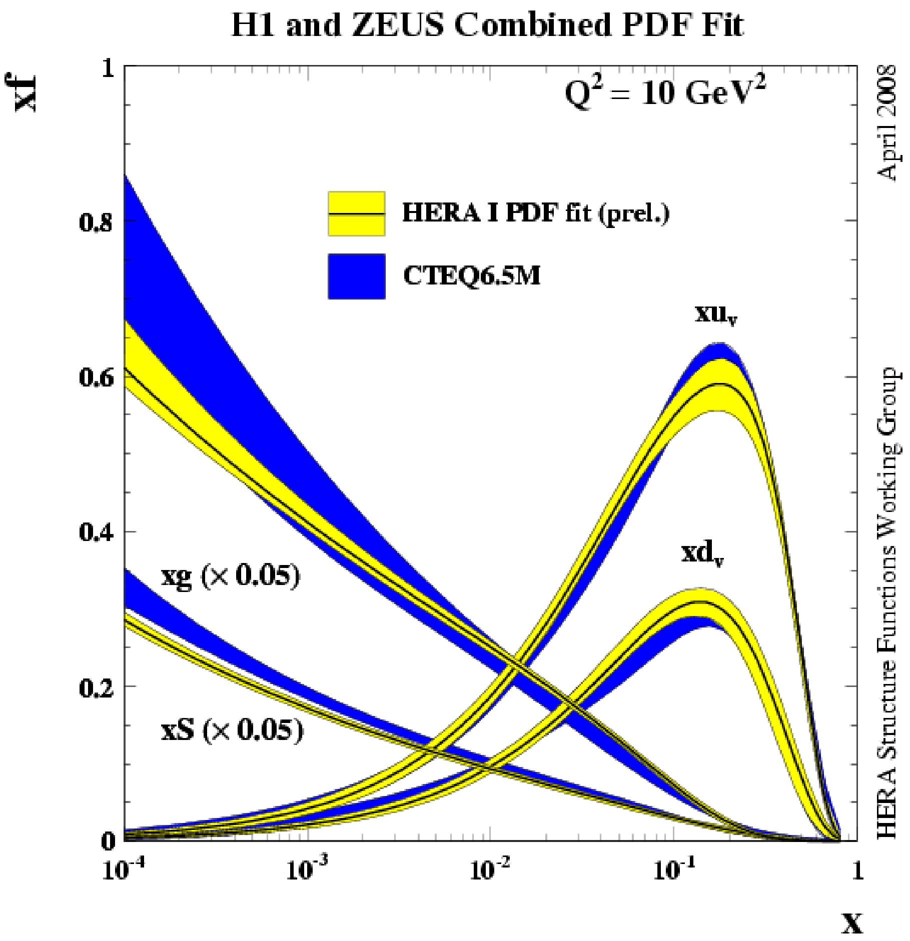
Resolution of previous discrepancies, improvement in level of uncertainty

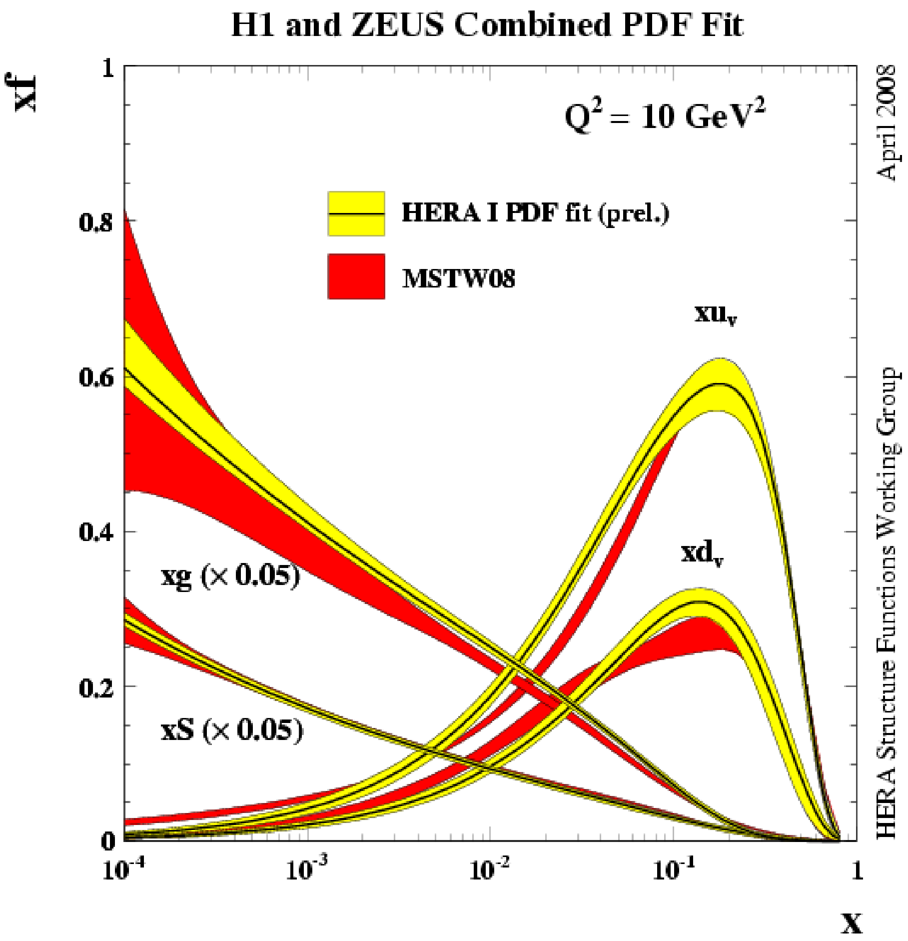
Compare to CTEQ and MRST analyses: older





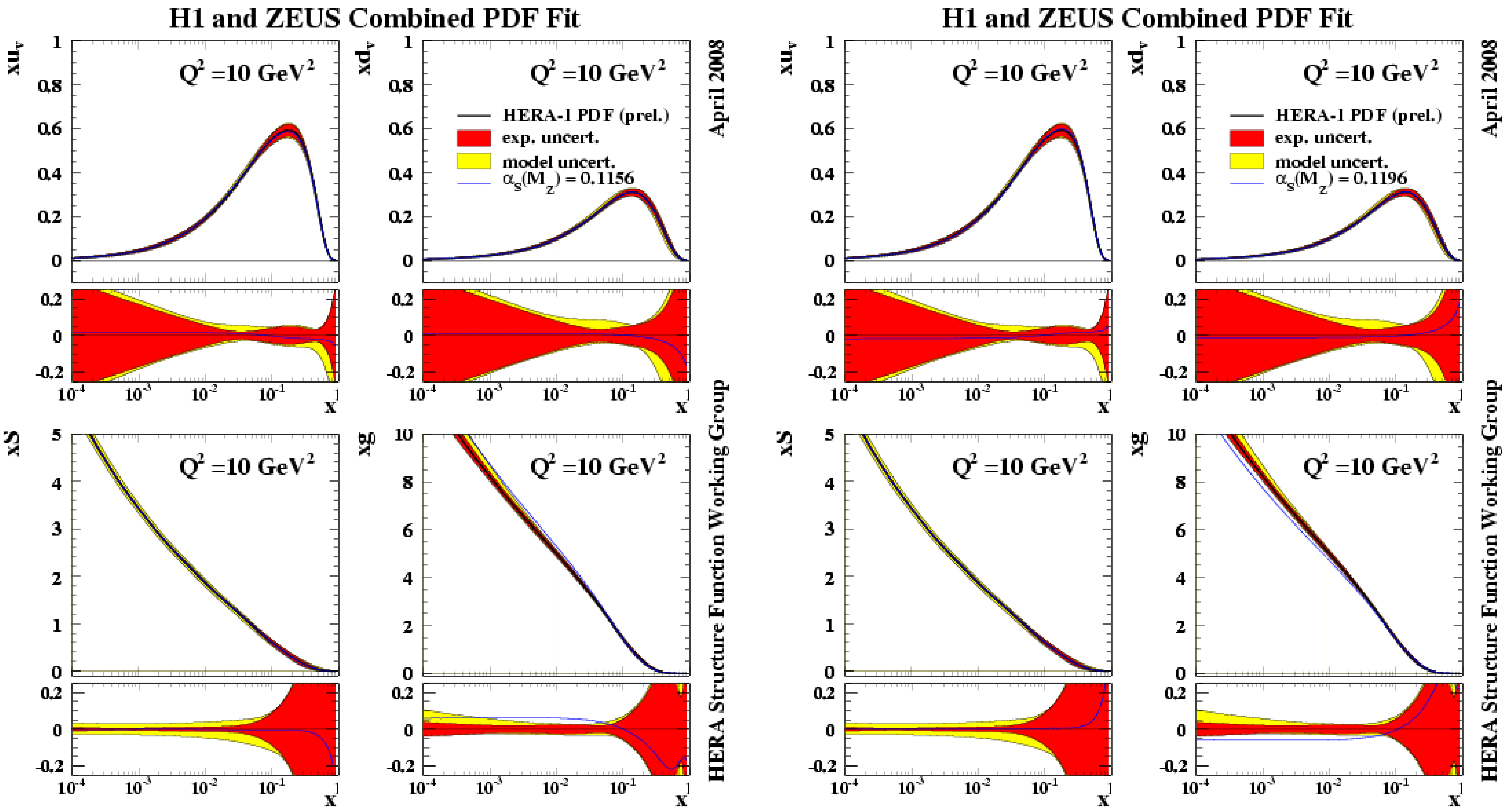
Compare to CTEQ and MRST analyses: newer





Note MSTW08 is as yet unpublished- I have a pre-release

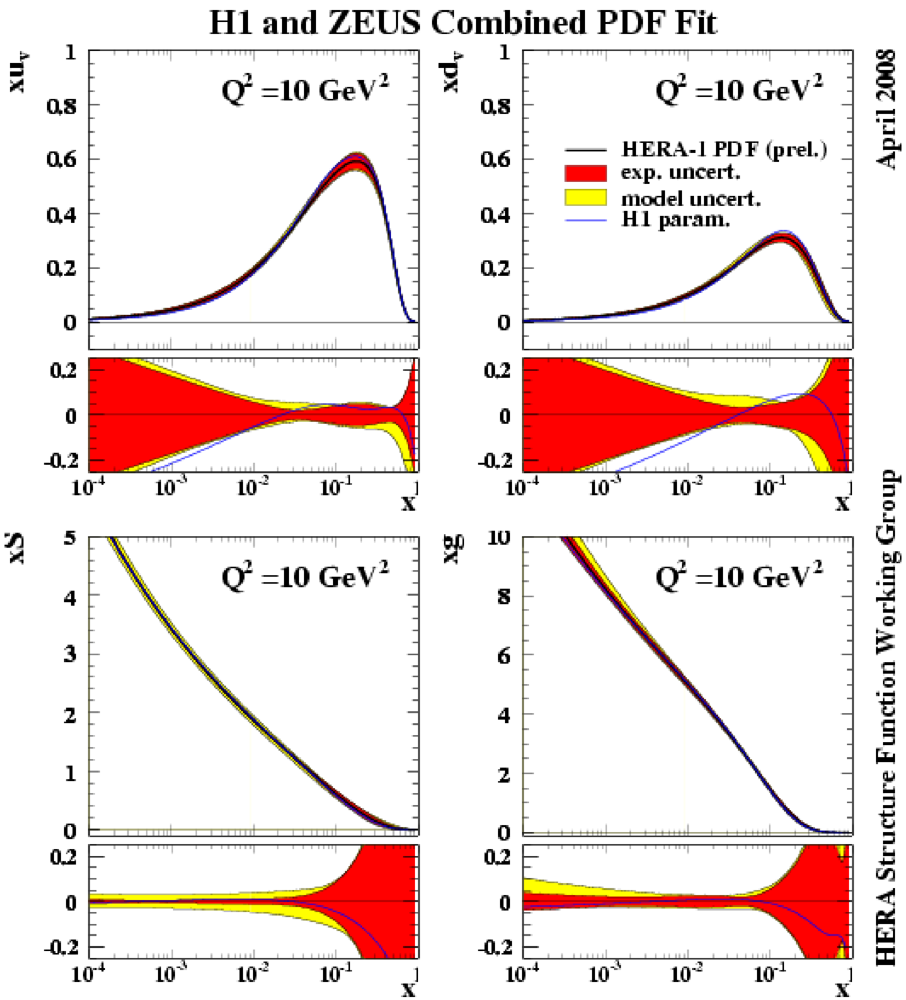
Variations: alpha_s

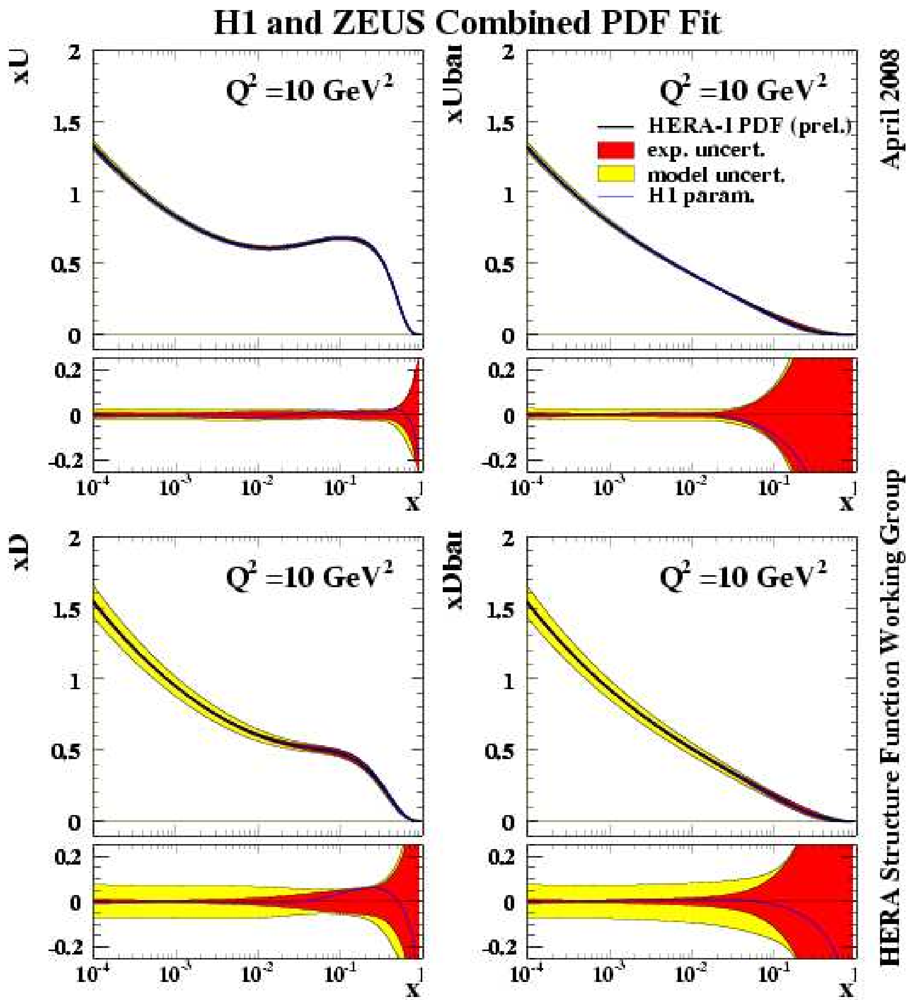


Comparison of central fit plus total uncertainties to variations with $\alpha_s(Mz)$=0.1156 (left) and 0.1196 (right)

Variation is outside the gluon error bands even when other model dependence is accounted.

Variations: use H1 style parametrization

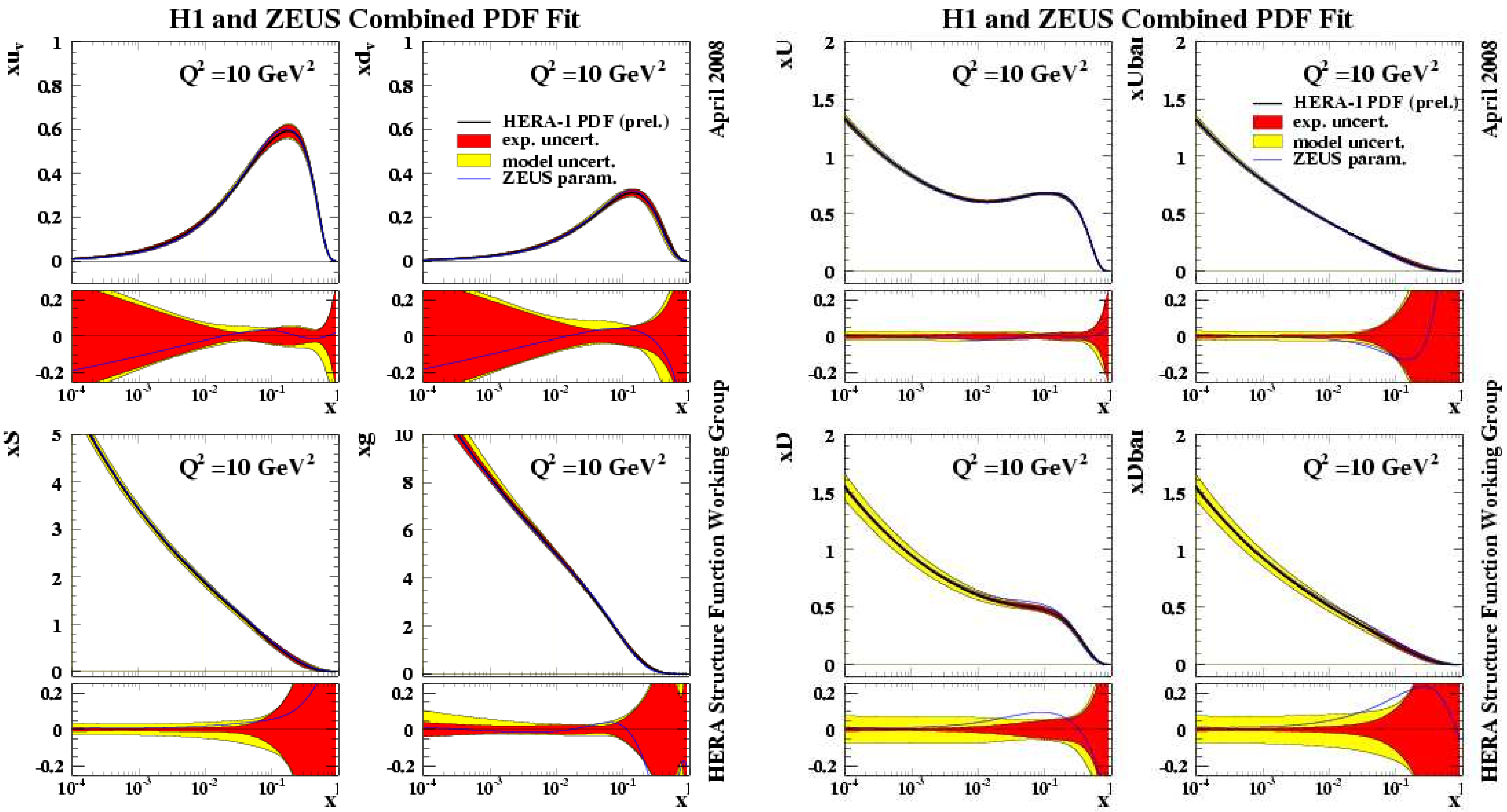




Comparison of central fit plus total uncertainties to parametrization variation using:
New H1 optimised parametrization

Marginally outside normal error bands for valence even when other model dependence is accounted (but note this is at low x where valence isn't very significant)

Variations: use ZEUS-style parametrization



Comparison of central fit plus total uncertainties to parametrization variation using: New ZEUS-JETS optimised parametrization

Inside error bands if other model dependence is accounted

Resolution of an old discrepancy

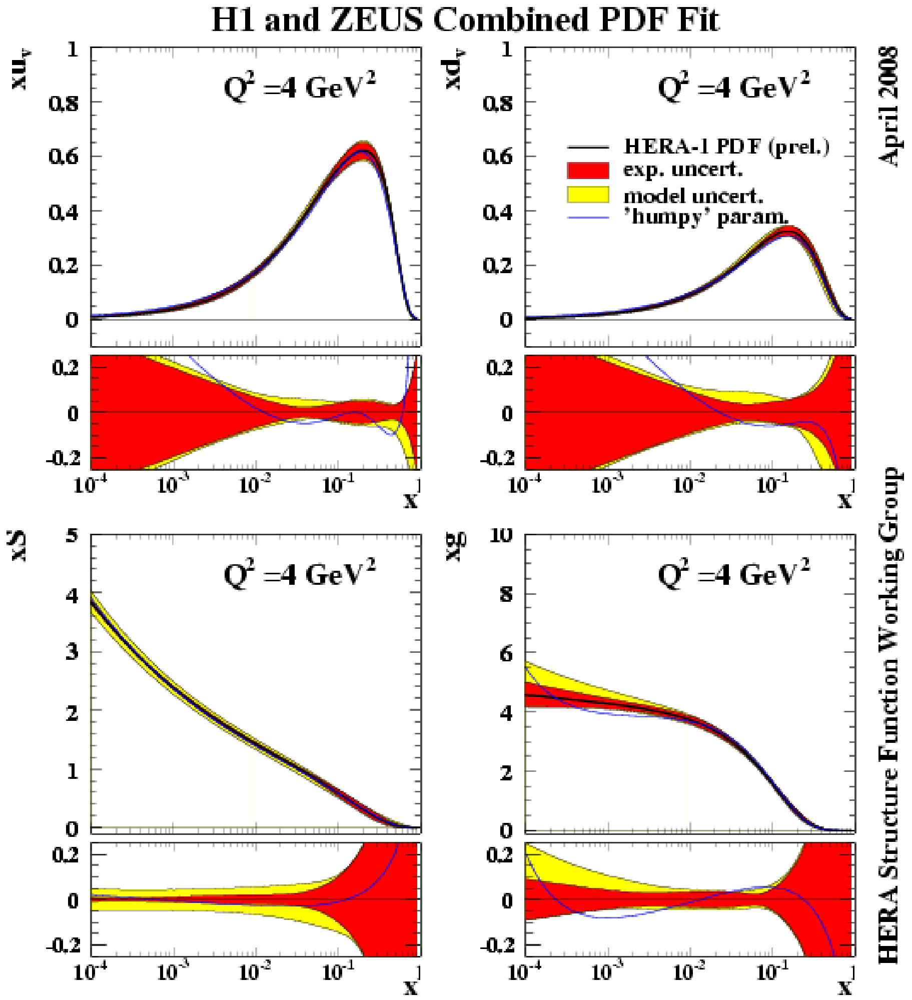
For each of the parametrizations, if a non-zero D parameter for the gluon is used, there are two minima: ‘straight’ gluon and ‘humpy’ gluon solution.

These look rather like the published ZEUS and H1 gluons respectively!

For the H1/ZEUS combined data set the χ2 of the straight solution is always lower by about 10 χ2 points. But whereas the humpy solutions are disfavoured by χ2 they are still acceptable fits

We compare the humpy and straight solutions for our chosen parametrization here. These parametrizations are very consistent.

2



Summary

The combined data set of ZEUS and H1 inclusive cross-section data for NC and CC e+p and e-p scattering has greatly improved precision compared to the measurements of either experiment separately

Dfferences between ZEUS and H1 PDF fitting analyses have also been resolved.

Treatment of experimental and model uncertainties have been carefully considered.

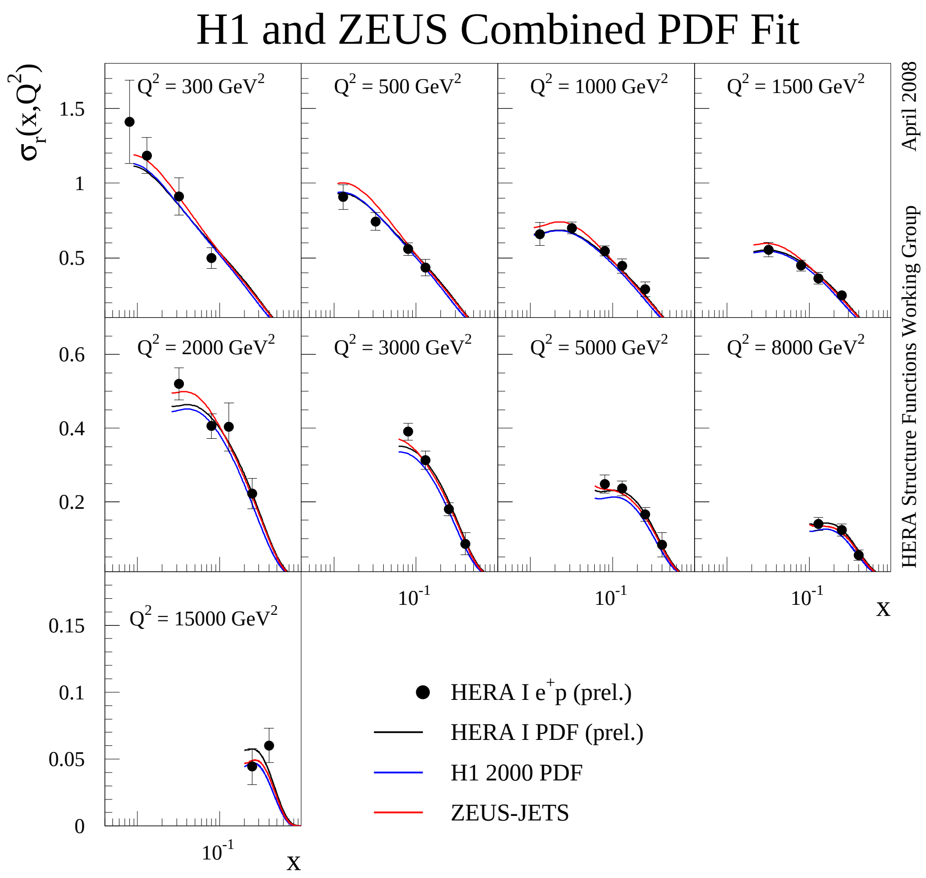
Since our combination procedure has resulted in a single data set with consistently treated systematics there is no need for an inflated $\Delta\chi 2$ in setting the errors on the PDFs.

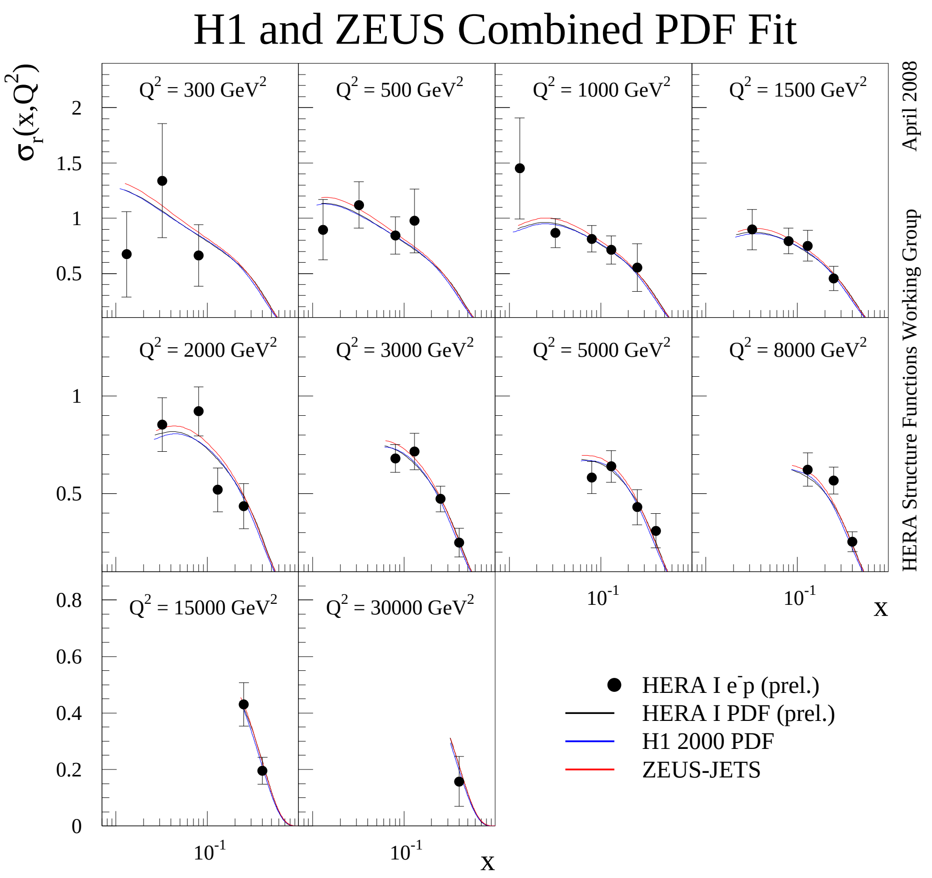
There is also no need for uncertain heavy target corrections.

This results in a HERA PDF set which has impressive precision compared to previous HERA analyses, and to the global fits.

EXTRAS

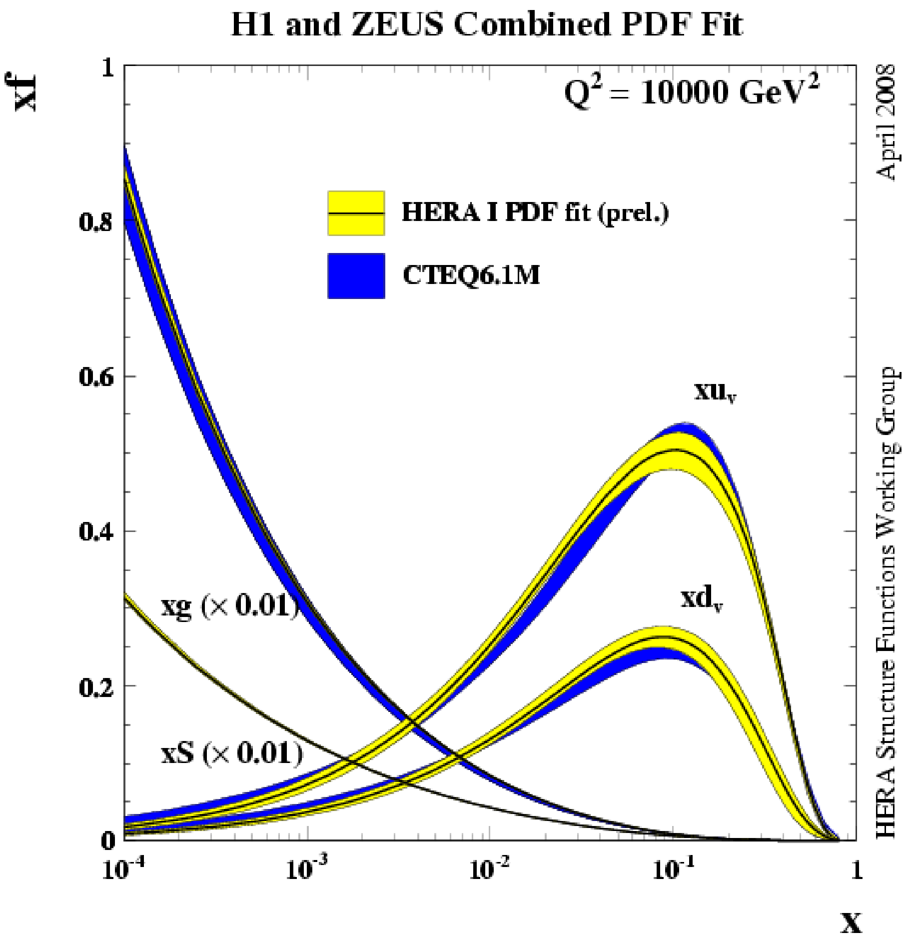
HERA I - Preliminary H1 and ZEUS QCD Fit

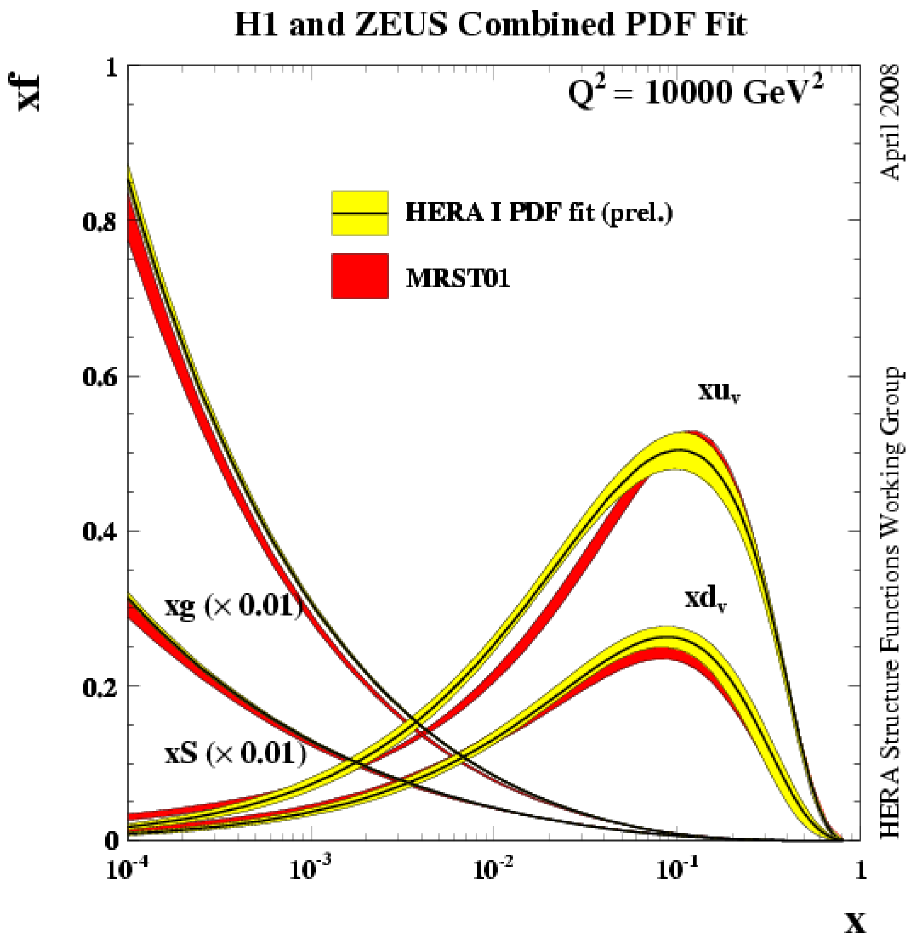




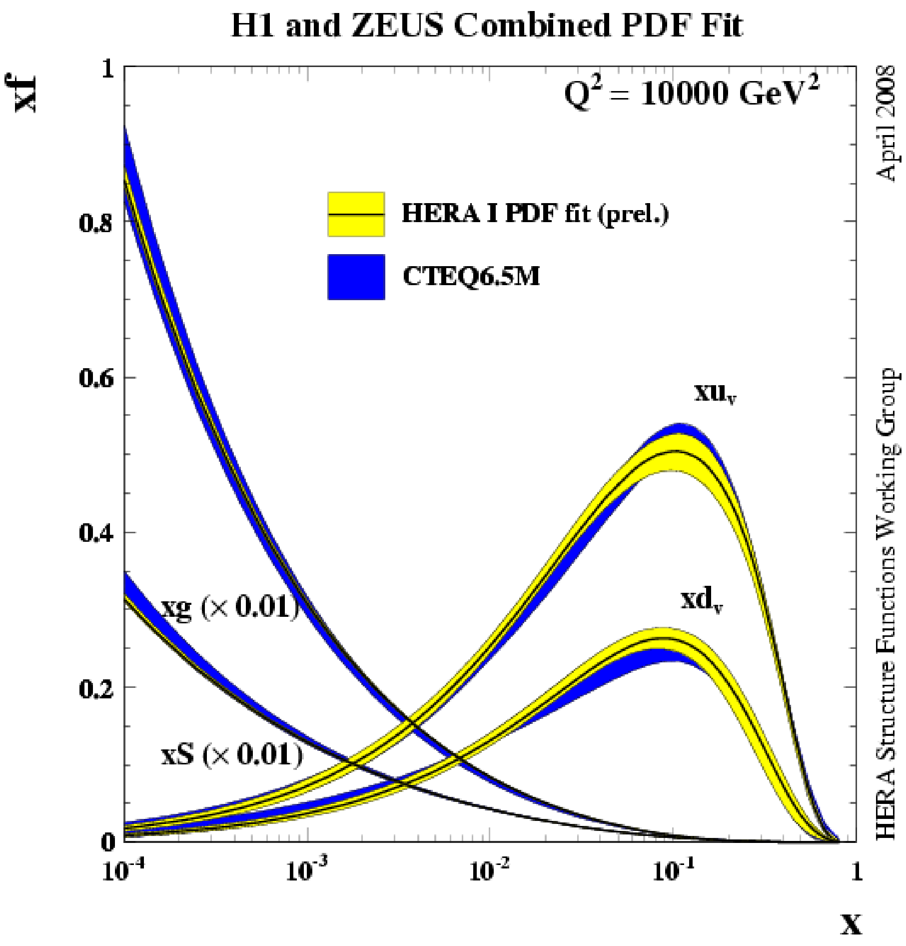
CC e+p (left) e-p (right) compared to older ZEUS-JETS PDF and H12000 PDF plus new HERA-I PDF.

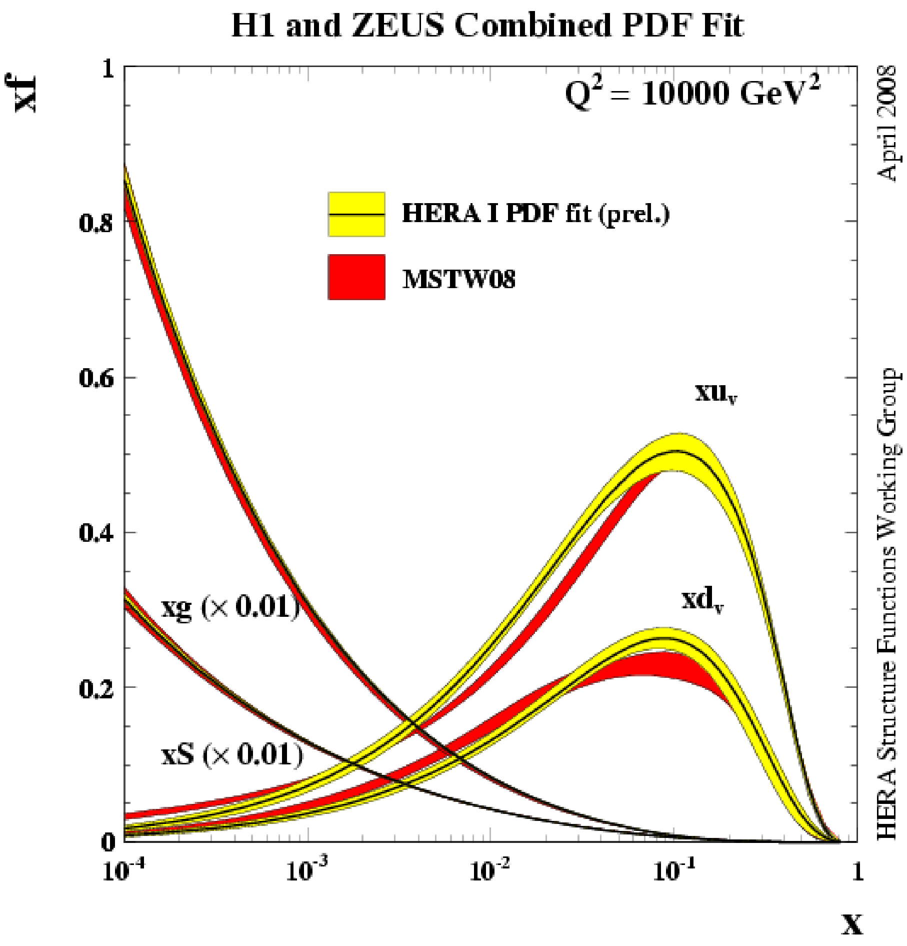
Compare to CTEQ and MRST analyses: older high scale



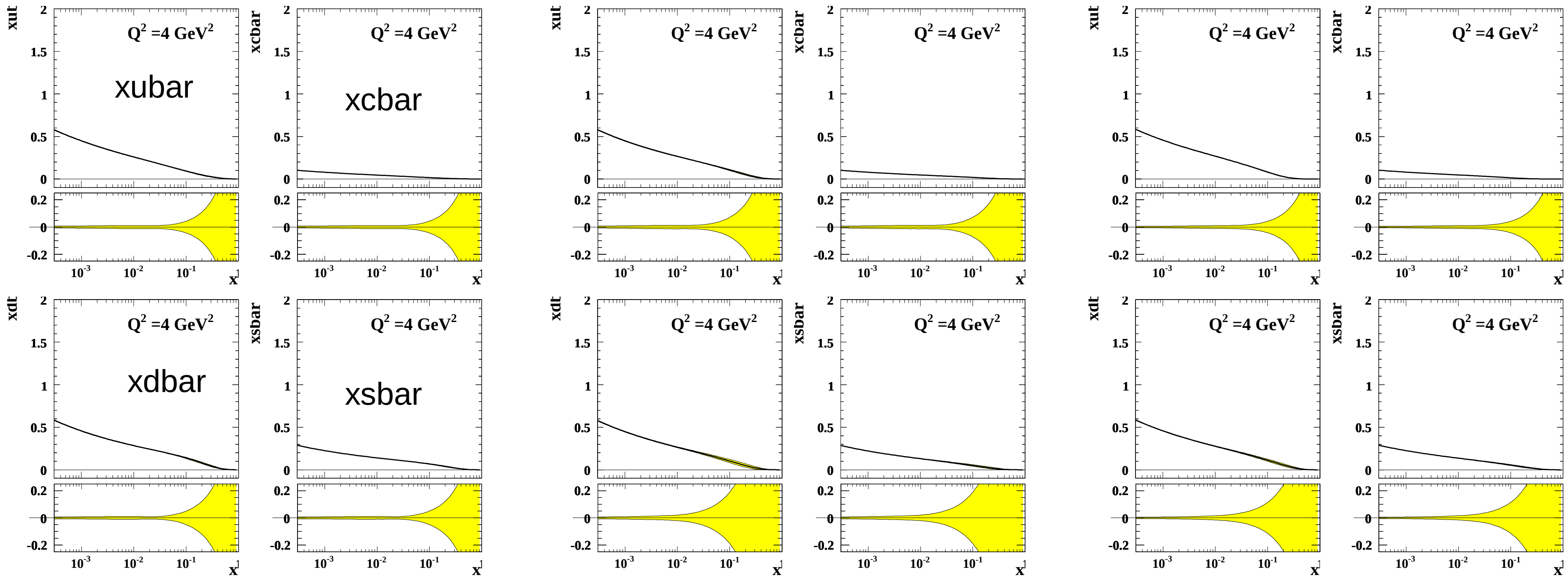


Compare to CTEQ and MRST analyses: newer high scale



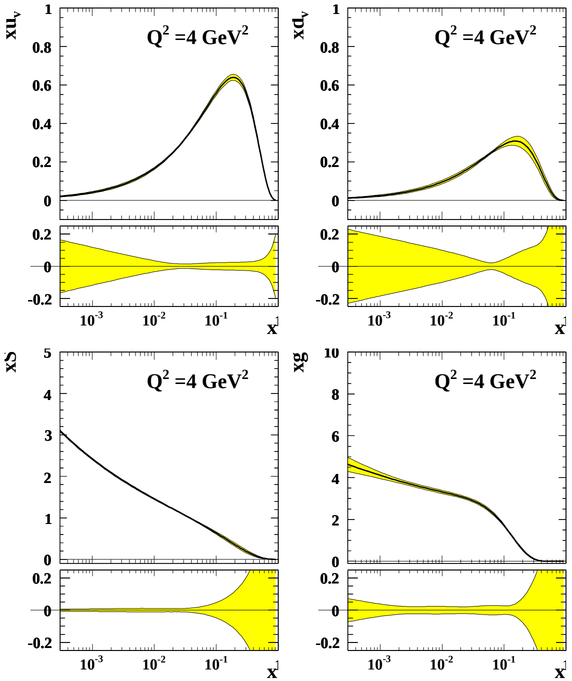


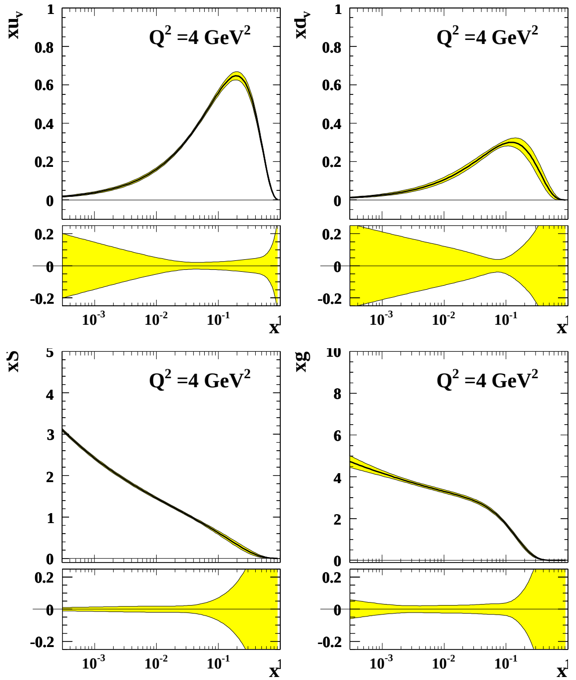
Now in terms of ubar, dbar, sbar, cbar

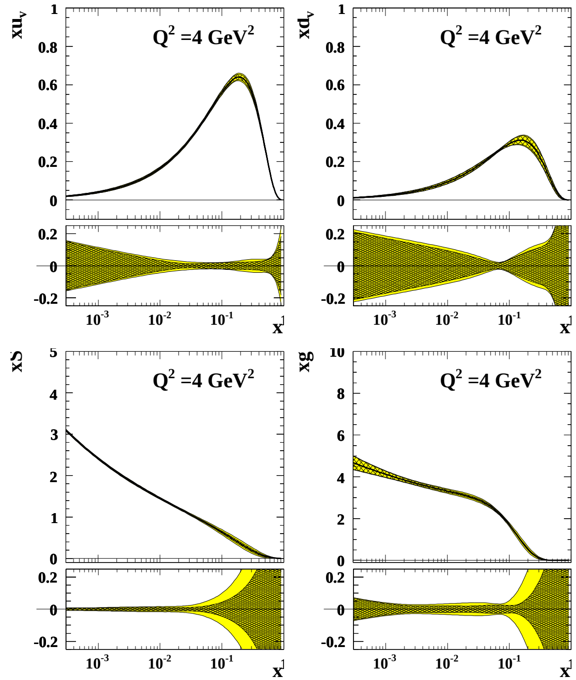


ZEUS-Jets Parametrization in between H1 parametrization

The similarity of these is perhaps even more remarkable given the different treatment of charm- clearly the fixed fraction fc=0.15 is about right compared to dynamical turn on at $Q^2=mc^2$







47 systematic errors added to statistical quadratically $\chi 2$= 428.0

47 systematic errors treated by Hessian method $\chi 2$=553.1

43 original sources of systematic errors added to statistical quadratically and 4 procedural errors Offset $\chi 2$=476.7

Central values very similar, uncertainties largest for OFFSET method, we chose this because it is most conservative. Note there is not much difference between these different error treatments since systematic errors not so big

Proposal that these $\chi 2$ values be made preliminary, all are for 563 degrees of freedom