Comparing ZEUS and H1 PDFs

Combining ZEUS and H1 PDFS?

A M Cooper-Sarkar HERA-LHC Workshop March 2005

- Compare ZEUS/H1 published analyses
- Hessian and Offset uncertainty estimation
- Compare ZEUS/H1 using the same analysis – separately
- -- together
- Advantages of combining at the level of the data sets not the fits

Comparison of ZEUS/H1 published analyses

Both ZEUS and H1 now make PDF fits to their own inclusive differential cross section data. Where does the information come from in a HERA only fit compared to a global fit ?

	Global	**HERA Only**
Valence Mostly uv	Predominantly fixed target data (ν-Fe and μD/μp)	High Q^2 NC/CC $e^{\pm}$ cross sections some dv
Sea	Low-x from NC DIS High-x from fixed target Flavour from fixed target	Low-x from NC DIS High-x less precise Flavour ?(need assumptions
Gluon	Low-x from HERA $dF_2/d\ln Q^2$ High-x from momentum sum	Low-x from HERA $dF_2/d\ln Q^2$ High-x from momentum sum

Tevatron jet data? HERA jet data?

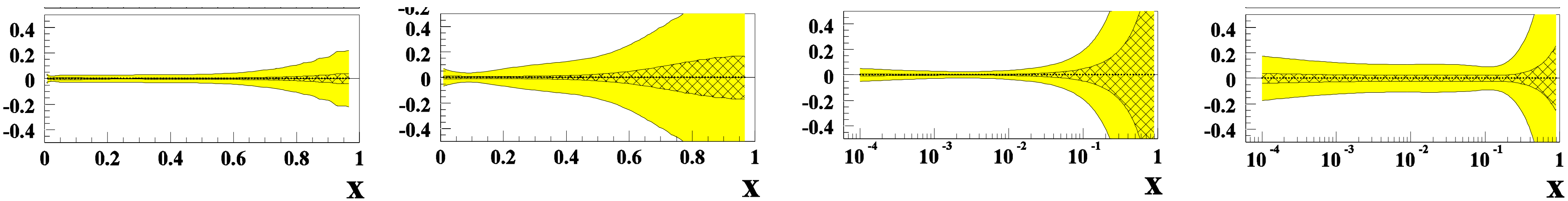
ANALYSES FROM HERA ONLY …

–Systematics well understood - measurements from our own experiments !!!

–No complications from heavy target Fe or D corrections

–No assumptions on isospin (d in proton = u in neutron ?)

Compare the uncertainties for uv, dv, Sea and glue in a global fit to DIS data

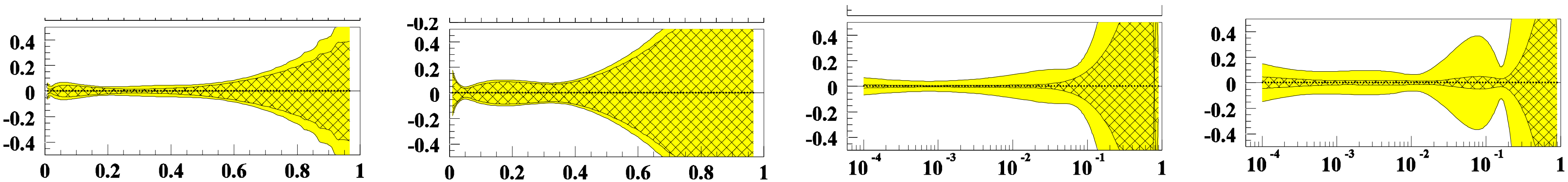


uv dv Sea Gluon

High-x Sea and Gluon are considerably less well determined than high-x valence (note log scales) even in a global fit

- this gets worse when fitting HERA data alone

Compare the uncertainties for uv, dv, Sea and glue in a fit to ZEUS data alone



uv and dv are now determined by the HERA highQ2 data not by fixed target data and precision is comparable- particularly for dv

Sea and gluon at low-x are determined by HERA data with comparable precision for both fits – but at mid/high-x precision is much worse

ZEUS PDF 2005 Analysis- OFFSET method used for PDF uncertainty estimates

Called the ZEUS-JETS fit- DESY-05-50

Consider the form of the parametrization at Q^2_0

- $xuv(x) = Au\ x^{av}\ (1-x)^{bu}\ (1 + c_u\ x)$
  $xdv(x) = Ad\ x^{av}\ (1-x)^{bd}\ (1 + c_d\ x)$
  $xS(x) = As\ x^{as}\ (1-x)^{bs}\ (1 + c_s\ x)$
  $xg(x) = Ag\ x^{ag}\ (1-x)^{bg}\ (1 + c_g\ x)$
  $x\Delta(x) = x(d-u) = A\Delta\ x^{av}\ (1-x)^{bs+2}$

No χ2 advantage in more terms in the polynomial

No sensitivity to shape of $\Delta = \bar{d} - \bar{u}$
$A\Delta$ fixed consistent with Gottfried sum-rule - shape from E866

Assume $\bar{s} = (\bar{d}+\bar{u})/4$ consistent with ν dimuon data

Au, Ad, Ag are fixed by the number and momentum sum-rules

au=ad=av for low-x valence since there is little information to distinguish

→ 12 parameters for the PDF fit

Now consider the high-x Sea and gluon

High-x sea is constrained by simplifying form of parametrization - c_s=0 → 11 param

High-x gluon is constrained by adding ZEUS JET data

H1 2003 PDF analysis – HESSIAN method used for error estimates with $\Delta\chi2=1$

Called H1 PDF 2000 –DESY-03-038 (Compare Cteq6.1 $\Delta\chi2=100$)

Consider the form of the parametrization at Q^2_0

10 free parameters:

$$xU(x)=A_U x^{b_U}(1-x)^{c_U}(1+e_U x+g_U x^3)$$
$$xD(x)=A_D x^{b_D}(1-x)^{c_D}(1+e_D x)$$
$$x\bar{U}(x)=A_{\bar{U}} x^{b_{\bar{U}}}(1-x)^{c_{\bar{U}}}$$
$$x\bar{D}(x)=A_{\bar{D}} x^{b_{\bar{D}}}(1-x)^{c_{\bar{D}}}$$
$$xg(x)=A_g x^{b_g}(1-x)^{c_g}(1+e_g x)$$

No $\chi2$ advantage in more terms in the polynomial

This looks like 19 parameters BUT

$A_U=A_{\bar{U}}$, $b_U=b_{\bar{U}}$, $A_D=A_{\bar{D}}$, $b_D=b_{\bar{D}} \rightarrow 15$

so that U and $\bar{U}$ (and D and $\bar{D}$) are equal as $x \rightarrow 0$ $\rightarrow$strong constraint on shape of low-x valence, where there's little data

and $b_{\bar{U}}=b_{\bar{D}} \rightarrow 14$, since there's no information on the difference of $\bar{U}$ and $\bar{D}$

Then the valence number sum rules and the momentum sum rule determine A_g, A_U, $A_D \rightarrow 11$ $\rightarrow$also constrains sea A's

Finally $A_{\bar{U}}=A_{\bar{D}}(1-f_s)/(1-f_c) \rightarrow$ 10 parameters constrains the amount of U and D in the sea, fs=0.33, fc=0.15 – massless heavy quark scheme

Hessian and Offset uncertainty estimation in PDF fitting……

Experimental systematic errors are correlated between data points, so the correct form of the **χ2** is

$$\chi^2 = \Sigma_i \; \Sigma_j \, [\, F_i^{QCD}(p) - F_i^{\,MEAS}] \, V_{ij}^{-1} \, [\, F_j^{QCD}(p) - F_j^{MEAS}]$$

$$V_{ij} = \delta_{ij}(\sigma_i^{STAT})^2 + \Sigma_\lambda \, \Delta_{i\lambda}^{SYS} \, \Delta_{j\lambda}^{SYS}$$

Where $_{i}^{SYS}$ is the correlated error on point **i** due to systematic error source **λ**

It can be established that this is equivalent to

$$\chi^2 = {}_i \; \frac{[\, F_i^{QCD}(p) - \; s_\lambda \Delta_{i\lambda}^{SYS} - F_i^{\,MEAS}]^2}{(\sigma_i^{STAT})^2} \; + \; s_\lambda^2$$

Where **s** are systematic uncertainty fit parameters of zero mean and unit variance

This form modifies the fit prediction by each source of systematic uncertainty

How ZEUS uses this: OFFSET method

3. Perform fit without correlated errors ($s_\lambda = 0$) for central fit
4. Shift measurement to upper limit of one of its systematic uncertainties ($s_\lambda = +1$)
5. Redo fit, record differences of parameters from those of step 1
6. Go back to 2, shift measurement to lower limit ($s_\lambda = -1$)
7. Go back to 2, repeat 2-4 for next source of systematic uncertainty
8. Add all deviations from central fit in quadrature (positive and negative deviations added in quadrature separately)
9. This method does not assume that correlated systematic uncertainties are Gaussian distributed

HESSIAN method

- Allow s_λ parameters to vary for the central fit

3. The total covariance matrix is then the inverse of a single Hessian matrix expressing the variation of $\chi 2$ wrt both theoretical and systematic uncertainty parameters.

4. If we believe the theory why not let it calibrate the detector(s)? Effectively the theoretical prediction is not fitted to the central values of published experimental data, but allows these data points to move collectively according to their correlated systematic uncertainties

5. The fit determines the optimal settings for correlated systematic shifts s_λ such that the most consistent fit to all data sets is obtained. In a global fit the systematic uncertainties of one experiment will correlate to those of another through the fit

6. We must be very confident of the theory to trust it for calibration– but more dubiously we must be very confident of the model choices we made in setting boundary conditions to the theory - increased model dependence.

7. CTEQ use this method but then raise the $\chi 2$ tolerance to $\Delta\chi 2=100$ to account for inconsistencies between data sets and model uncertainties. H1 use it on their own data only with $\Delta\chi 2=1$

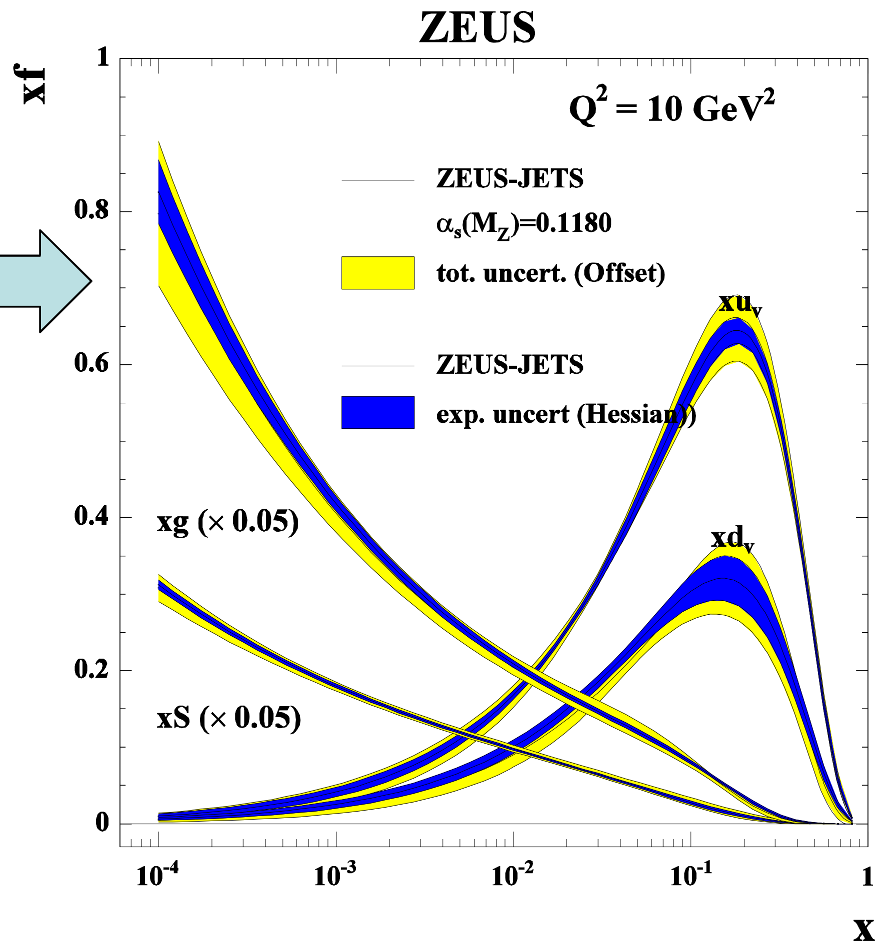
The Hessian method does give a smaller estimated of the PDF errors if you stick to $\Delta\chi 2=1$

Comparison off Hessian and Offset methods for ZEUS-JETS FIT

However it gives larger model errors, because each change of model assumption can give a different set of systematic uncertainty parameters, $s\lambda$, and thus a different estimate of the shifted positions of the data points.

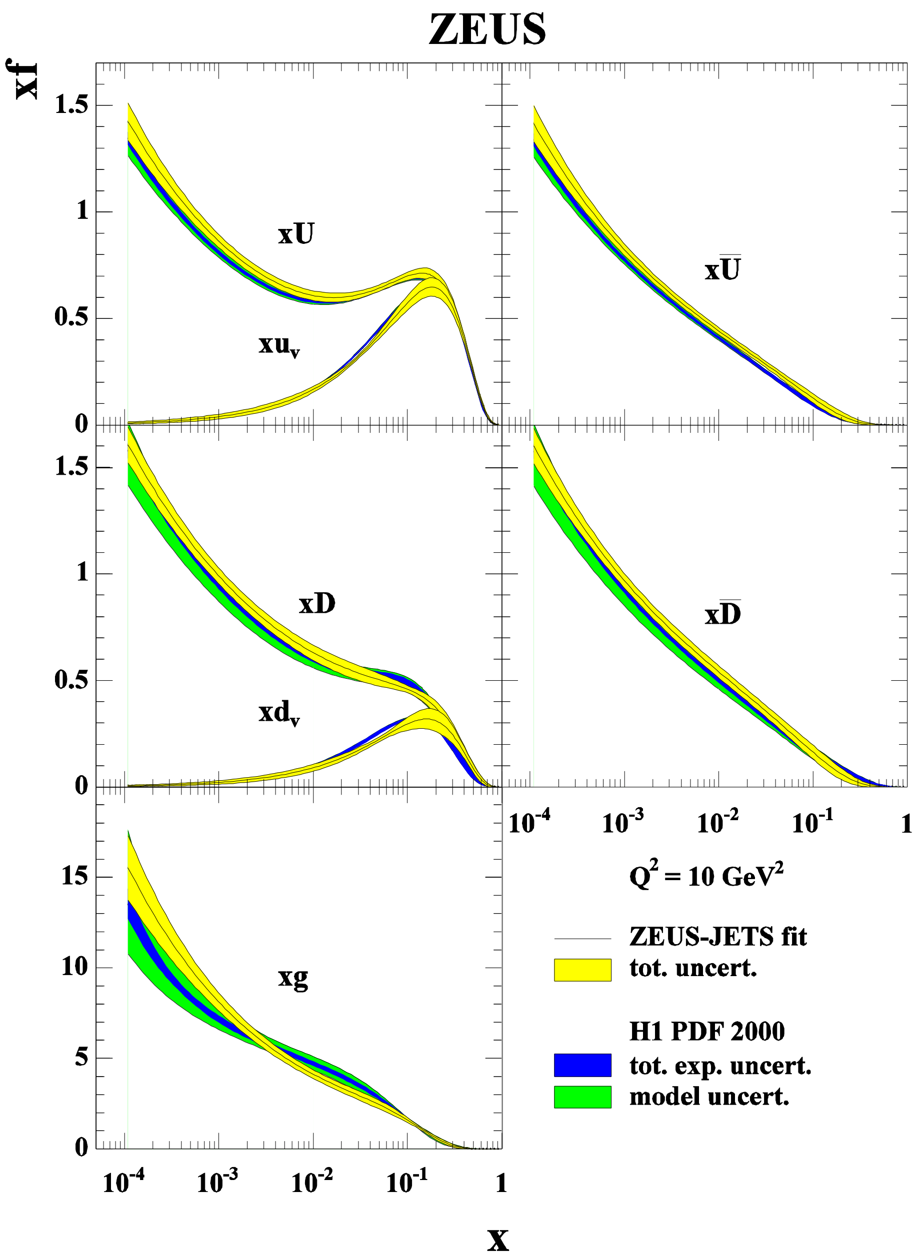
Compare the latest H1 and ZEUS PDFs –SEE next slide—in the end there is no great advantage in the Hessian method..

(However there might be if we could use it without model/theoretical assumptions….)



For the gluon and sea distributions the Hessian method gives a much narrower error band. Equivalent to raising the $\Delta\chi 2$ in the Offset method to 50.

ZEUS/H1 published fits comparison



Compare in terms of

$U = u + c = u_v + u_{sea} + c$,

$D = d + s\ (+b) = d_v + d_{sea} + s\ (+b)$

and the corresponding Ubar Dbar distributions

Model uncertainty is also included in the comparison

e.g. variation of the input form of

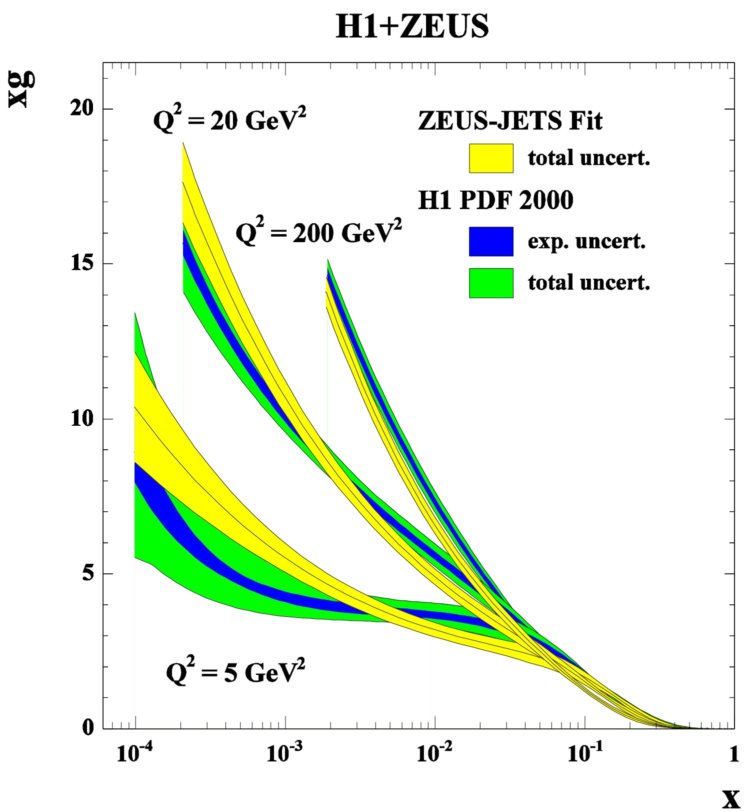
xq(x), xg(x) at Q^2_0, value of $Q2_{0}$, ,

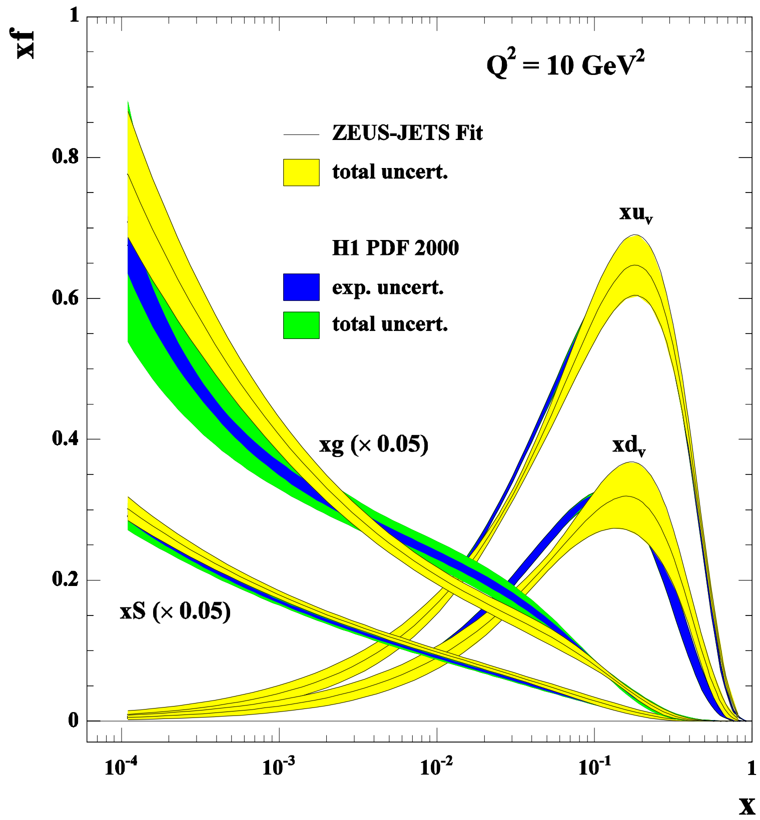
cuts applied to data

Model uncertainties are large compared to the HESSIAN exp. errors of H1, and small compared to the OFFSET exp. errors of ZEUS.
Comparison with model errors included gives similar size of errors

Or in more familiar format

ZEUS/H1 published fits comparison





Both collaborations include model errors –

These are large compared to the HESSIAN exp. errors of H1, and small compared to the OFFSET exp. errors of ZEUS. Comparison with model errors included gives similar size of errors – but some difference in central values

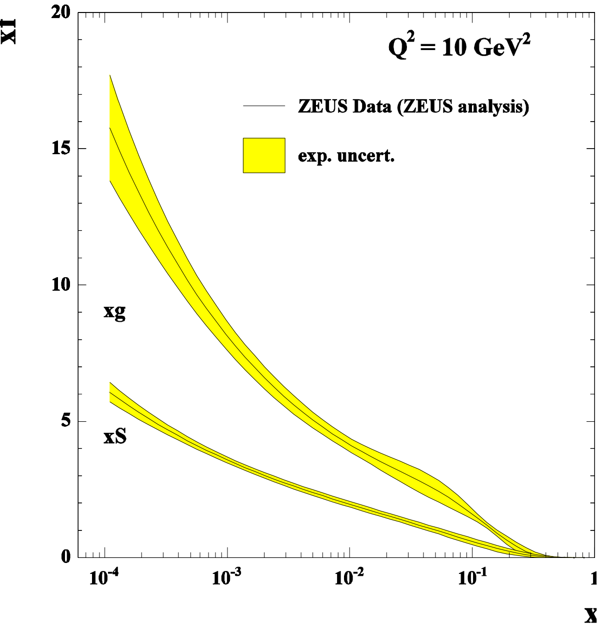
Comparison of ZEUS and H1 using same analysis procedure separately

That's about as far as we can get comparing these different analyses on different data sets

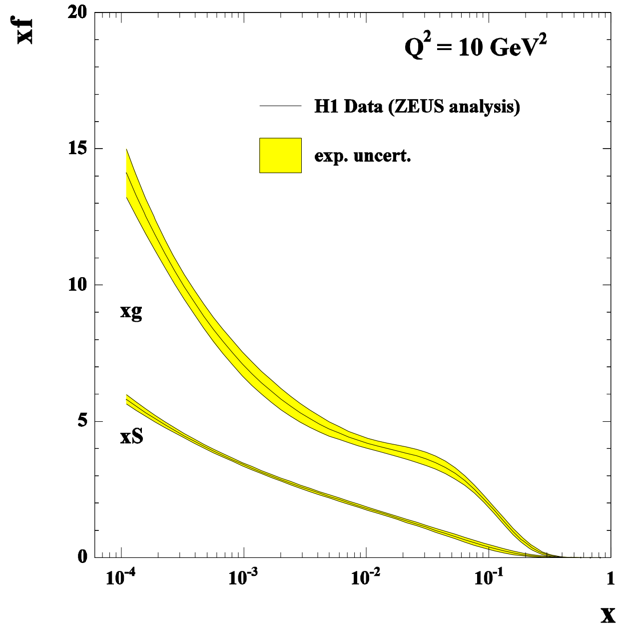
Let's consider putting the H1 and ZEUS data through the same analysis procedure

Using the ZEUS analysis procedure.

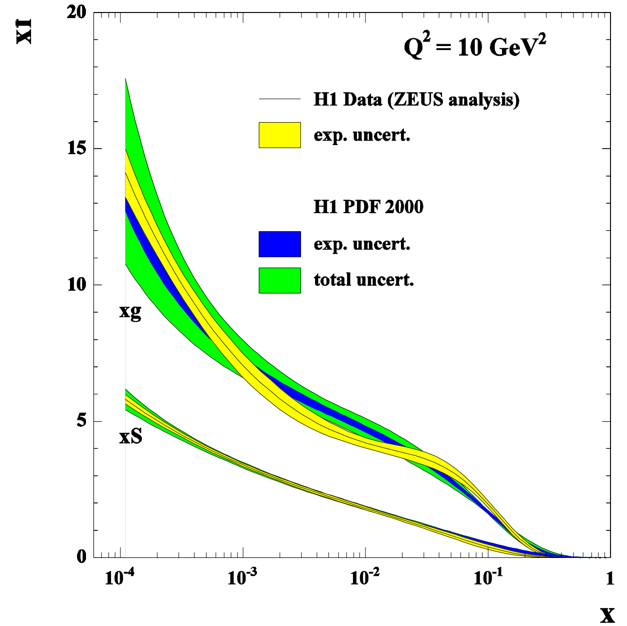
For this comparison the JET data is not included in the ZEUS analysis so that both H1 and ZEUS use inclusive differential cross-section data only



ZEUS analysis/ZEUS data



ZEUS analysis/H1 data



ZEUS analysis/H1 data compared to

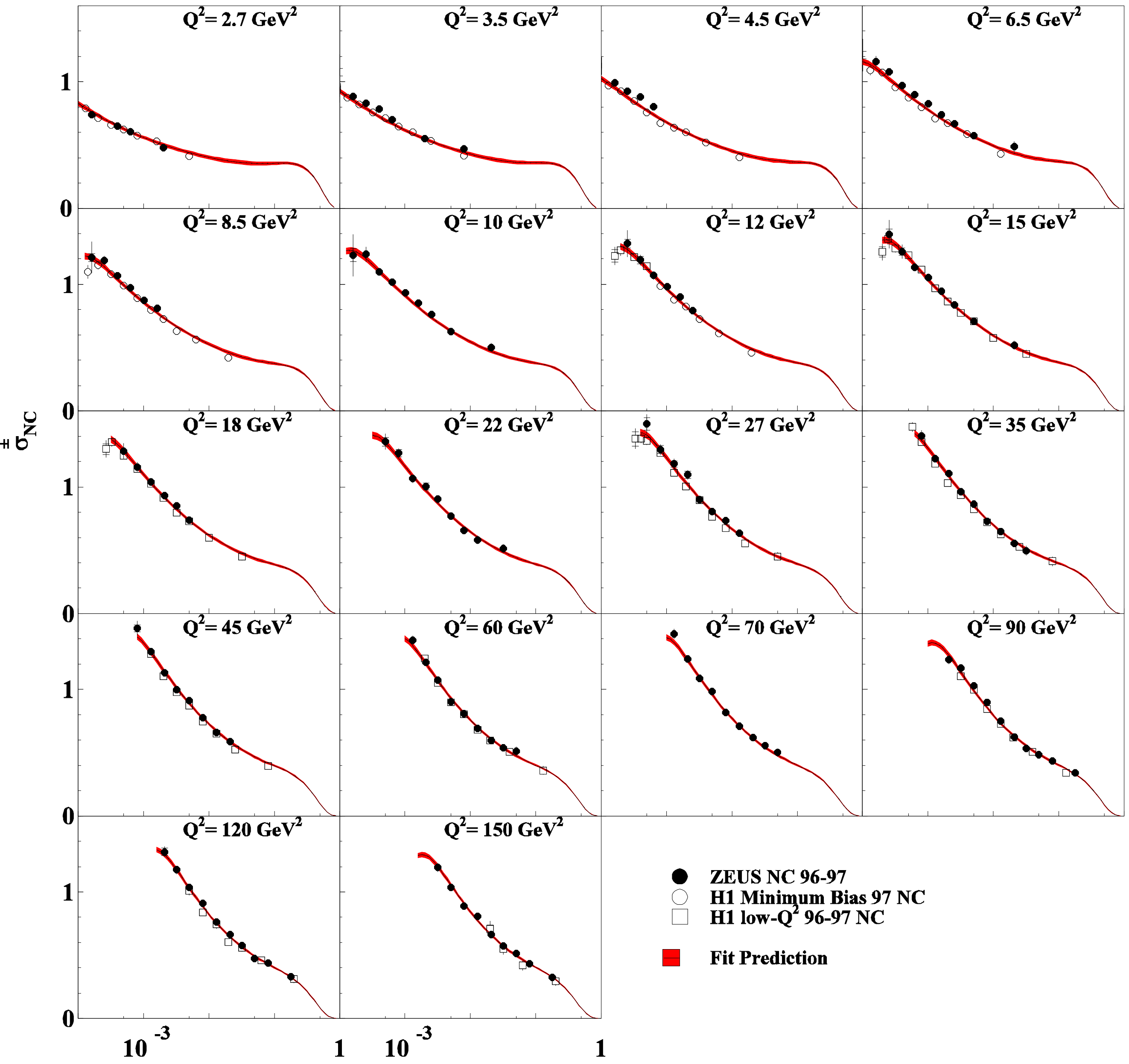
H1 analysis/H1 data

Here we see the effect of differences in the data, recall that the gluon is not directly measured (no jets)

The data differences are most notable in the large 96/97 NC samples at low-Q2 The data are NOT incompatible, but seem to 'pull against each other'

IF a fit is done to ZEUS and H1 together the χ2 for both these data sets rise compared to when they are fitted separately………..

Here we see the effect of differences of analysis choice - form of parametrization at Q2_0 etc

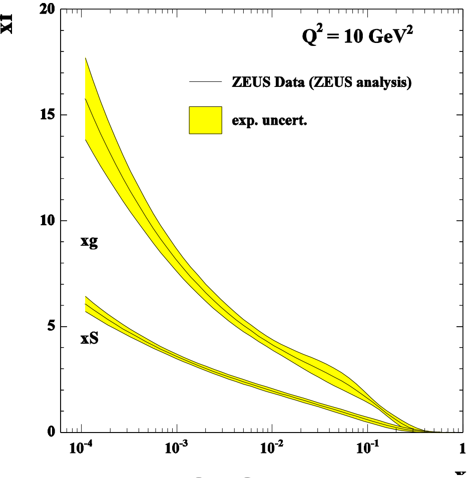


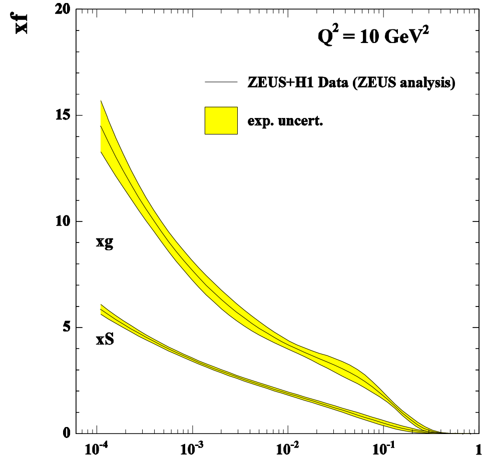
See if you can spot the data differences between ZEUS/H1 at low Q2..It is mostly in slope.

Comparison of ZEUS and H1 using same analysis procedure together

Now let's try putting both ZEUS and H1 data through the same analysis procedure together rather than separately

Using the ZEUS analysis procedure



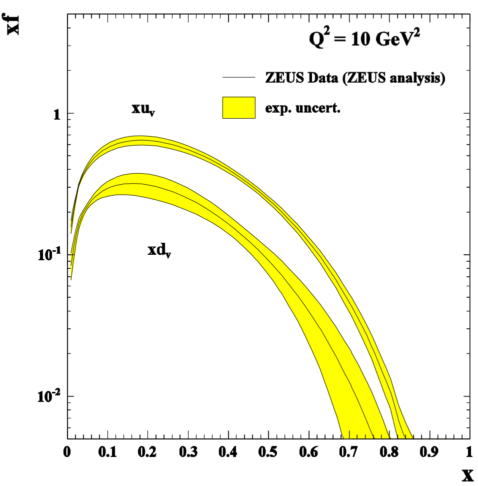


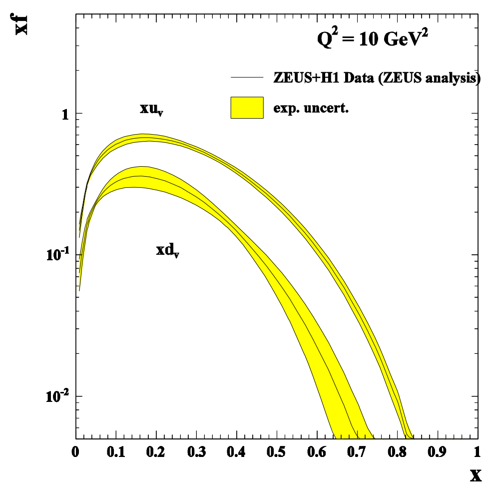
ZEUS ONLY

ZEUS+H1

Using both H1 and ZEUS brings no big improvement for the sea and gluon determination- statistical uncertainty improves - but systematic uncertainty does not

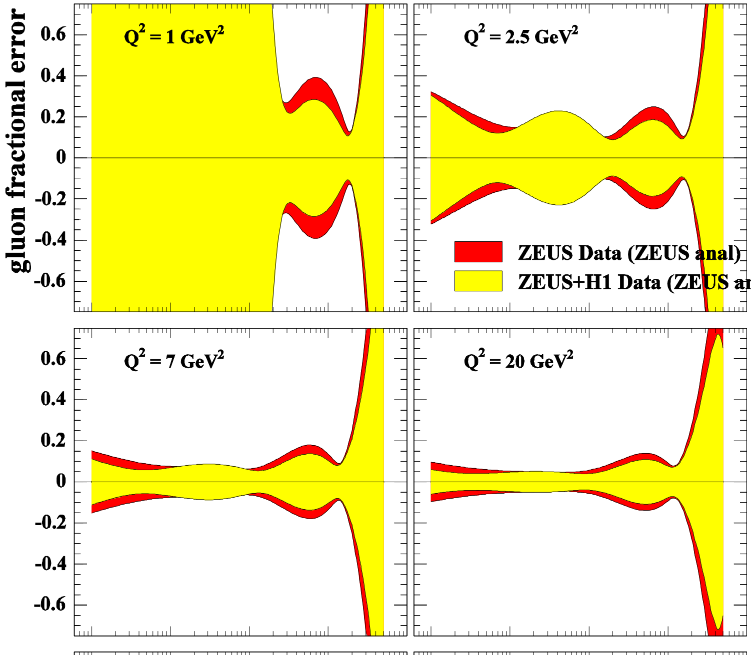
-χ2 for each data set increases compared to when they are fitted individually

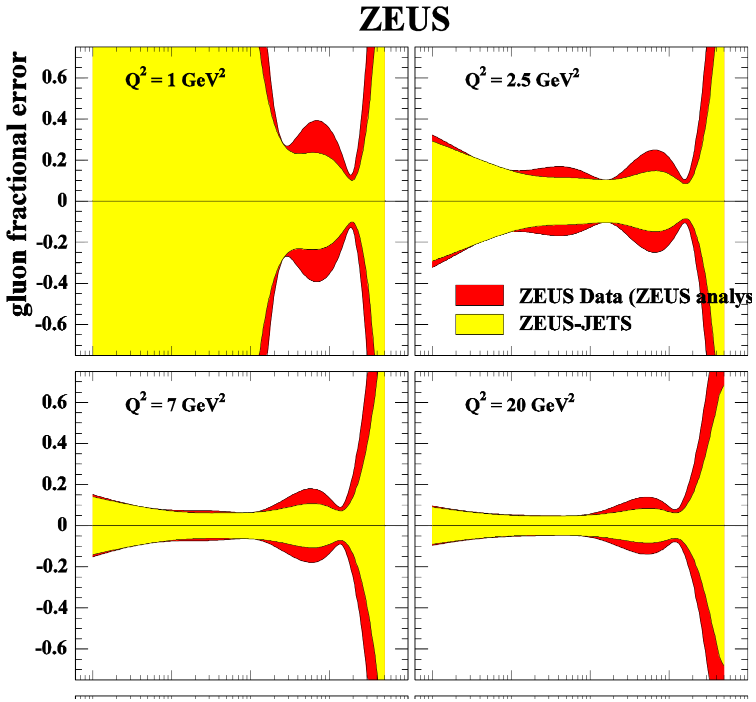




Using both H1 and ZEUS data does bring improvement to the high-x valence distributions, where statistical errors dominate

Gluon uncertainties as fractional differences from central value





ZEUS + H1 data sets – $\chi 2$ for each data set increases when the other data set is added

ZEUS + ZEUS-JETS data sets are compatible -no increase in $\chi 2$ for inclusive xsecn data when jet data are added

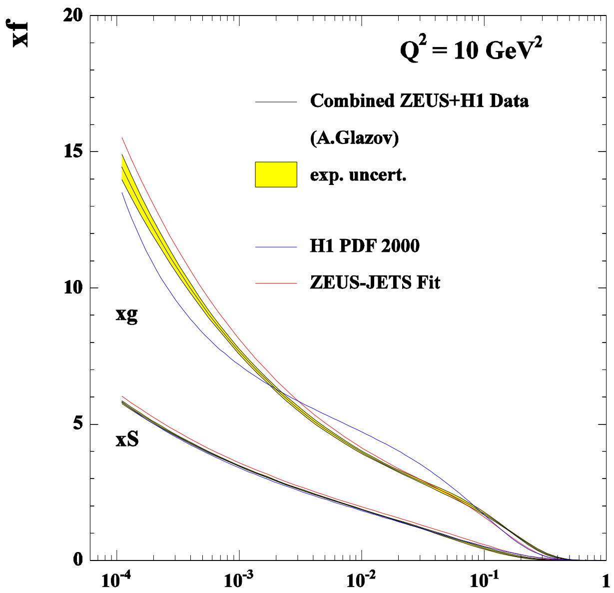
Comparison of adding H1 and ZEUS inclusive xsecn data with the effect of adding ZEUS-JET data to ZEUS inclusive xsecn data

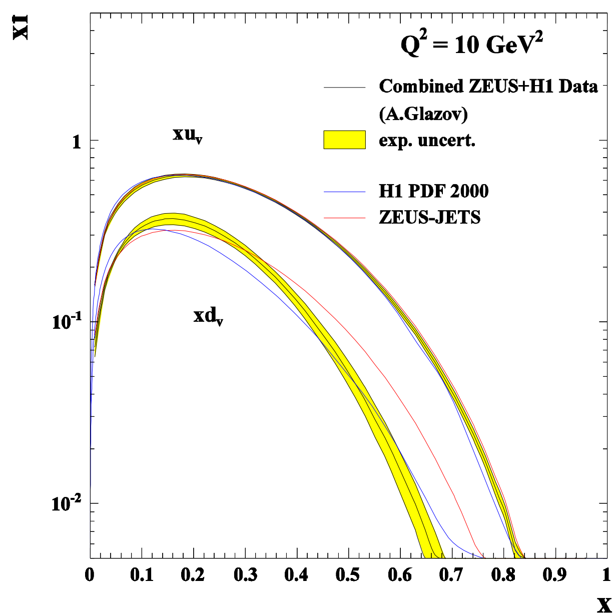
Jet data give increased precision at middling and high-x, adding H1 data gives a little more precision at low-x

Combining at the level of the data sets

So it is hoped that combining the data sets could bring real advantages in decreasing the PDF errors, if the differences in the data sets can be resolved.

- \- see talk by A. Glazov
- This fit essentially combines the data sets in a ‘theory free’ manner assuming only that each experiment is measuring the same ‘truth’
- The combination is a Hessian fit which fits the systematic uncertainty parameters of each data set to obtain the best fit to this assumption
- Once the fit is done the systematic uncertainties of the combined data points (set by $\Delta\chi 2 = 1$ for the averaging fit) are a lot smaller than the statistical errors-
- one can try a simple fit to this combined data for which statistical and systematic errors are combined in quadrature





Fit to the ZEUS + H1 averaged inclusive cross section data set

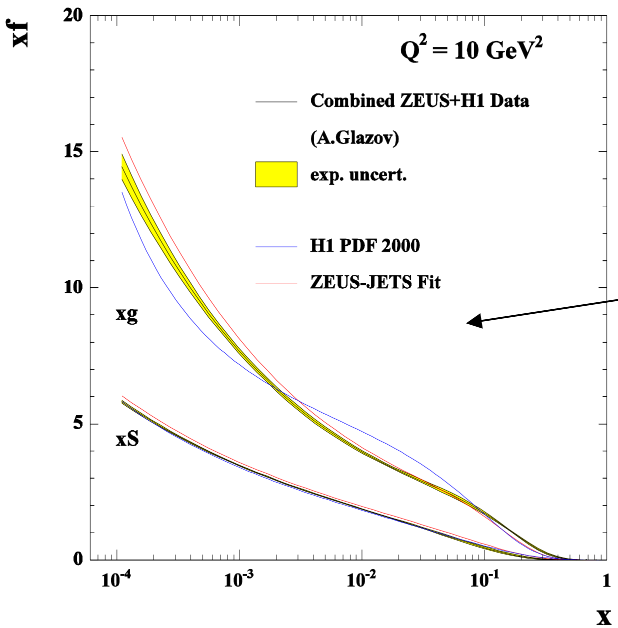
And this simple fit results in very small experimental uncertainties on the PDFs

Caution: very preliminary NO model dependence + averaging procedure also preliminary

Compare to the published PDF shapes for H1 PDF 2000 and ZEUS-JETS-

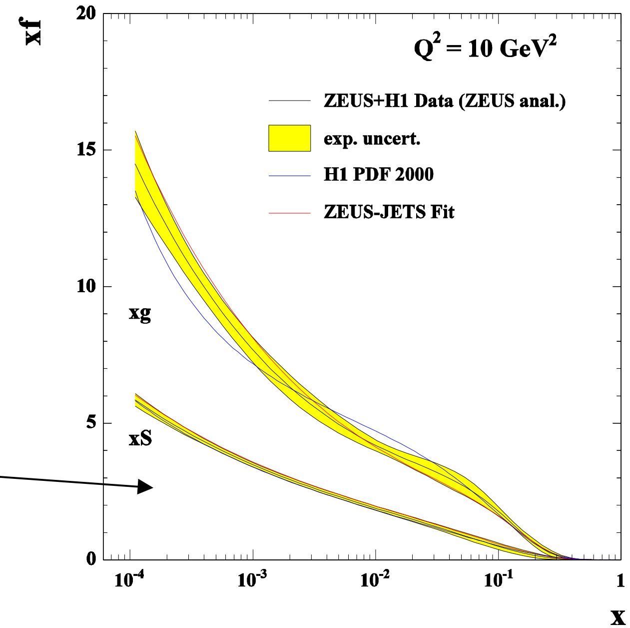
Gluon is more ‘ZEUS-like’

d valence is not really like either



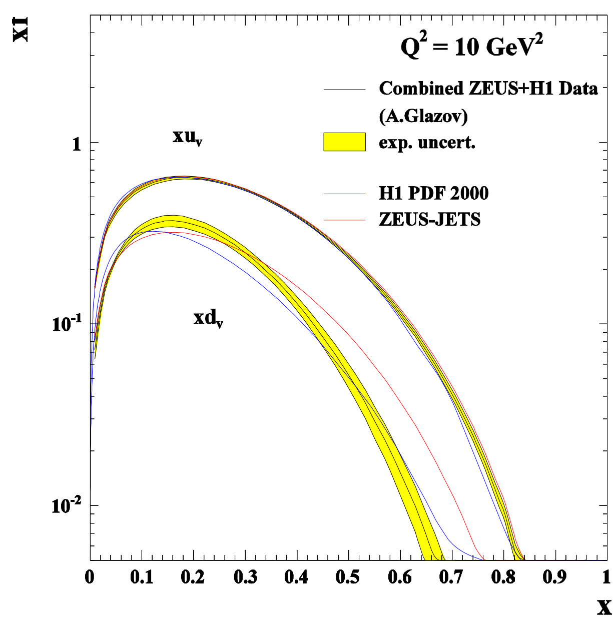
Compare this PDF fit to the H1 and ZEUS averaged inclusive xsecn data

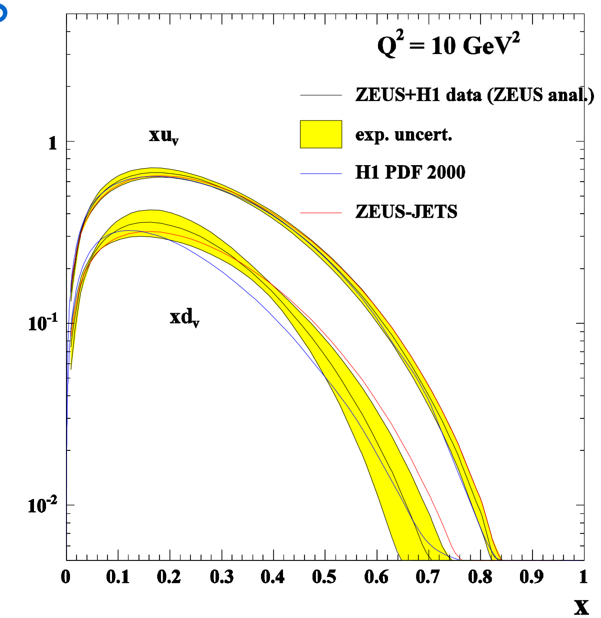
To the PDF fit to H1 and ZEUS inclusive xsecn data NOT averaged –where we get more of a compromise between ZEUS and H1 published PDF shapes

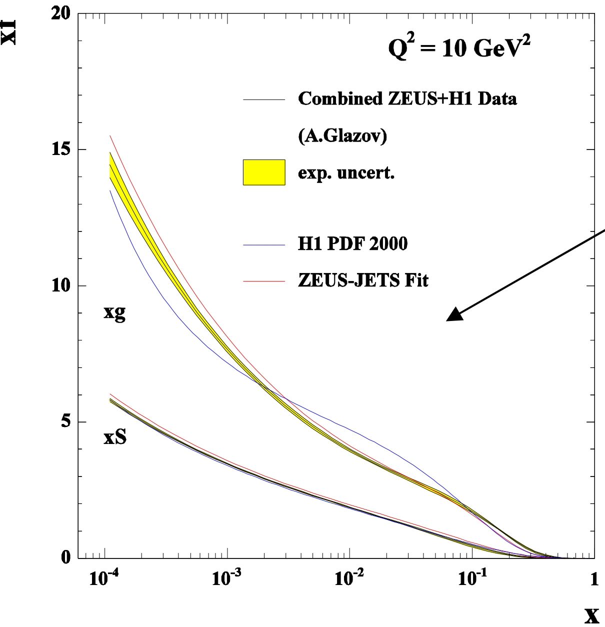


The PDF fit to H1 and ZEUS not averaged was done by the OFFSET method ..

We could consider doing it by the HESSIAN method- allowing the systematic errors parameters to be detemined by the fit

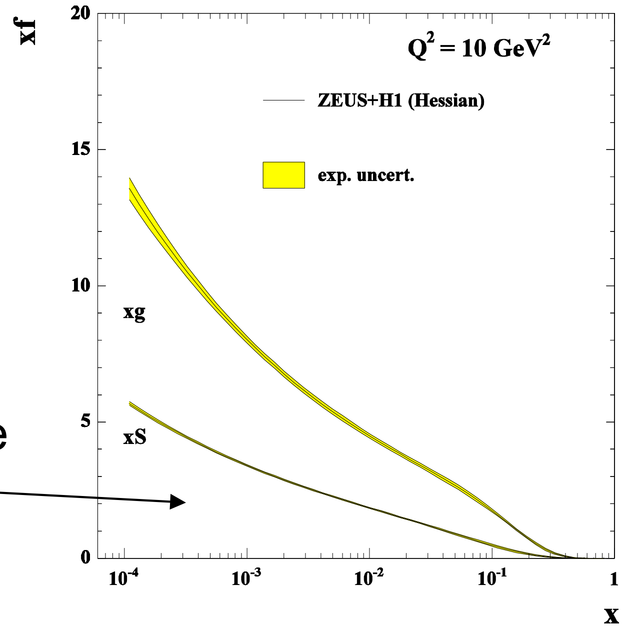




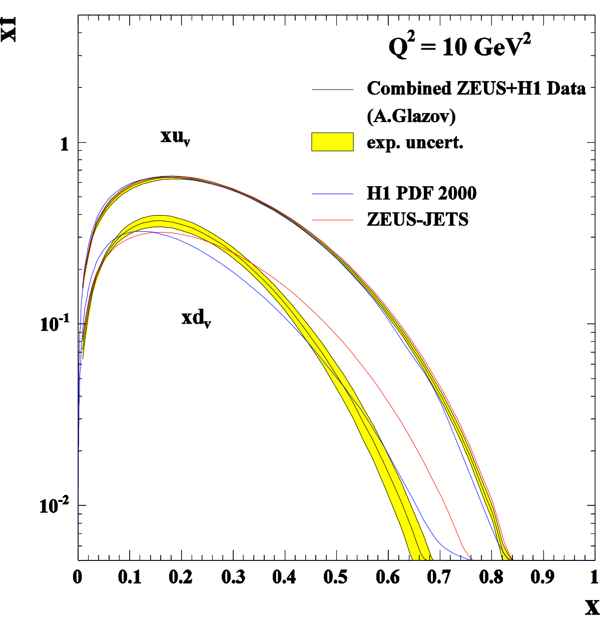


Compare this PDF fit to the H1 and ZEUS averaged inclusive xsecn data

To the PDF fit to H1 and ZEUS inclusive xsecn data NOT averaged –done by the HESSIAN method

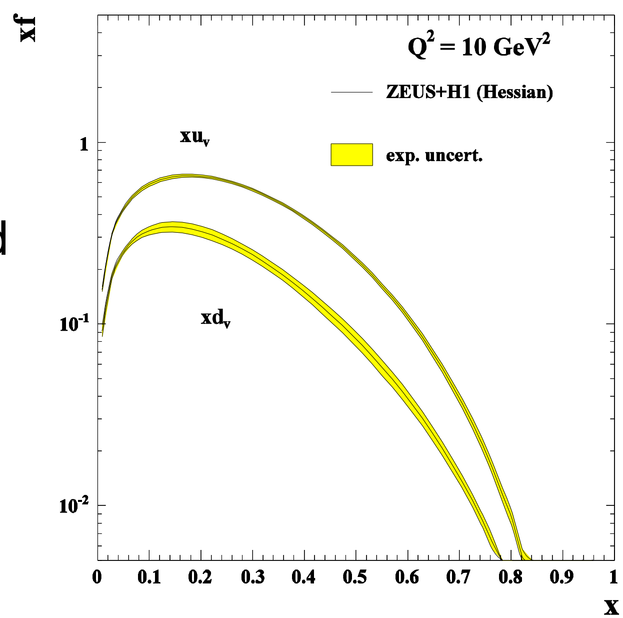


As expected the errors are much more comparable



But the central values are rather different

This is because the systematic shifts determined by these fits are different



systematic shift s_λ	QCDfit Hessian ZEUS+H1	GLAZOV theory free ZEUS+H1
zd1_e_eff	1.65	0.31
zd2_e_theta_a	-0.56	0.38
zd3_e_theta_b	-1.26	-0.11
zd4_e_escale	-1.04	0.97
zd5_had1	-0.40	0.33
zd6_had2	-0.85	0.39
zd7_had3	1.05	-0.58
zd8_had_flow	-0.28	0.83
zd9_bg	-0.23	-0.42
zd10_had_flow_b	0.27	-0.26
h2_Ee_Spacal	-0.51	0.61
h4_ThetaE_sp	-0.19	-0.28
h5_ThetaE_94	0.39	-0.18
h7_H_Scale_S	0.13	0.35
h8_H_Scale_L	-0.26	-0.98
h9_Noise_Hca	1.00	-0.63
h10_GP_BG_Sp	0.16	-0.38
h11_GP_BG_LA	-0.36	0.97

A very boring slide- but the point is that it may be dangerous to let the QCDfit determine the optimal values for the systematic shift parameters.

And using $\Delta\chi 2=1$ on such a fit gives beautiful small PDF uncertainties but a central value which is far from that of the theory free combination.. So what are the real uncertainties?

Conclusions

Published analyses are not in strong disagreement once model dependence is accounted for

But there are differences in the data which lead to somewhat different gluon shapes and this in turn means that combining these data sets in a PDF fit is a matter of compromise

There may be advantages in an averaging of the data sets which accounts for correlated systematic uncertainties