HERAPDF2.0 NNLOJets

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H1/ZEUS March 2019

Updating HERAPDF2.0Jets with new H1 lowQ2 jet data AND
Going to NNLO with the jets

- What do new jets do?
- What does NNLO do?
- New PDFs at NNLO at $\alpha_s(M_Z)$= 0.118 and 0.115

- Free $\alpha_s(M_Z)$ fit at NNLO

$\alpha_s(M_Z)=0.1150 \pm 0.0008_{(exp)} {}^{+0.0002}_{-0.0005 (model/param)} \pm 0.0006_{(had)} \pm 0.0027_{(scale)}$

Compare the NLO result as published

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

The HERAPDF2.0jets contains

ZEUS di-jets = 22 --cut to 16 for new NNLOfit

DIS JETzeus96/97 = 30

H1 HERA1 highq2 =24

H1 HERA1 lowq2 = 22 - cut to 16 for new NNLOfit

H1 2013 inclusive= 24

H1 2013 dijets = 24

H1 2013 trijets = 16 -cut

To go to NNLO we need some changes

- Firstly trijets are not available at NNLO we HAVE to cut them out
- Secondly there have to be more stringent cuts on the lowQ2 jets at NNLO
- Thirdly we have to cut ~6 data points, and on ZEUS dijets

We use a kinematic cut on low Q2 jets μ = sqrt(ptave^2+Q^2) > 13.5

And the removal of 6 points from ZEUS dijets

on the basis of large scale variations both at NLO and NNLO and unstable scale variations NLO to NNLO, respectively- see next slide and back-up

This work established that **scale variations** of predictions for a fixed set of PDF parameters are **MUCH smaller at NNLO** (bar some ZEUS dijet points).

Cut is such that points with scale variations>25% NLO and 10% NNLO are cut.

Then we also add

H1 2016 inclusive =48—cut to 32 for this NNLO fit

H1 2016 dijets =48—cut to 32 for this NNLO fit

I have investigated these cuts not just in terms of

i)the size of NLO to LO k-factors, as was done already for NLO kfactor <2.5 —now use kfactor<2.2
but also in terms of a kinematic cut ii)$\mu = \sqrt{(ptave^2 + Q^2)} > 13.5$
AND finally in terms of the iii) size of scale variations at NLO and NNLO

What I have done is take the parameters of the HERAPDF2.0 Q2>3.5 fit and fix them and then look at renormalisation and factorisation scale changes of a factor of two up and down on **ALL** the jet data sets.

I have done this at both NLO and NNLO and compared. With the exception of some ZEUS dijet points NNLO scale variations are always less than NLO variations
Details in backup

The three criteria above cut much the same points
The kinematic cut is simplest
This cuts NLO scale variations >~24% and NNLO scale variations > ~10%

There is a choice of scales to be made for the jets.

For HERAPDF2.0Jets NLO we chose renormalisation =(Q2+pt2)/2, factorisation =Q2
But it turns out that for NNLO jets a choice of renormalisation =(Q2+pt2) is better (better= giving lower chisq $\Delta\chi2$~ -15)
And for H1 2016 lowQ2 jets factorisation=renorm scale is MUCH better than factorisation= Q2 for either of the above choices.
This is quite understandable at lowQ2 and probably should have been used for the older low Q2 data set as well. It will be done from now on.

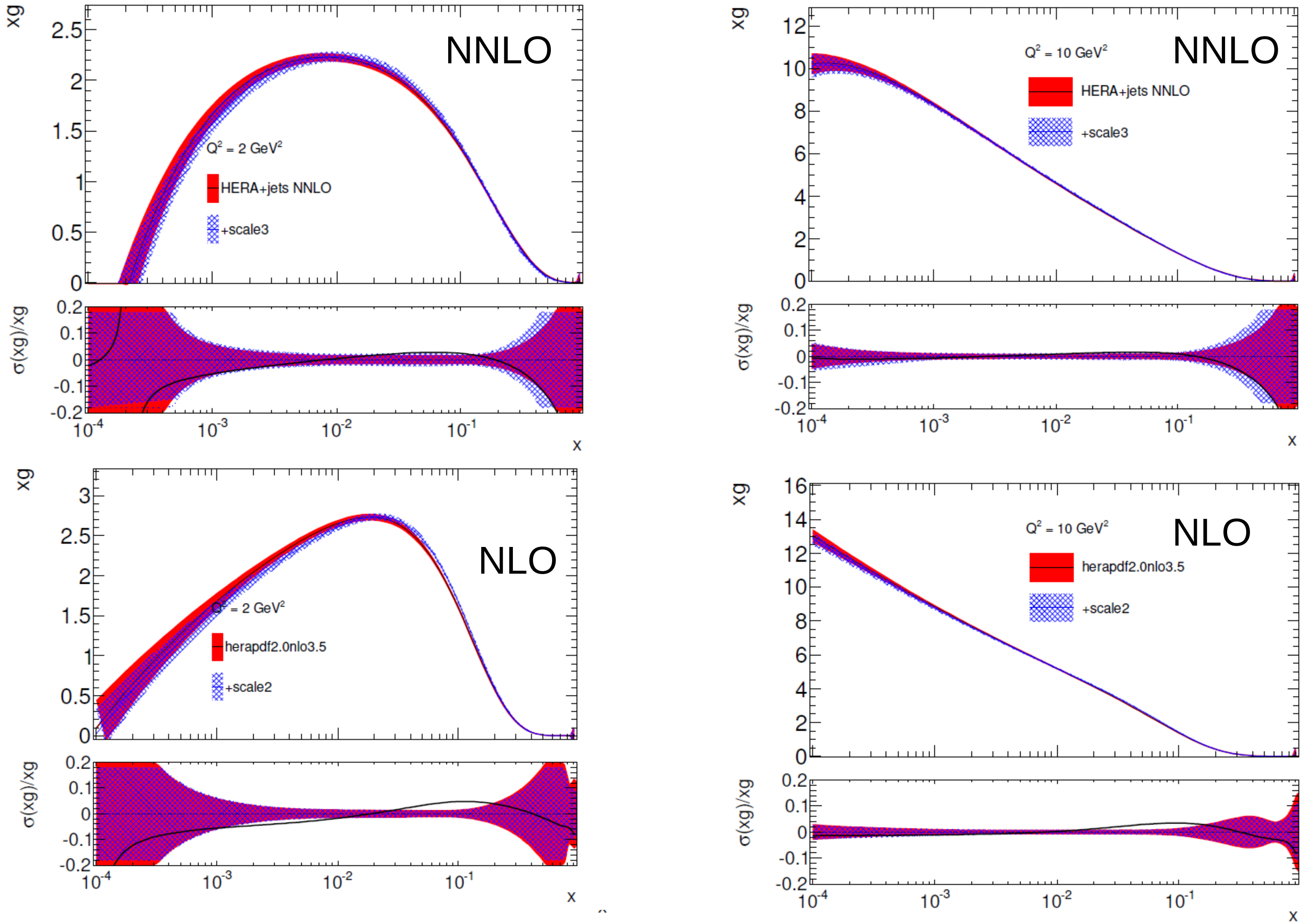
In fact the 'optimal' scale choice for NLO and NNLO is different – if optimal means lower chisq. (NLO has lower chisq $\Delta\chi2$~ -15 for the old scale choice)
Since we are concentrating on NNLO we will use
Renormalisation= Q2 +pt2,
Factorisation=Q2+pt2
(in practice using Q2 or Q2+pt2 for high Q2 jets doesn't make a any significant difference)
And we use it for both NNLO and NLO unless otherwise stated

Further points:
- The new 2016 lowQ2 jets have some systematic correlations to the older 2013 high Q2 jets– this does not change things much **but it is done**
- There is an extra low pt bin for the high Q2 set, which was published along with the newer low Q2 set. We chose not to use this.
- All statistical correlation matrices for 2013 and 2016 H1 jets are used by default

Let's reassure you about scales with a comparison of how much difference this makes at NNLO and NLO (with fixed alphas)

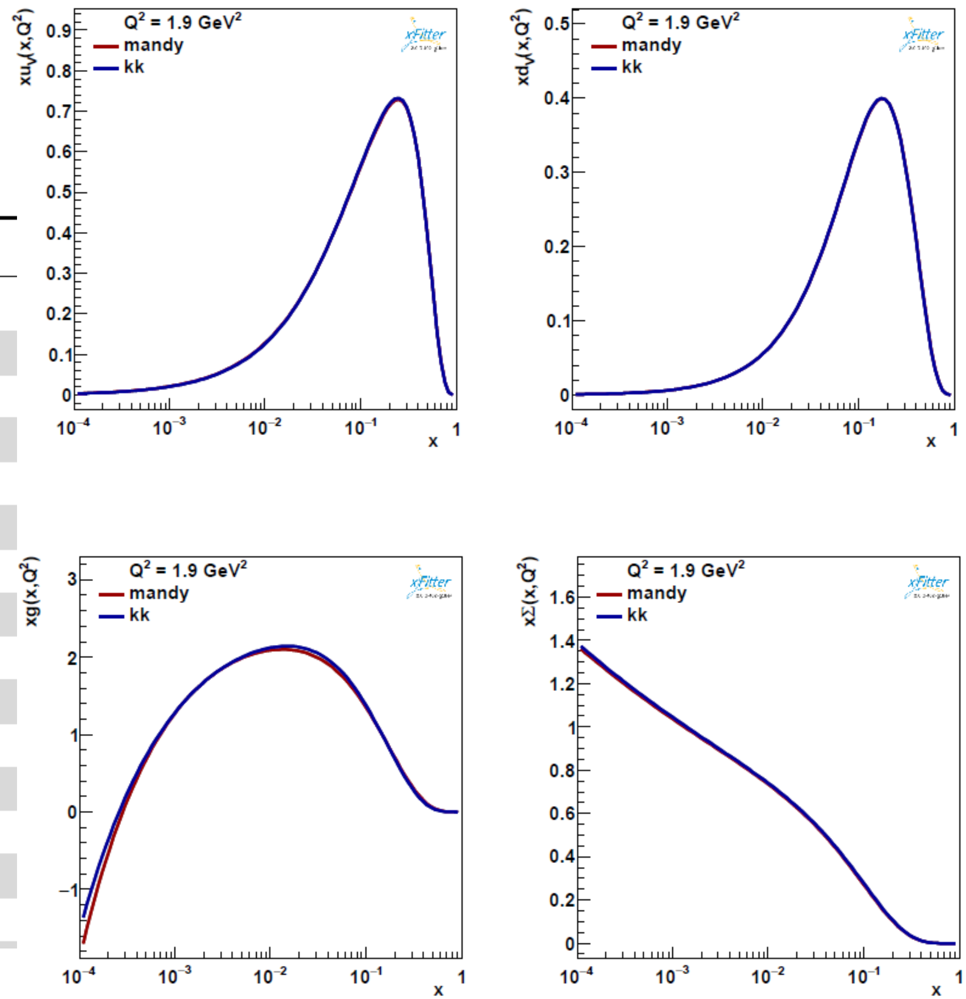
Compare scale 2=(Q2+pt2)/2 and Scale3=Q2+pt2. **What do scale changes do?**

Answer: very little if alphas is fixed



Comparisons between xFitter and Oxford code for NLO/NNLO old jets and old+new jets are in back-up. Here I show only the final NNLO for ALL jets comparison

Parameter	mandy	kk
'Bg'	-0.099±0.066	−0.072 ± 0.072
'Cg'	5.09±0.50	5.65 ± 0.52
'Aprig'	0.13±0.10	0.15 ± 0.12
'Bprig'	-0.423±0.055	−0.397 ± 0.059
'Cprig'	25.00	25.00
'Buv'	0.801±0.027	0.810 ± 0.027
'Cuv'	4.819±0.084	4.854 ± 0.083
'Euv'	10.4± 1.4	10.3 ± 1.4
'Bdv'	0.983±0.089	0.984 ± 0.090
'Cdv'	4.58±0.39	4.62 ± 0.39
'CUbar'	6.8± 2.7	7.2 ± 1.9
'DUbar'	0.77±3.5	1.6 ± 2.5
'ADbar'	0.287±0.011	0.286 ± 0.011
'BDbar'	-0.119±0.0049	−0.1207 ± 0.0050
'CDbar'	8.79± 1.67	8.4 ± 1.5
[illegible]		[illegible]



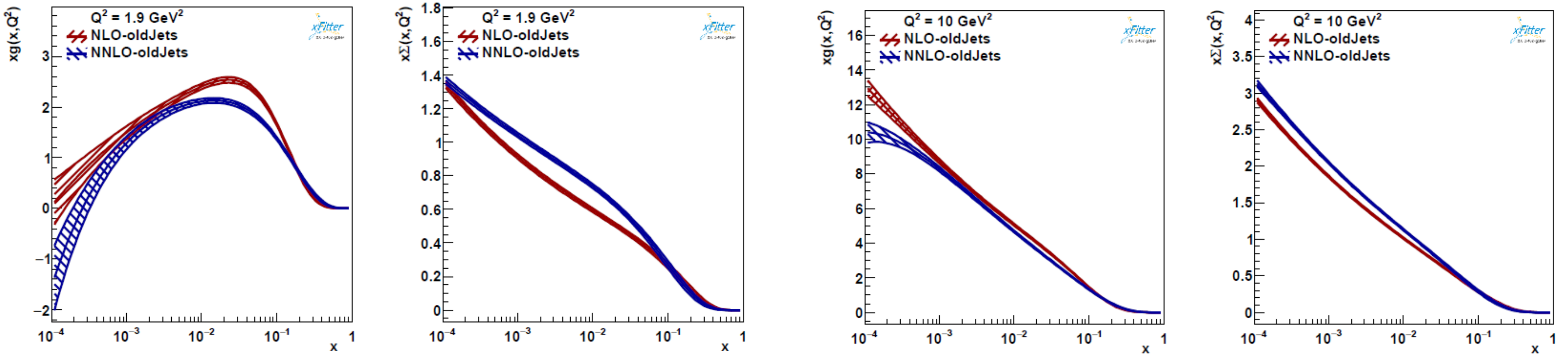
And for this fit the chisq comparison for the jets is given here.

(The inclusive data is much as it ever was)

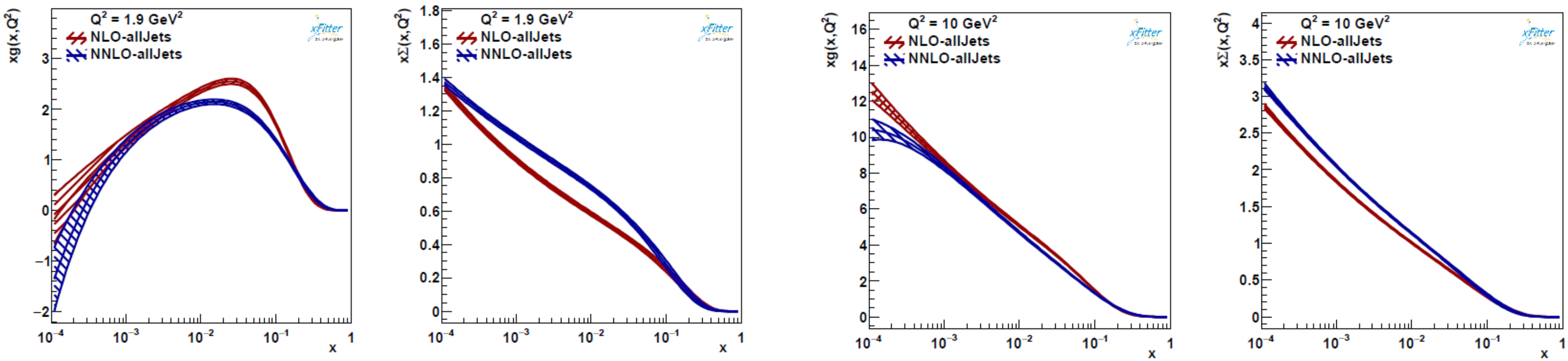
Dataset	mandy	kk
H1 normalised inclusive jets with unfolding 1	9.9 / 4	10 / 4
H1 normalised inclusive jets with unfolding 2	3.9 / 4	4.0 / 4
H1 normalised inclusive jets with unfolding 3	2.2 / 4	1.8 / 4
H1 normalised inclusive jets with unfolding 4	8.3 / 4	7.8 / 4
H1 normalised inclusive jets with unfolding 5	8.3 / 4	7.3 / 4
H1 normalised inclusive jets with unfolding 6	3.9 / 4	3.9 / 4
H1 normalised dijets with unfolding 1	19 / 4	19 / 4
H1 normalised dijets with unfolding 2	4.5 / 4	4.7 / 4
H1 normalised dijets with unfolding 3	5.9 / 4	6.1 / 4
H1 normalised dijets with unfolding 4	5.6 / 4	5.1 / 4
H1 normalised dijets with unfolding 5	6.0 / 4	5.4 / 4
H1 normalised dijets with unfolding 6	1.8 / 4	1.8 / 4
ZEUS inclusive dijet 98-00/04-07 data 1	2.0 / 4	2.7 / 4
ZEUS inclusive dijet 98-00/04-07 data 2	2.9 / 4	2.7 / 4
ZEUS inclusive dijet 98-00/04-07 data 3	5.9 / 4	6.2 / 4
ZEUS inclusive dijet 98-00/04-07 data 4	1.8 / 4	2.1 / 4
ZEUS inclusive dijet 98-00/04-07 data 5	1.2 / 3	0.90 / 3
ZEUS inclusive dijet 98-00/04-07 data 6	0.67 / 3	0.55 / 3
H1 low Q2 inclusive jet 99-00 data 1	1.0 / 2	1.1 / 2
H1 low Q2 inclusive jet 99-00 data 2	0.37 / 2	0.39 / 2
H1 low Q2 inclusive jet 99-00 data 3	1.4 / 2	1.4 / 2
H1 low Q2 inclusive jet 99-00 data 4	1.1 / 2	1.2 / 2
H1 low Q2 inclusive jet 99-00 data 5	0.20 / 2	0.23 / 2
H1 low Q2 inclusive jet 99-00 data 6	0.81 / 3	0.81 / 3
H1 low Q2 inclusive jet 99-00 data 7	6.3 / 3	6.7 / 3

Dataset	mandy	kk
H1 normalised inclusive jet 99-00 data 2	1.5 / 4	1.6 / 4
H1 normalised inclusive jet 99-00 data 1	4.7 / 4	4.8 / 4
H1 normalised inclusive jet 99-00 data 3	1.1 / 4	0.99 / 4
H1 normalised inclusive jet 99-00 data 4	4.1 / 4	4.2 / 4
H1 normalised inclusive jet 99-00 data 5	6.3 / 4	6.7 / 4
H1 normalised inclusive jet 99-00 data 6	8.1 / 4	8.2 / 4
ZEUS inclusive jet 96-97 data 1	4.8 / 5	3.9 / 5
ZEUS inclusive jet 96-97 data 2	5.2 / 5	5.6 / 5
ZEUS inclusive jet 96-97 data 3	5.8 / 5	5.8 / 5
ZEUS inclusive jet 96-97 data 4	9.9 / 5	9.4 / 5
ZEUS inclusive jet 96-97 data 5	3.0 / 5	3.0 / 5
ZEUS inclusive jet 96-97 data 6	4.2 / 5	4.2 / 5
H1 low Q2 inclusive jets normalised 1	4.6 / 4	4.8 / 4
H1 low Q2 inclusive jets normalised 2	3.9 / 4	3.7 / 4
H1 low Q2 inclusive jets normalised 3	1.9 / 4	1.8 / 4
H1 low Q2 inclusive jets normalised 4	2.2 / 4	2.2 / 4
H1 low Q2 inclusive jets normalised 5	1.1 / 4	1.0 / 4
H1 low Q2 inclusive jets normalised 6	4.8 / 4	4.8 / 4
H1 low Q2 inclusive jets normalised 7	1.1 / 4	1.3 / 4
H1 low Q2 inclusive jets normalised 8	5.0 / 4	4.9 / 4
H1 low Q2 dijets normalised 1	2.9 / 4	2.9 / 4
H1 low Q2 dijets normalised 2	2.3 / 4	2.3 / 4
H1 low Q2 dijets normalised 3	1.4 / 4	1.6 / 4
H1 low Q2 dijets normalised 4	2.1 / 4	2.2 / 4
H1 low Q2 dijets normalised 5	0.32 / 4	0.34 / 4
H1 low Q2 dijets normalised 6	0.36 / 4	0.32 / 4
H1 low Q2 dijets normalised 7	1.7 / 4	1.8 / 4
H1 low Q2 dijets normalised 8	1.5 / 4	1.5 / 4
Correlated χ^2	114	115

What does NNLO do ? Fit using inclusive +old jets



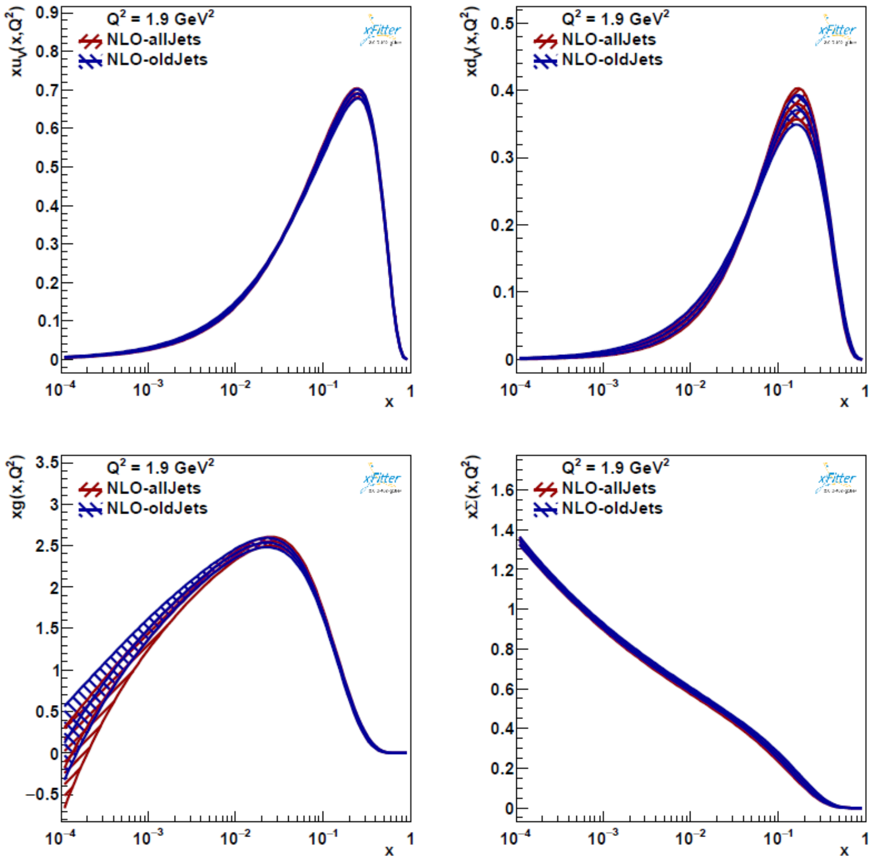
What does NNLO do ? Fit using inclusive +old +new jets

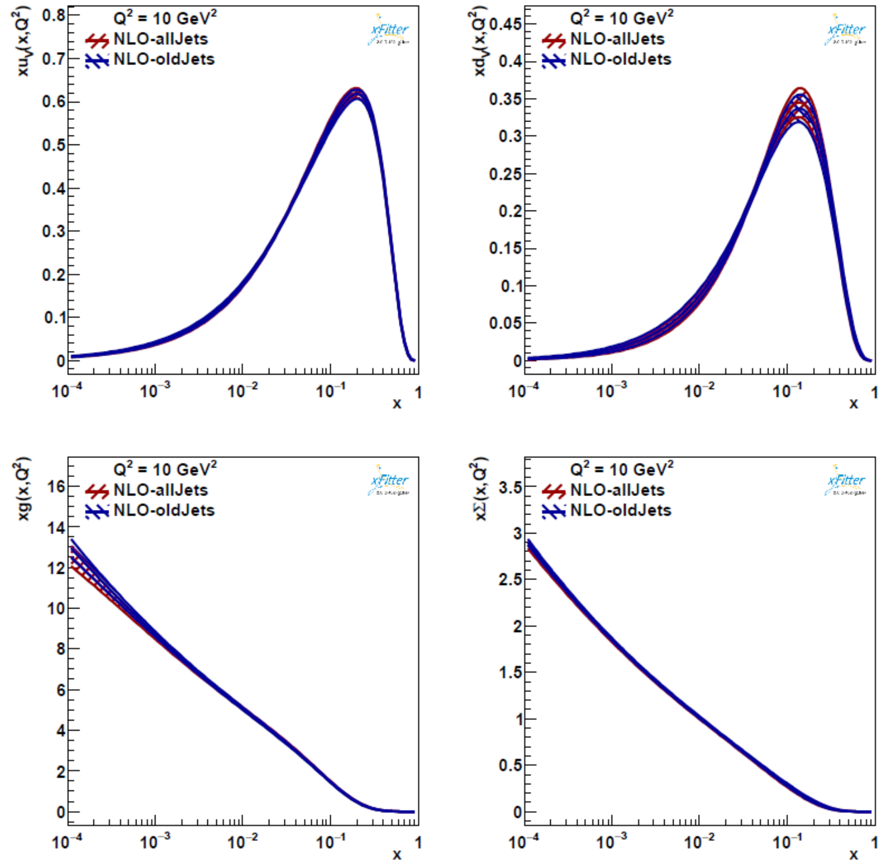


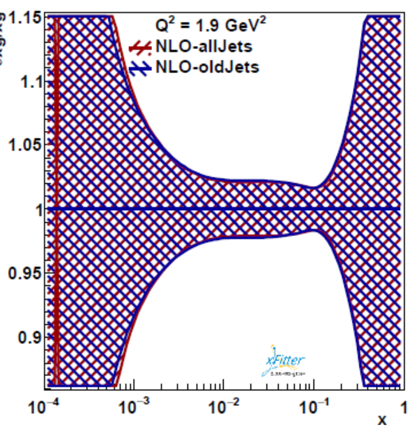
What does NNLO DO?
Answer: the same as it did for inclusive

The plots at Q2=10 Gev2 look just like the NNLO to NLO plots in the HERAPDF2.0 paper for inclusive only

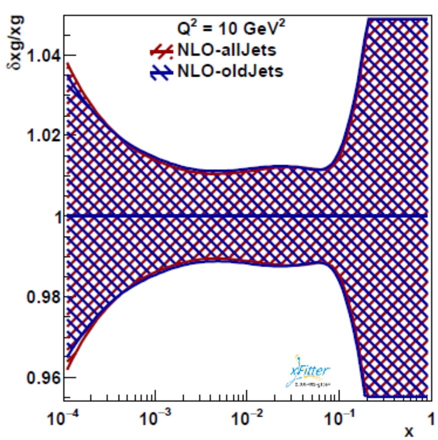
What do new jets do? NLO



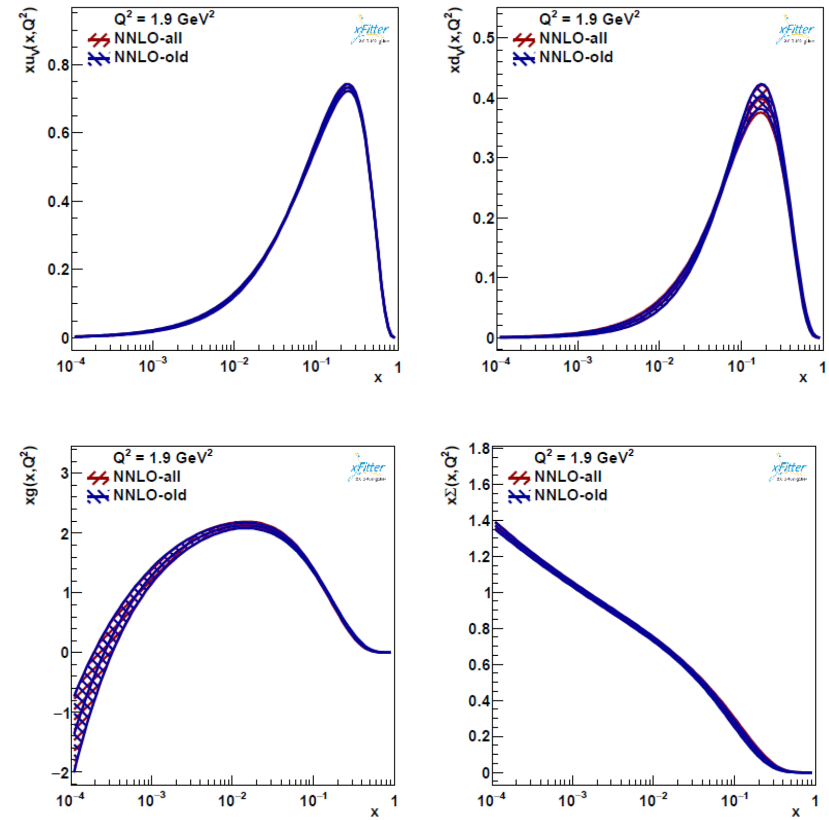


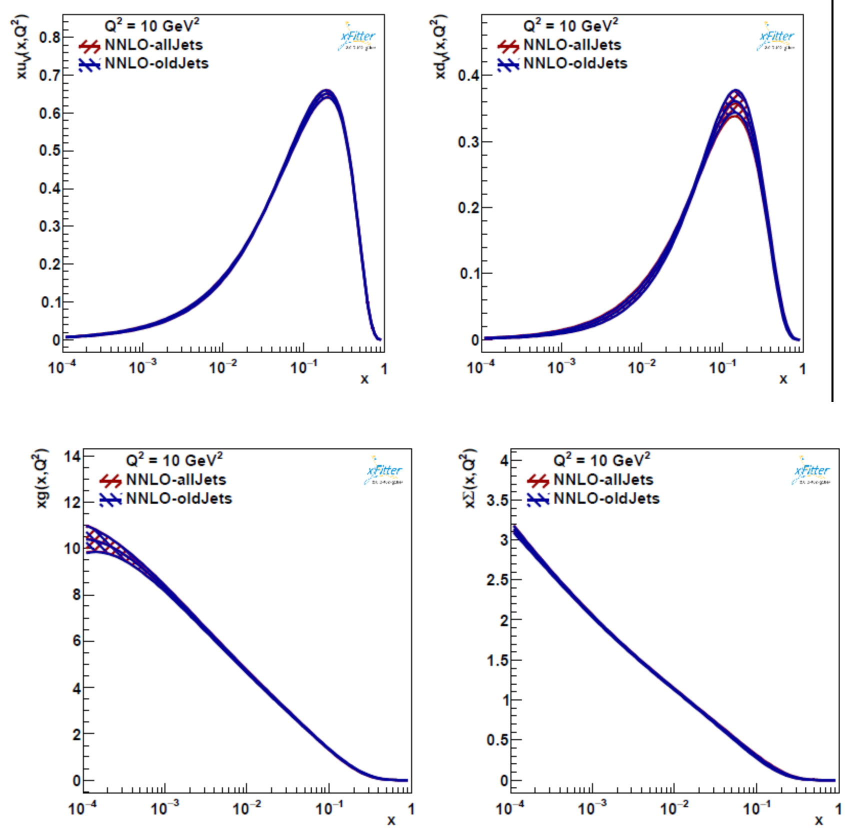


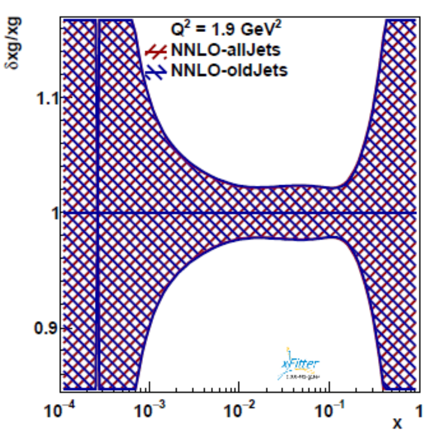
The answer is: not a lot when alphas is fixed



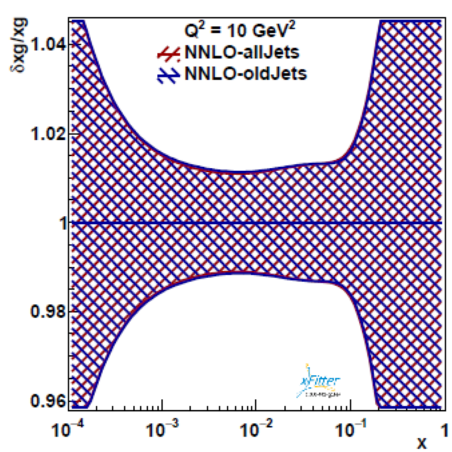
What do new jets do? NNLO







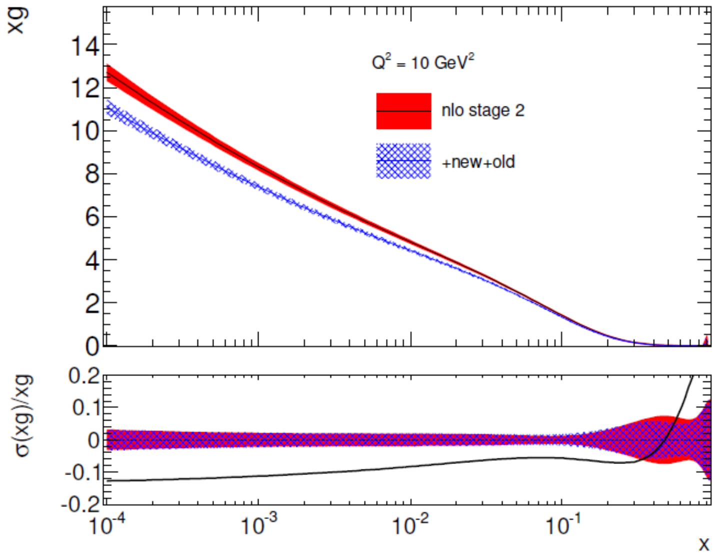
The answer is: not a lot when alphas is fixed



Now what do new jets do? With free ($\alpha_s(M_Z)$)

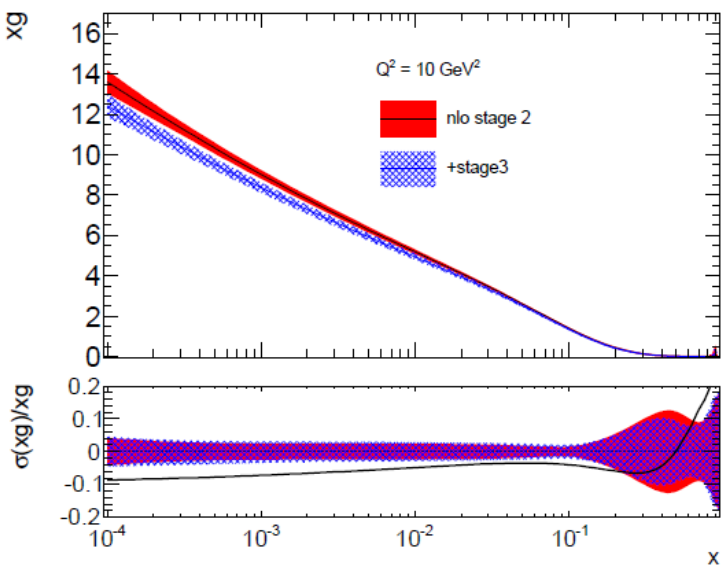
At NLO and new scale=Q2+pt2. **Answer they change** $\alpha_s(M_Z)$ **from 0.120 to 0.124**

New scales



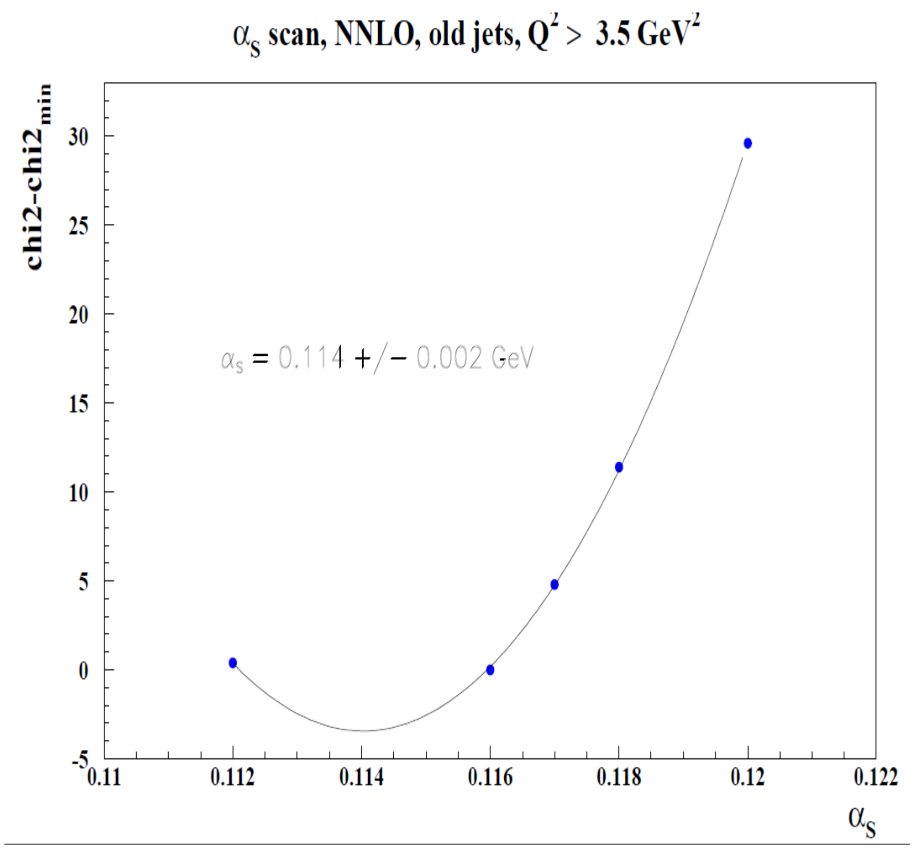
But I hear you all protest, $\alpha_s(M_Z)$ **was not 0.120 for our old jets HERAPDF2.0, it was 0.118**!
YES because we used a different scale, using (Q2+pt2)/2 we get an $\alpha_s(M_Z)$ change from 0.118 to 0.122 using the new jets.

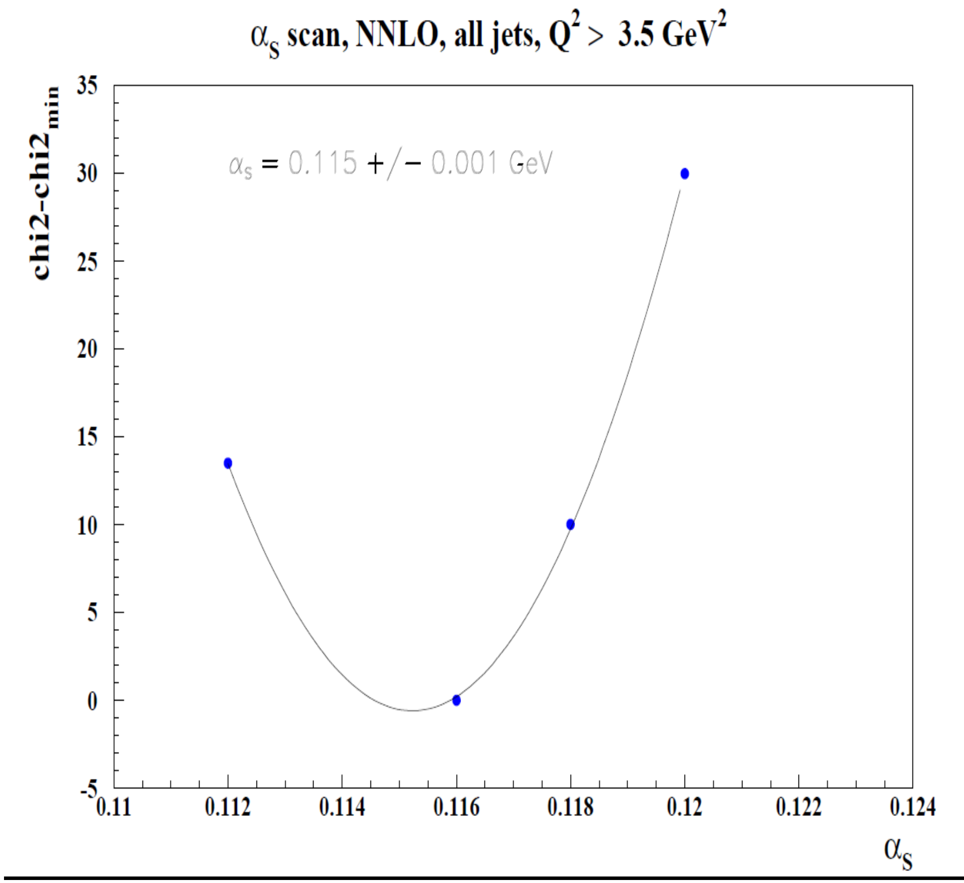
And the change in $\alpha_s(M_Z)$ with scale is compatible with our previous estimates of NLO scale uncertainty



Old scales

But NOTE the new jets do not change alphas so much for NNLO
--note these are both ROUGH early results just for the purposes of a new/old comparison

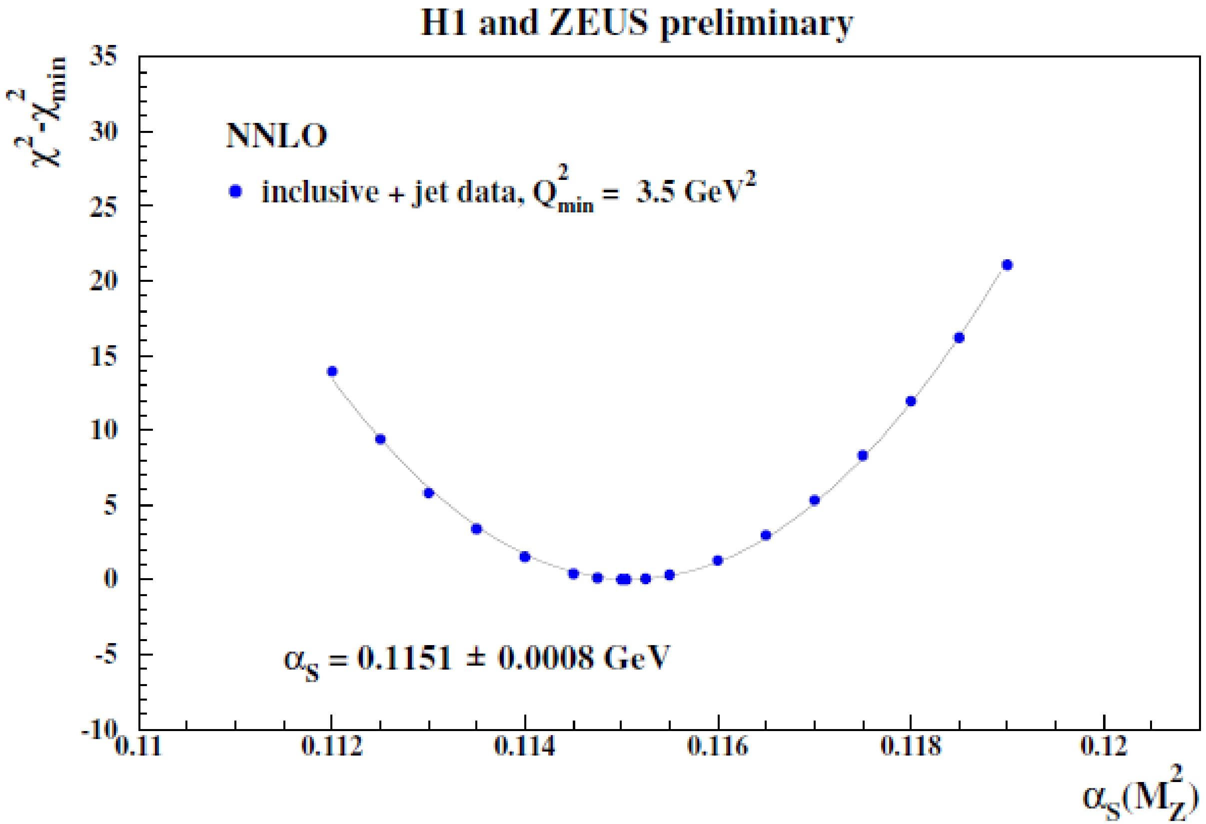




However, let us move on from these new/old comparisons to the final fits to ALL jets at NNLO..

Now we have done much better with the NNLO fit to ALL jets

Scanning $\alpha_s(M_Z)$ and fitting $\alpha_s(M_Z)$ agree well



Stefan's NOTES-
chi**2 as a function of alpha_s with "many" points, to read off the experimental error, compare to the Minuit error.

- **Scan 0.11505**
- And we now have a fully converged fit with Hesse errors to compare

> Fit 0.11503

$\alpha_s(M_Z)$ =0.11503 ± 0.00084(exp) from fit

REQUEST Preliminary PLOT and value..

** 3 **HESSE
****
COVARIANCE MATRIX CALCULATED SUCCESSFULLY

FCN= 1598.50 FROM HESSE STATUS=OK 170 CALLS 792 TOTAL
EDM= 0.30E+00 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER				INTERNAL INTERNAL
NO.	NAME	VALUE	ERROR	
2	Bg	-0.88884E-01	0.55258E-01	
3	Cg	6.1597	0.48794	
7	Aprig	0.13412	0.10394	
8	Bprig	-0.41795	0.60080E-01	
12	Buv	0.78172	0.27402E-01	
13	Cuv	4.8873	0.84328E-01	
15	Euv	10.355	1.3577	
22	Bdv	1.0026	0.82074E-01	
23	Cdv	4.9287	0.37803	
33	CUbar	7.2747	1.7611	
34	DUbar	2.3135	2.5721	
41	ADbar	0.27330	0.11307E-01	
42	BDbar	-0.12448	0.50627E-02	
43	CDbar	10.448	1.9791	
101	alphas	0.11503	0.83956E-03	

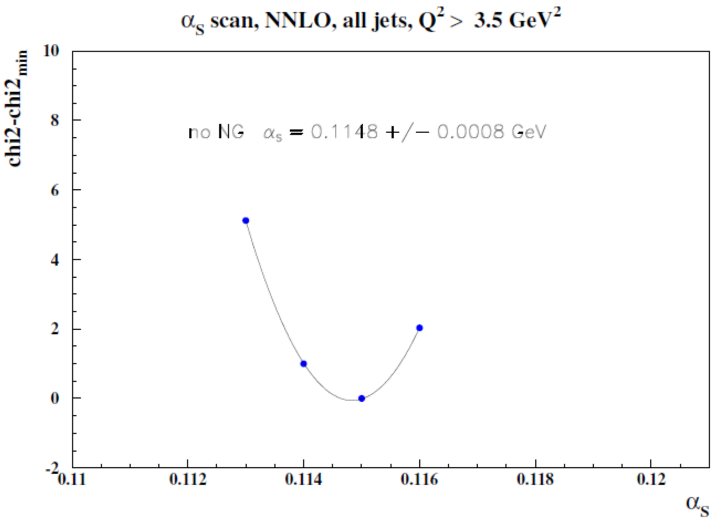
$\chi 2$=1598.5 for free $\alpha_s(M_Z)$ fit
1343 data points, 1328 degrees of freedom
$\chi 2$/d.o.f =1.203

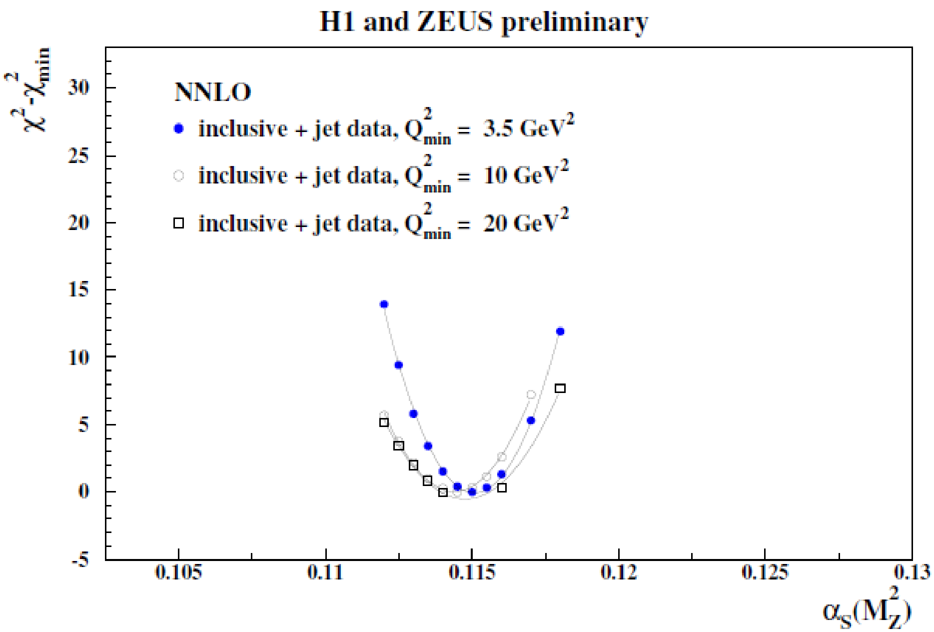
$\chi 2$=1609.3 for fixed $\alpha_s(M_Z)$=0.118
1343 data points, 1329 degrees of freedom
$\chi 2$/d.o.f =1.205

Compare $\chi 2$/d.o.f =1.205 for HERAPDF2.0NNLO (with only 1131 degrees of freedom)

To address the low-x, Q2 issue directly we did two more things

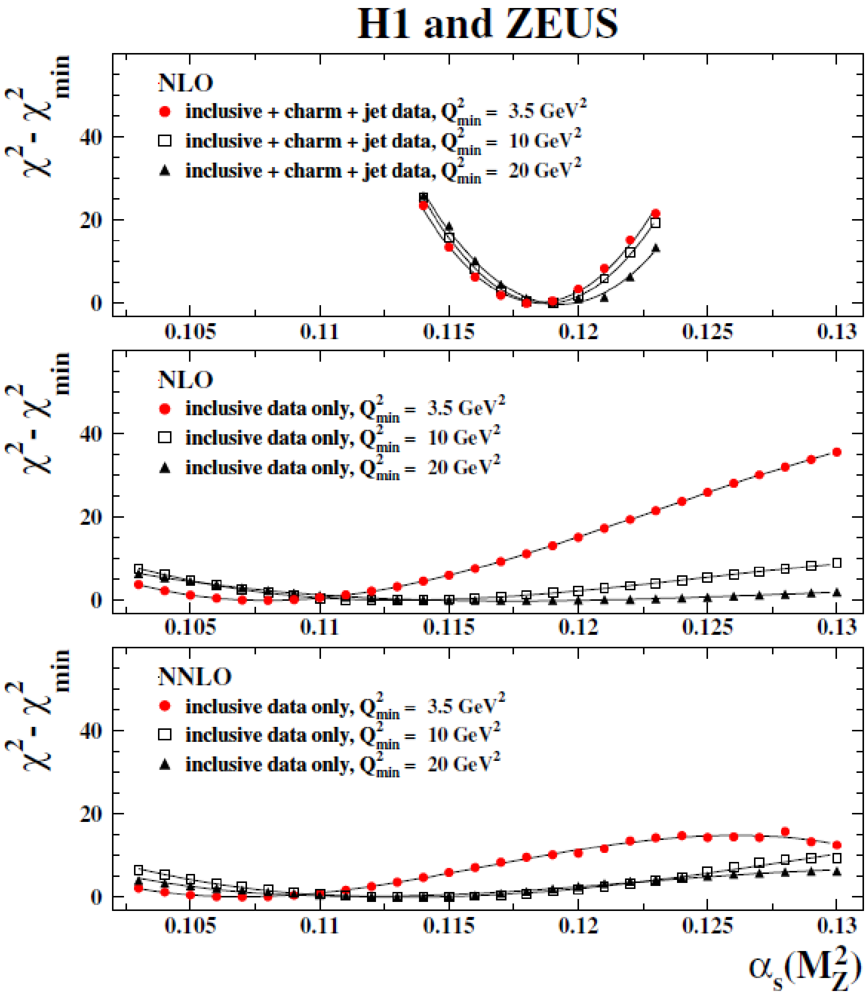
1. A fit with no negative gluon term
2. Fits with Q^2>10, 20 GeV^2 cuts

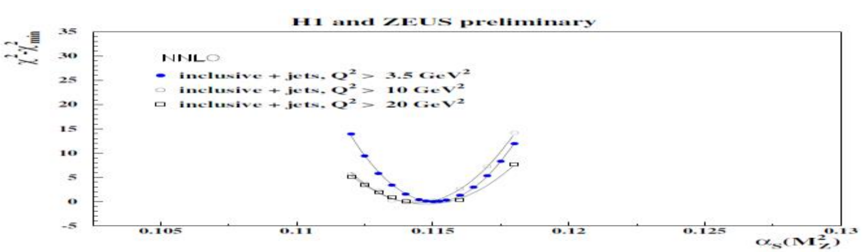




With no negative gluon term
$\alpha_s(M_Z)$ =0.1148 ± 0.0008
Compatible with standard result

The central values from the three scans are:
0.1150 Q^2>3.5
0.1144 Q^2>10
0.1148 Q_2>20
All within experimental error





Here I try to put it on the same scale

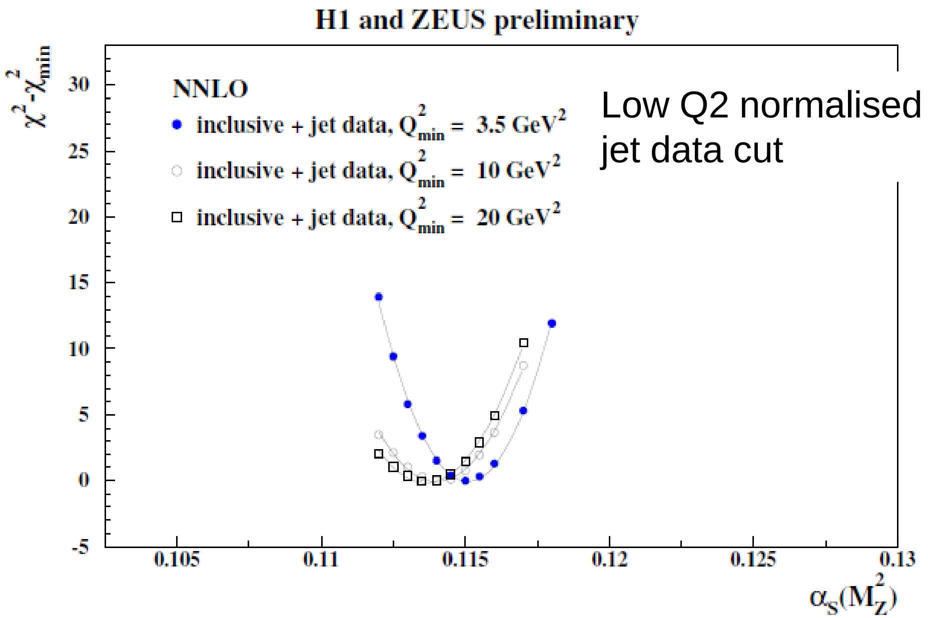
Stefan's notes
the main comparison here would be
(a) alpha_s scans [as figure 65 in HERAPDF2.0 but now in NNLO]

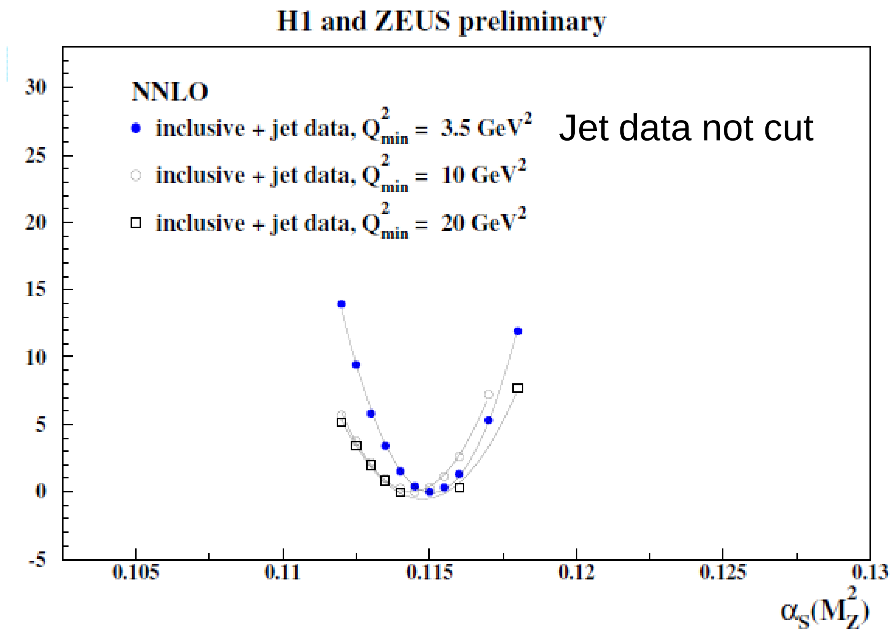
So let's compare this new scan on the same scale as Fig 65
Similar level of accuracy to NLO and $\alpha_s(M_Z)$ clearly moves lower at NNLO – But note we are using a different scale now– with the old scale choice used at NLO it would be even lower ~ $\alpha_s(M_Z)$ =0.1135

BUT Daniel suggested that for the higher Q2 cuts the low Q2 normalised data should also be cut for the corresponding Q2 values.

So we have also done this

REQUEST Preliminary—which of these?





The central values from the three scans are:
0.1150 ± 0.0008 Q2>3.5
0.1140 ± 0.0011 Q2>10
0.1136 ± 0.0011 Q2>20
Values are consistent but there is a trend?

The central values from the three scans are:
0.1150 ± 0.0008 Q2>3.5
0.1144 ± 0.0010 Q2>10
0.1148 ± 0.0010 Q2>20
Values are consistent- no trend

Now we need to determine further uncertainties

1. Hadronisation uncertainty

Stefan's notes:

hadronisation uncertainty derived from offset method. The correlated H1 hadronisation uncertainty will be counted twice for practical reasons. This is accepted for the preliminary but will have to be corrected for the publication

The value determined from the offset method is ± 0.0006

2. Parametrisation and model uncertainty determined from the usual procedures

Of varying mb 4.5±0.25, mc 1.43 ±0.06, fs 0.4±0.1, q2min $3.5^{+1.5}_{-1.0}$ GeV2

Q^2_0 =1.9±0.3 GeV2(and mc has to be varied up simultaneously)

Adding D and E parameters one at a time to all distributions which do not have them

This gives Model/parametrisation uncertainty $^{+0.0002}/_{-0.0005}$

3. Scale uncertainty to be determined from the usual procedure

This was to vary factorisation and renormalisation scales both separately and simultaneously by a factor of two taking the maximal positive and negative deviations. These are assumed to be 50% correlated and 50% uncorrelated.

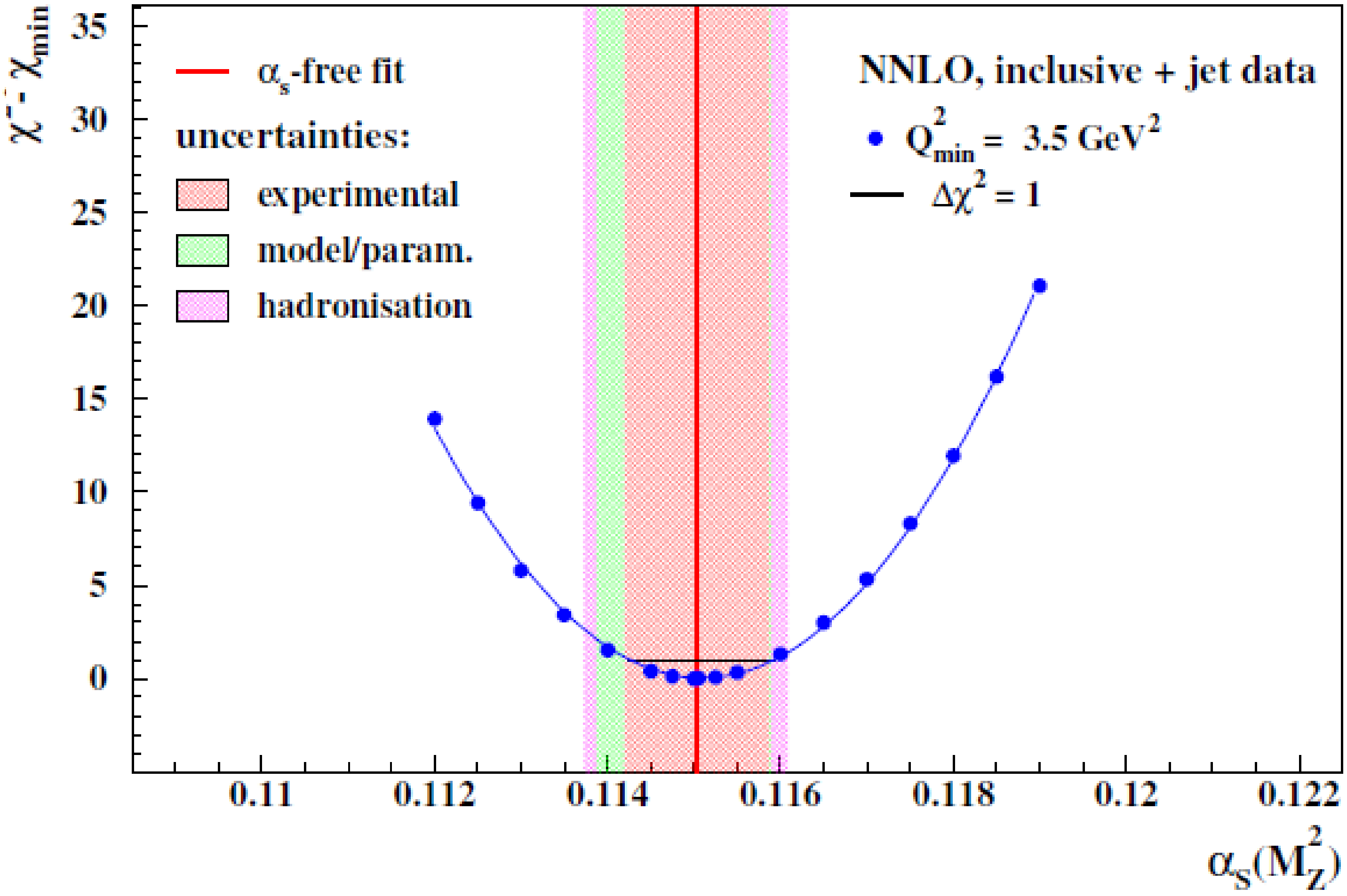
This gives scale uncertainty $^{+0.0026}/_{-0.0027}$ by far the largest uncertainty.

$\alpha_s(M_Z)=0.1150 \pm 0.0008_{(exp)}\ ^{+0.0002}_{-0.0005(model/param)} \pm 0.0006_{(had)} \pm 0.0027_{(scale)}$

Compare the NLO result

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

H1 and ZEUS preliminary



NOW for the PDFs

Stefan's notes

comparisons of PDFS. There are three fits to be compared:

HERAPDF2.0 NNLO

HERAPDF2.0Jets NNLO (fixed alpha_s)

HERAPDF2.0Jets NNLO (free alpha_s)--- We think this free fit is NOT actually the most instructive as a PDF. We think that fixed alpha_s fits at $\alpha_s(M_Z)$=0.118 and 0.115 are better

we would like to see all sensible comparisons (of the "standard" PDF flavours in particular the gluon density)

and then select the most instructive figures for the preliminary.

We will show u valence, d-valence, gluon and total Sea.

The separate ubar and dbar are available—but do not tell us much more

Where available, we would like to include error bands on the new fits.

YES we now have this

if possible, also show results with a cut on

Q^2>10,20 on inclusive data (as done for HERADPF2.0) but not on jet data. jet data are already restriced to high scales sqrt(Q^2+pt^2)>10, there is no need to cut on Q^2 alone.

We do this for Q2>10—it was not done for Q2>20 for HERAPDF2.0—only for the scan

HERAPDF2.0 NNLO

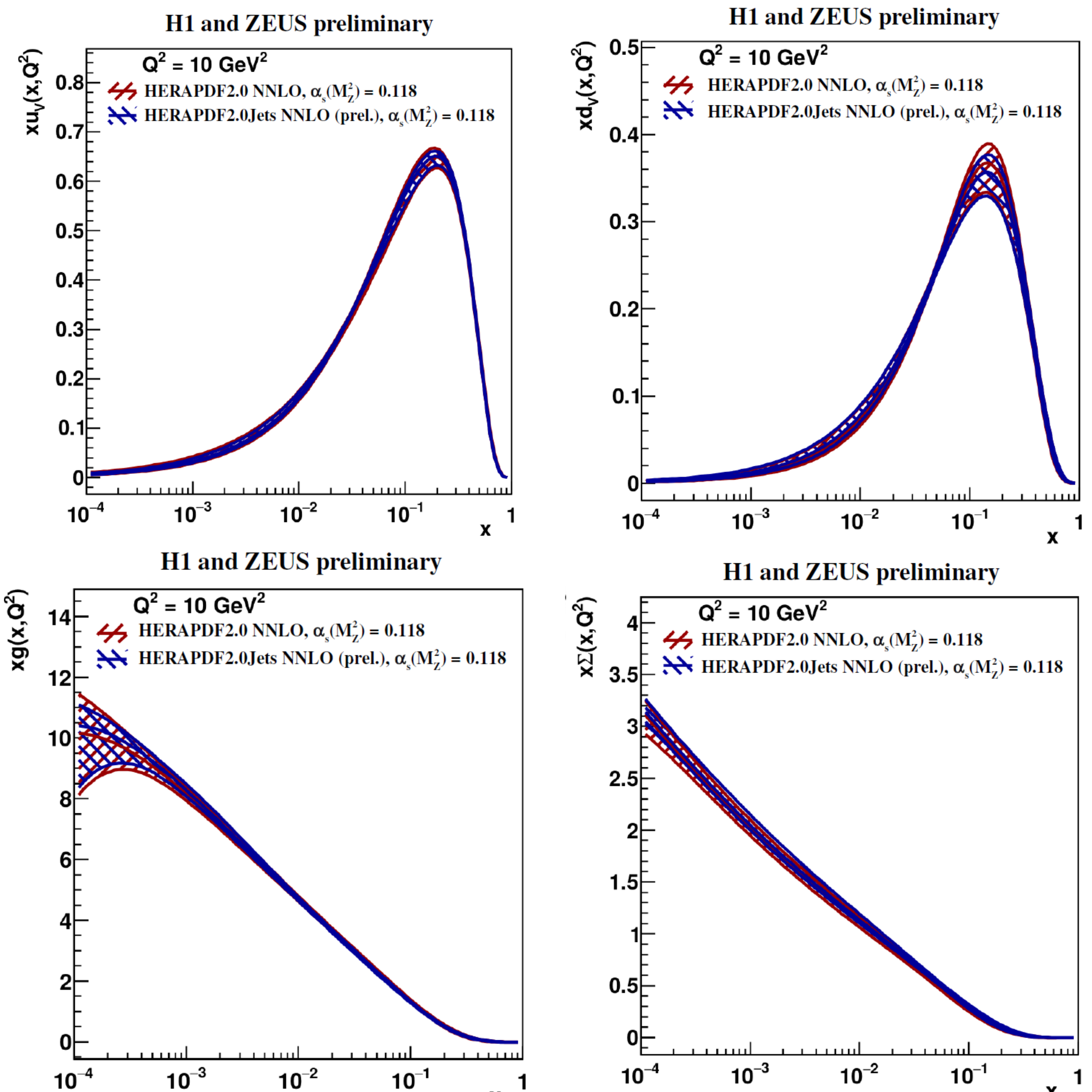
HERAPDF2.0Jets NNLO (fixed alpha_s)

HERE for alpha_S =0.118

Full uncertainties are included

Exp+model+param for both fits

REQUEST Preliminary



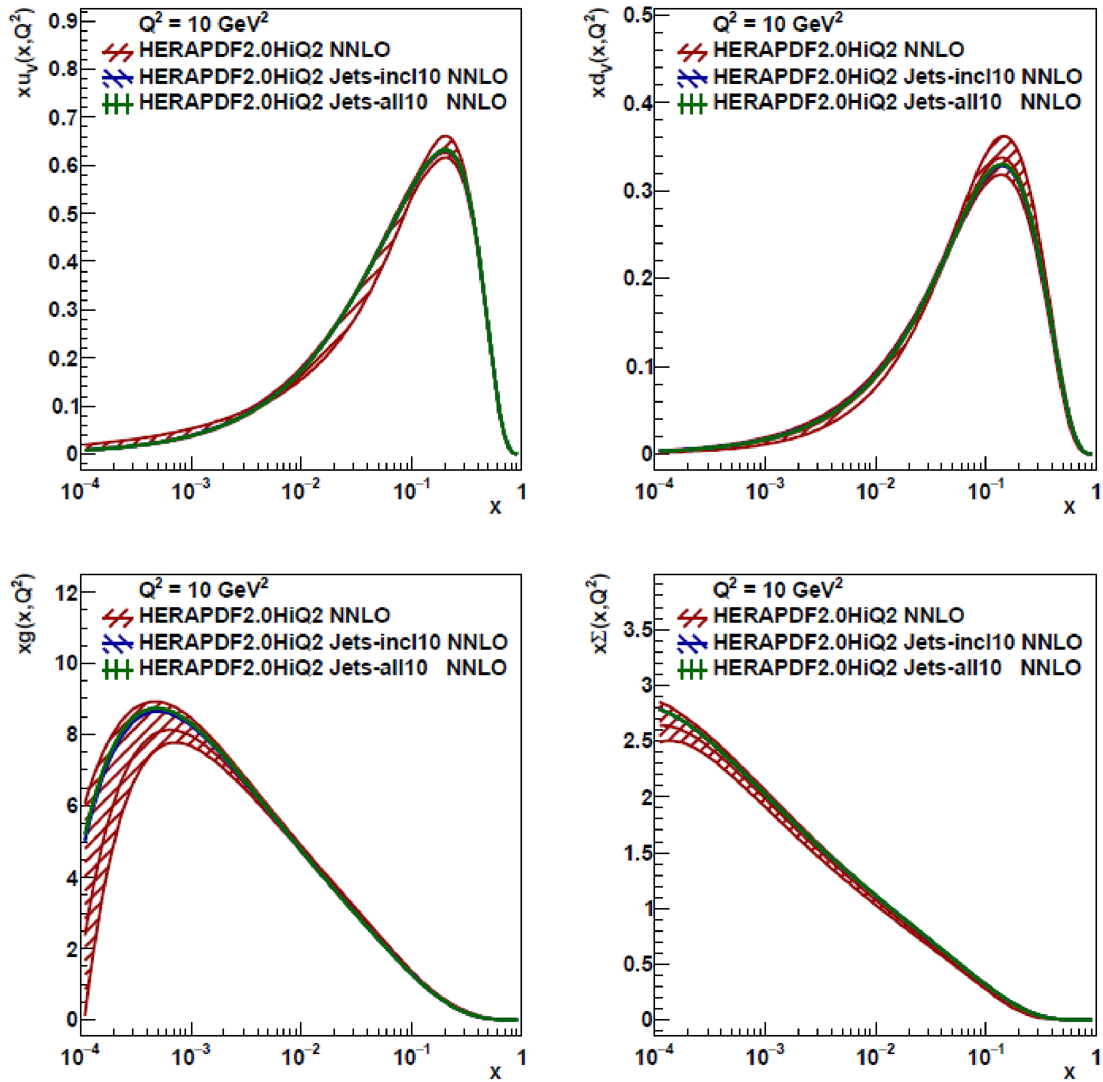
if possible, also show results with a cut on
Q^2>10 on inclusive data

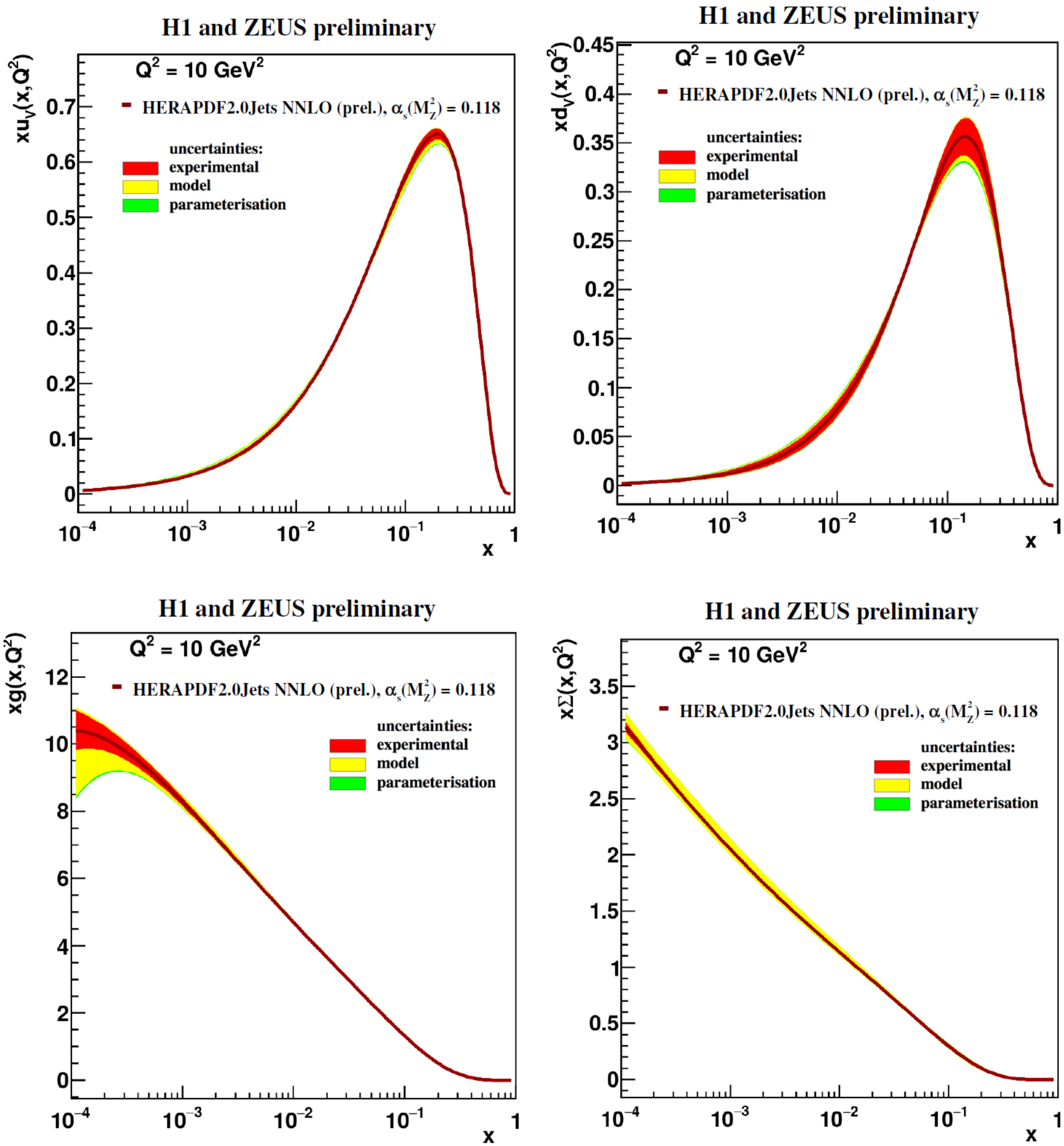
See this as a line on these plots (and there is also a line for the Q2>10 fit with appropriate low Q2 normalised jets cut)
They compare well to the published HERAPDF2.0HiQ2NNLO Which also has a Q2>10 cut.

We do not have full errors on Q2>10 fits I do not think we need them.
We don't have to do this again --it was never much used!

The message is that the Jets do not affect the Q2>10 fit much.

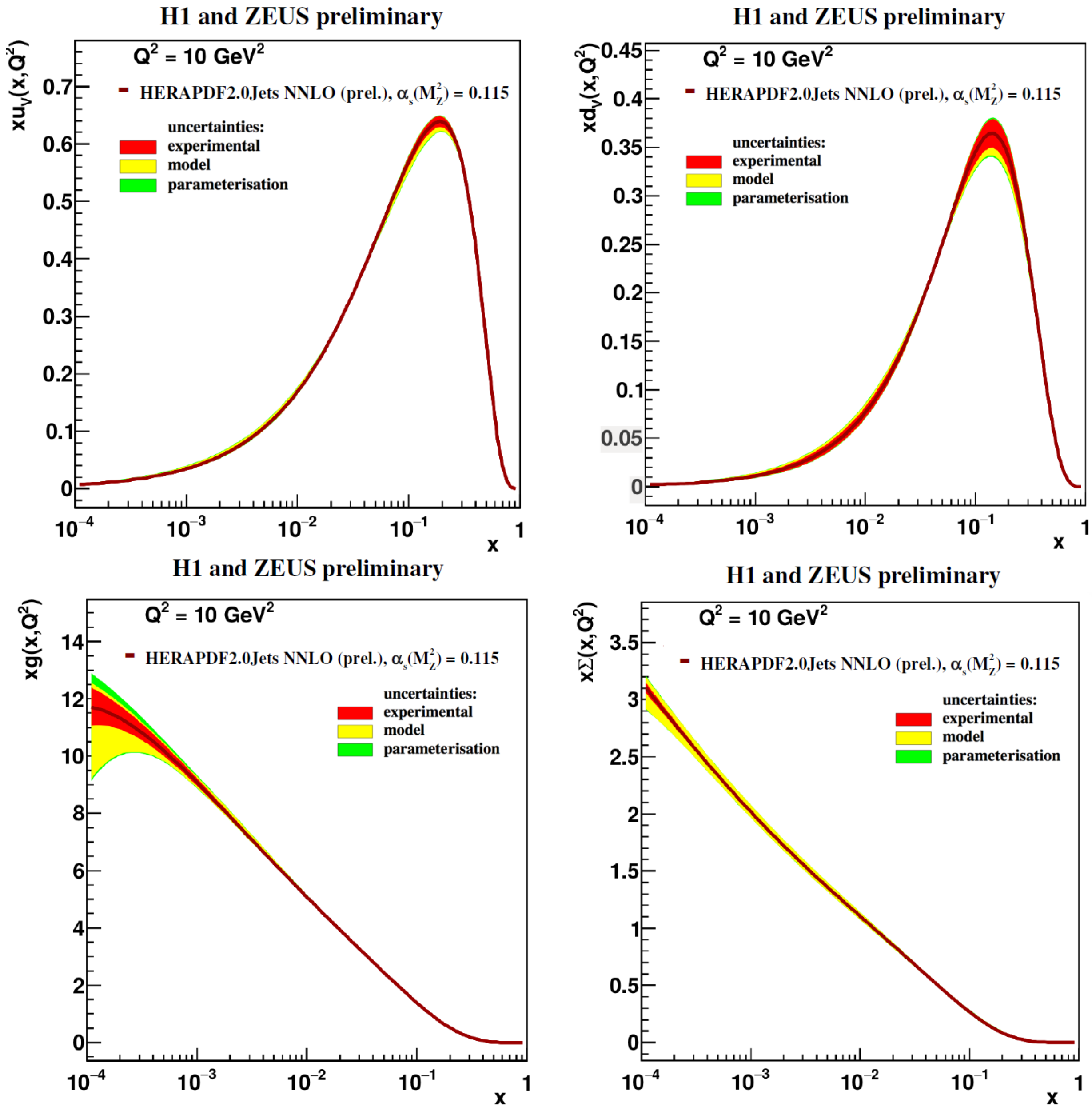
NOTE this is with the negative gluon term.



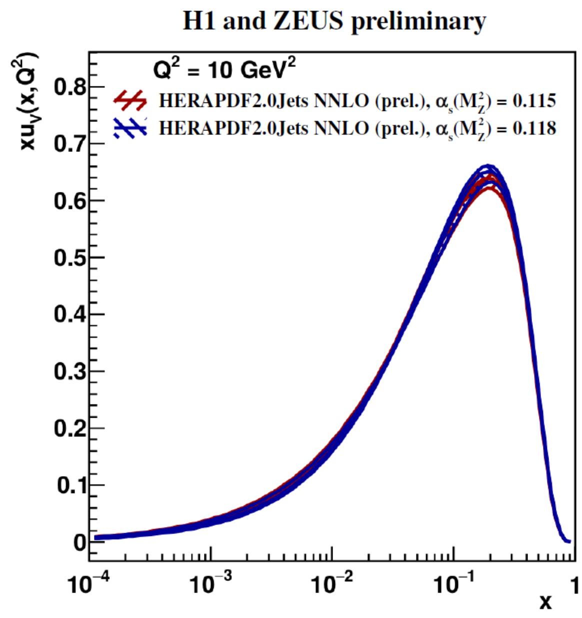


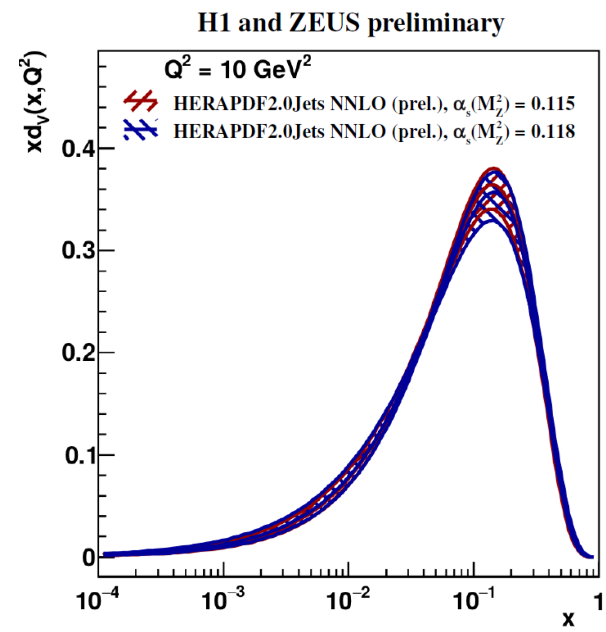
REQUEST Preliminary
As=0.118

REQUEST Preliminary
As=0.115

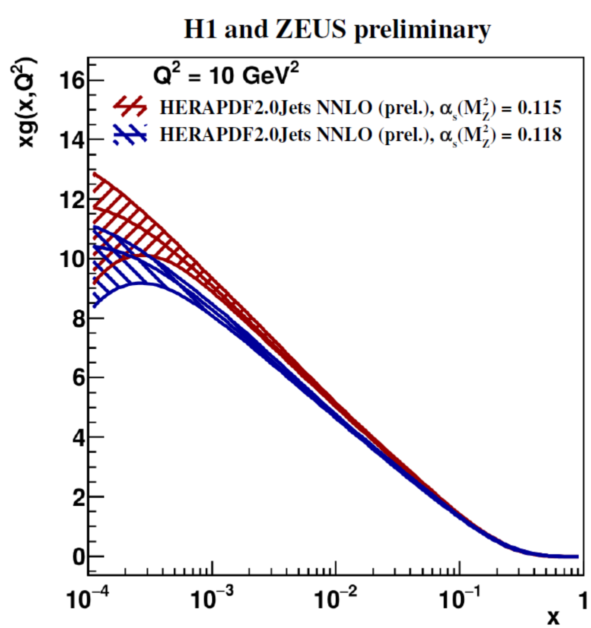


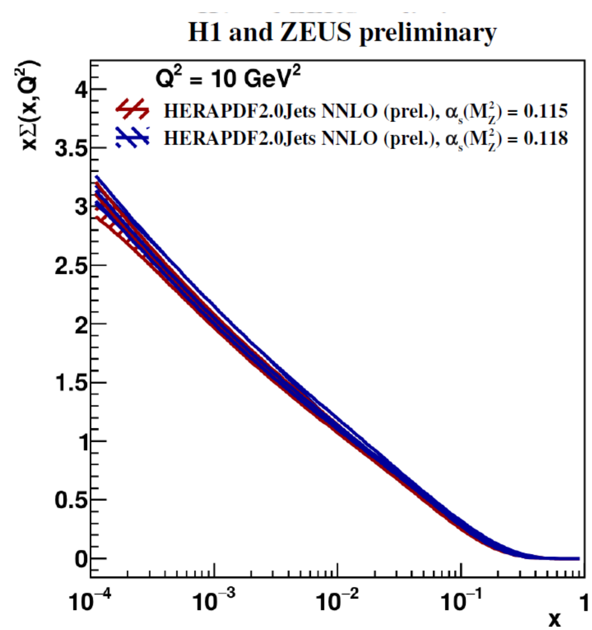
NOW compare fixed alphas=0.118 with 0.115
We think this is better than a free alphas fit

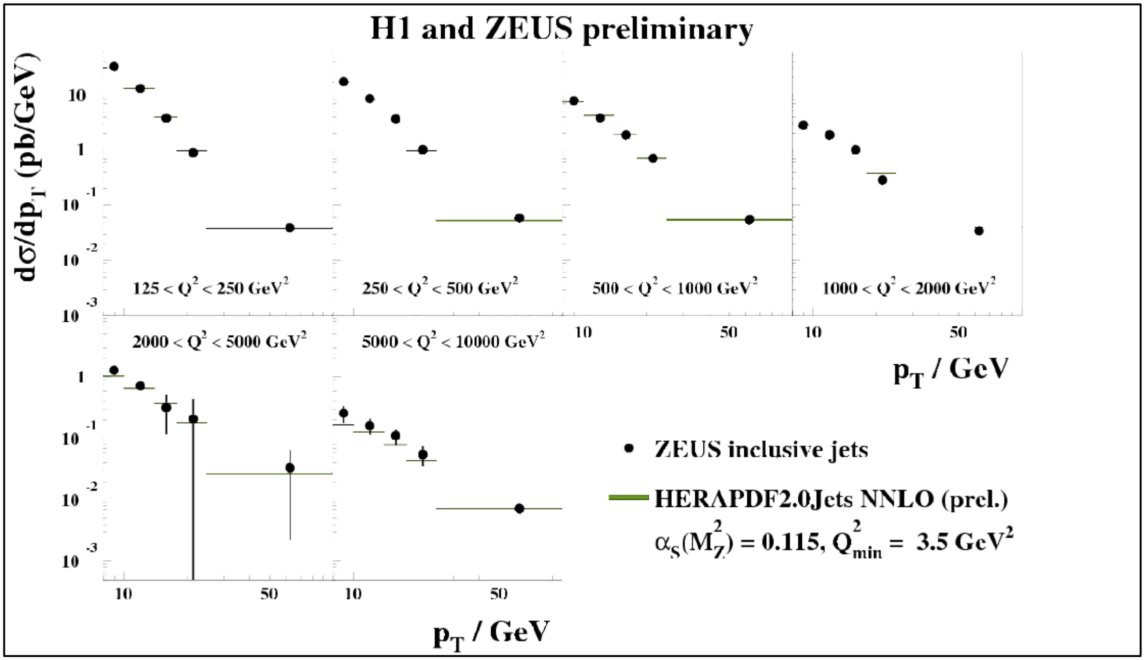




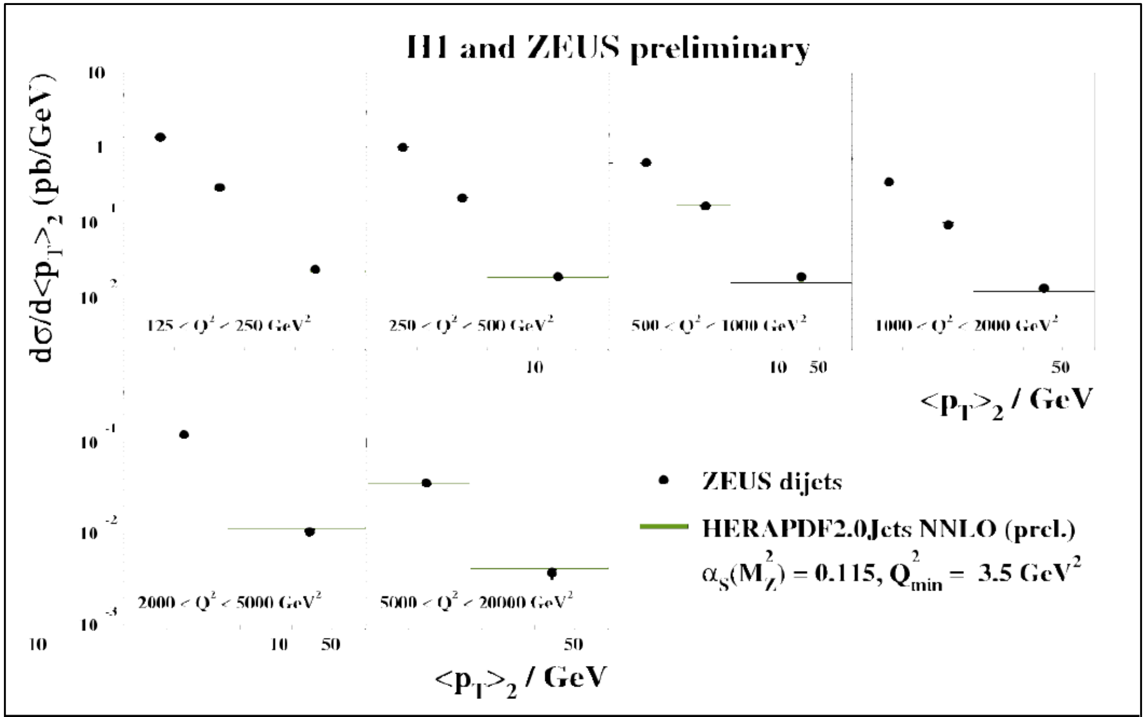
REQUEST Preliminary



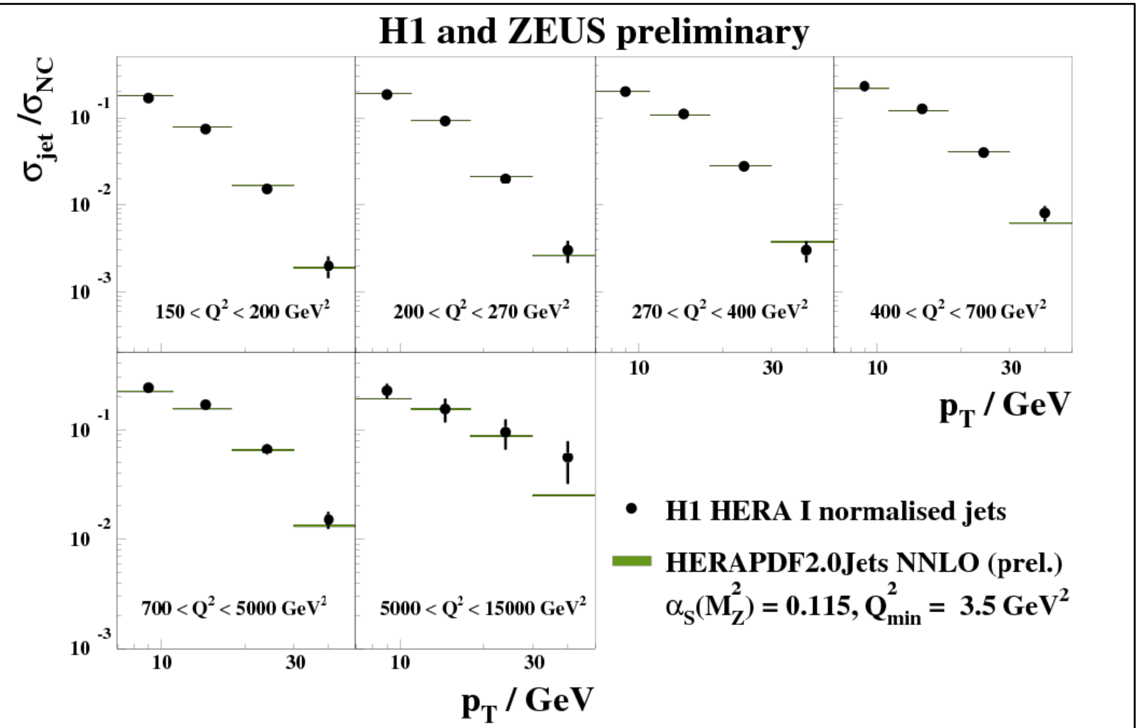




Now compare the NNLO fit with $\alpha_s(M_Z)$=0.115 to the jet data



REQUEST Preliminary



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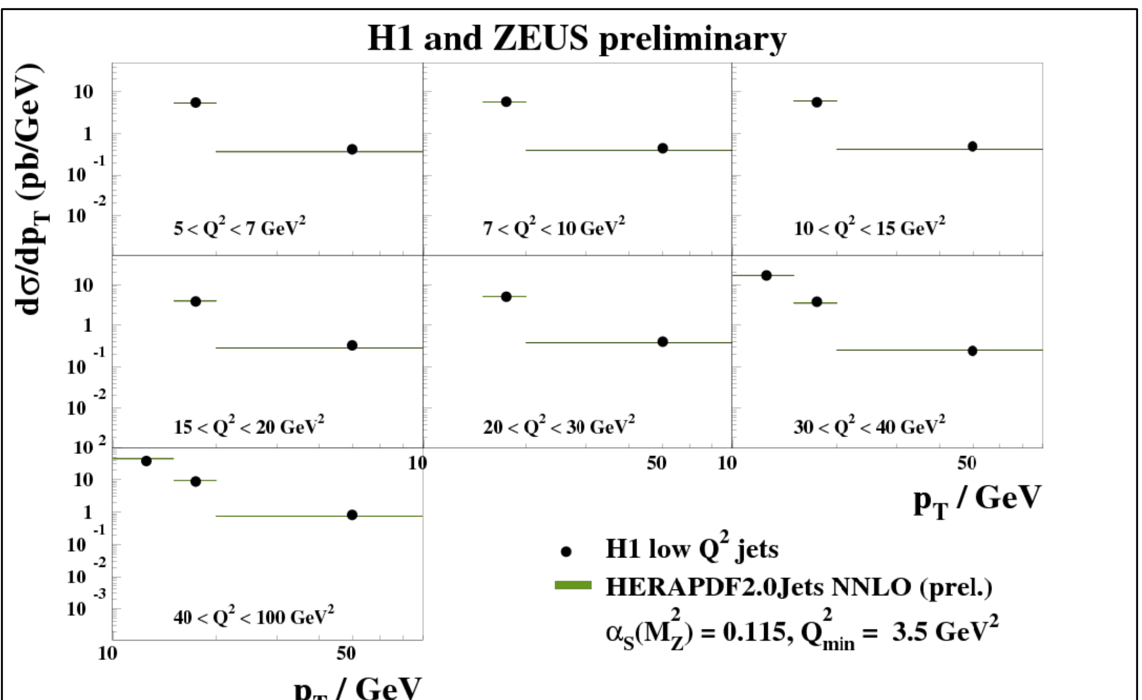

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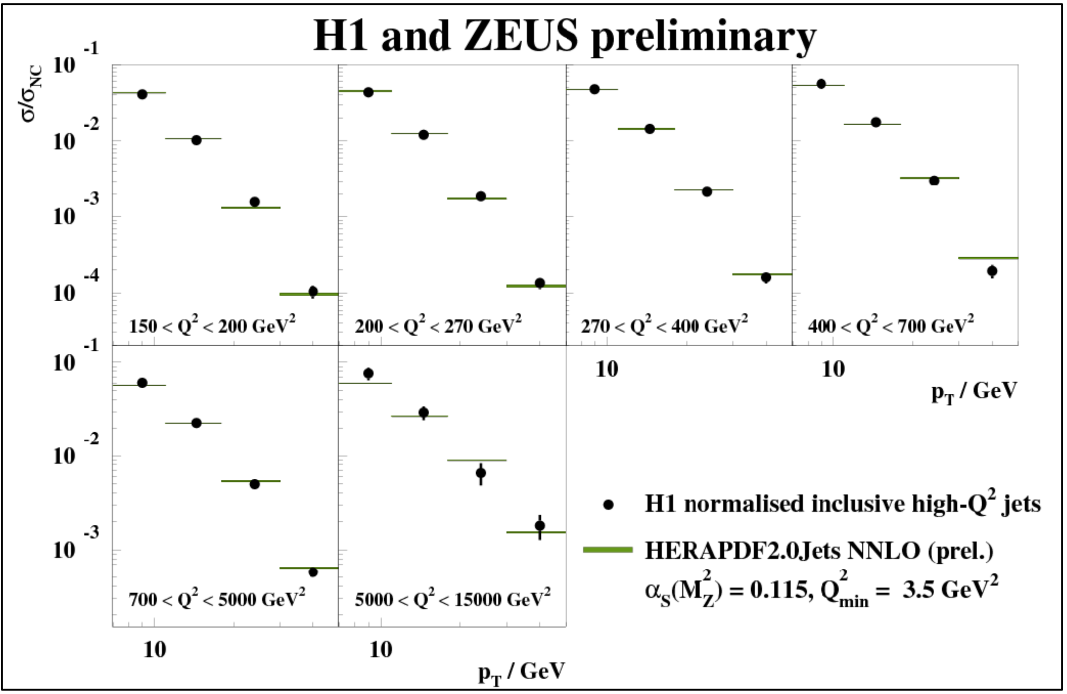
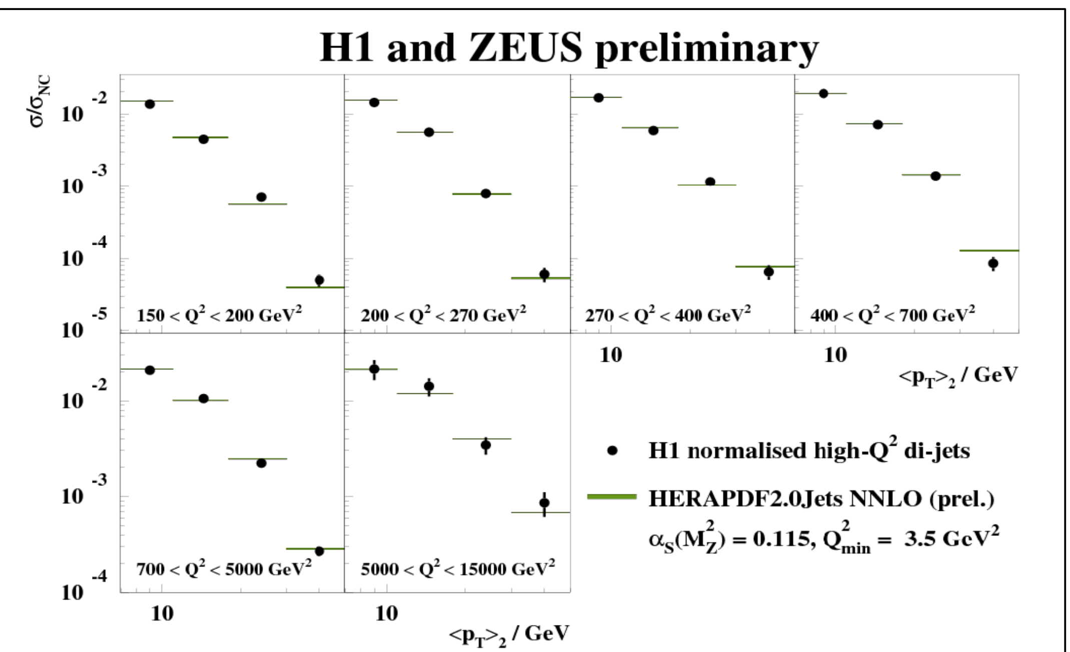
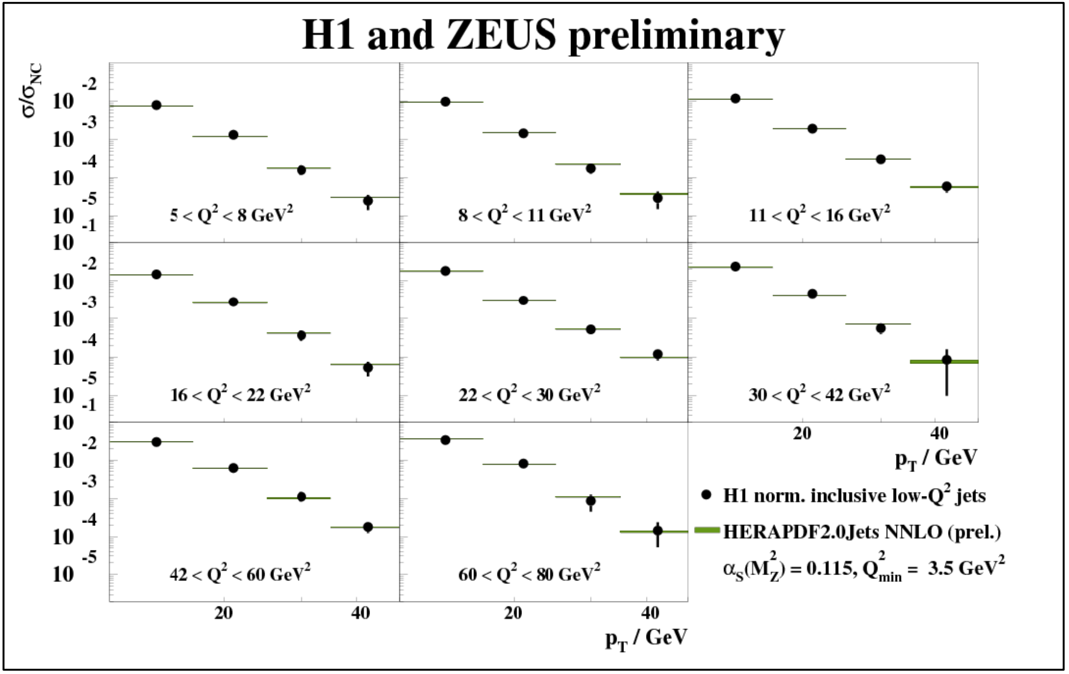


REQUEST Preliminary





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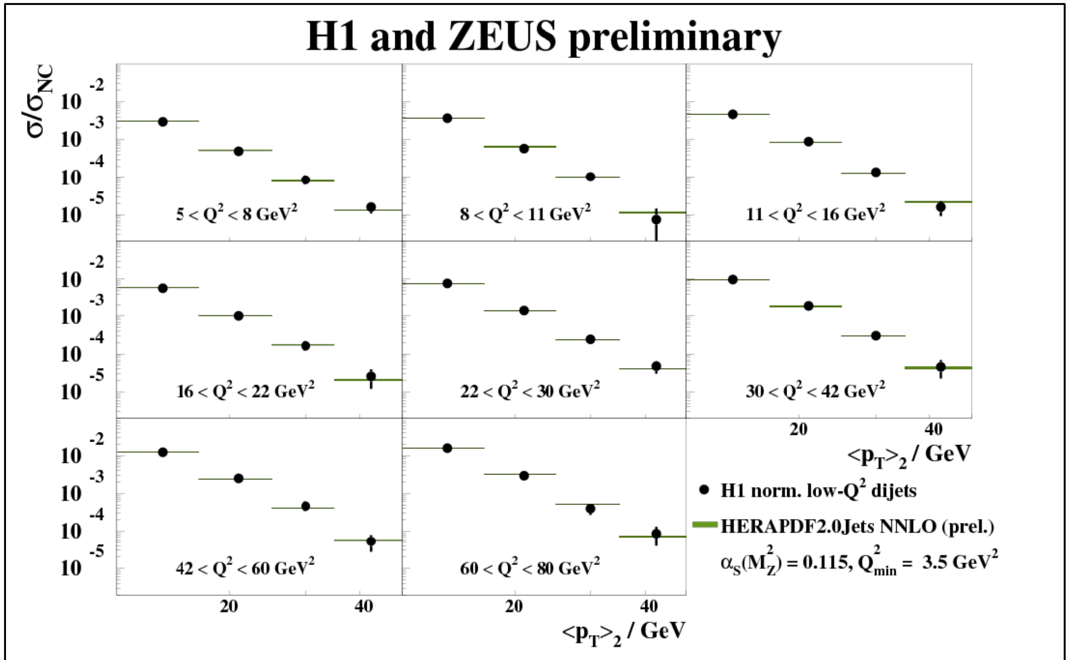
REQUEST Preliminary



Preliminary conclusions

What does NNLO do?

- It changes the shapes of the gluon and sea PDFs in the same way as it did for inclusive only fits
- It decreases scale uncertainty
- It decreases the value of $\alpha_S(M_Z)$

What do new low Q2 jets do?

No significant changes at fixed $\alpha_S(M_Z)$

When $\alpha_S(M_Z)$ is free it raises the value of $\alpha_S(M_Z)$ at NLO, by ~0.004, with corresponding change in gluon shape. This change is compatible with NLO scale uncertainty.

However at NNLO there is not much difference in $\alpha_S(M_Z)$ with or without the new jets.

The NNLO value is

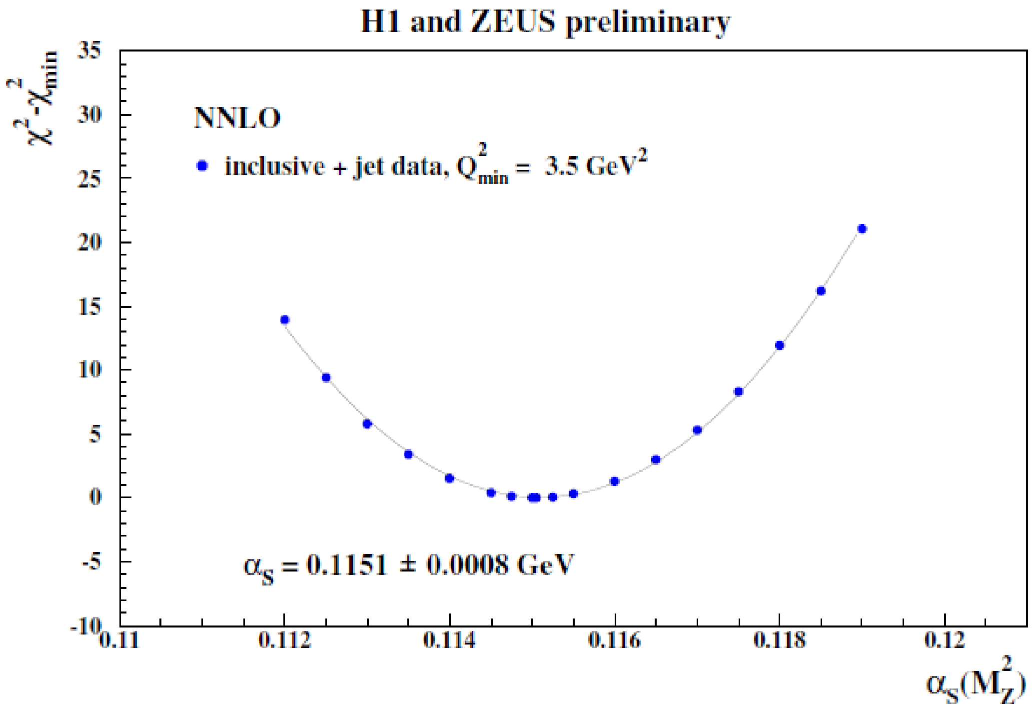
$\alpha_s(M_Z)=0.1150 \pm 0.0008_{(exp)}\ {}^{+0.0002}_{-0.0005(model/param)} \pm 0.0006\ _{(had)} \pm 0.0027\ _{(scale)}$

Compare the NLO result

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

Preliminary requests

REQUEST Preliminary



$\chi2$=1598.5 for free $\alpha_s(M_Z)$ fit
1343 data points, 1328 degrees of freedom
$\chi2$/d.o.f =1.203

Compare $\chi2$/d.o.f =1.205 for HERAPDF2.0NNLO (with only 1131 degrees of freedom)

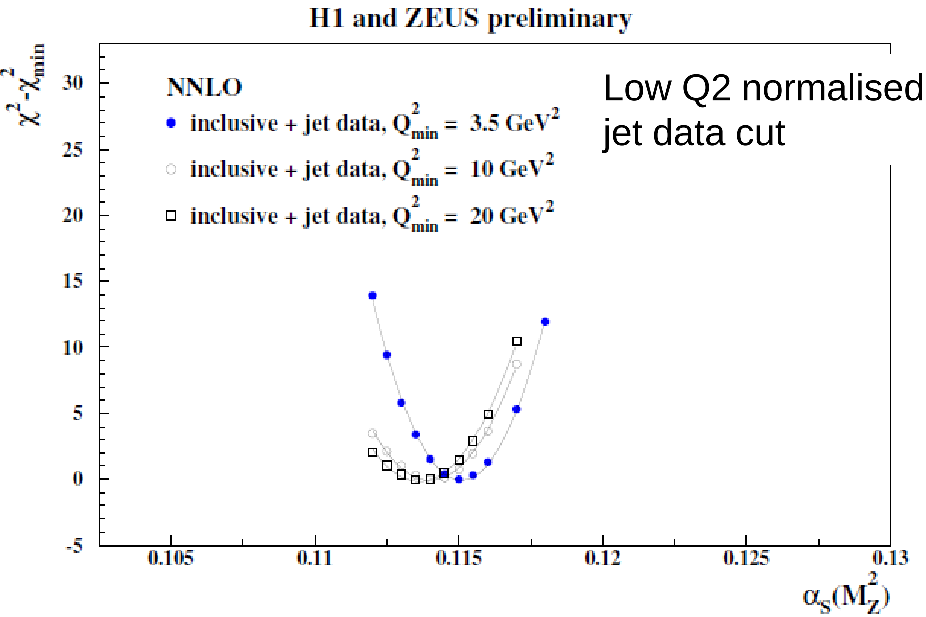
$\alpha_s(M_Z)$ =0.11503 ± 0.00084(exp) from fit
Add model, param, hadronisation and scale uncertainties

$\alpha_s(M_Z)=0.1150 \pm 0.0008_{(exp)}\ ^{+0.0002}_{-0.0005(model/param)} \pm 0.0006_{(had)} \pm 0.0027_{(scale)}$

Compare the published NLO result
$\alpha_s(M_Z)=0.1183 \pm 0.0009_{(exp)} \pm 0.0005_{(model/param)} \pm 0.0012_{(had)}\ ^{+0.0037}_{-0.0030(scale)}$

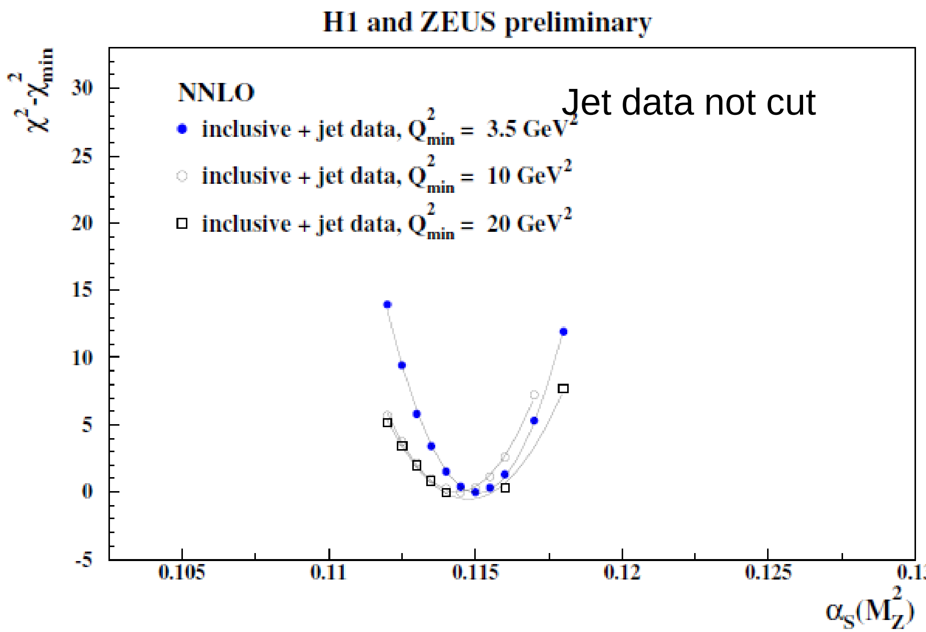
REQUEST Preliminary—which of these?

Low Q2 normalised jet data cut



The central values from the three scans are:
0.1150 ± 0.0008 Q2>3.5
0.1140 ± 0.0011 Q2>10
0.1136 ± 0.0011 Q2>20
Values are consistent but there is a trend?

Jet data not cut



The central values from the three scans are:
0.1150 ± 0.0008 Q2>3.5
0.1144 ± 0.0010 Q2>10
0.1148 ± 0.0010 Q2>20
Values are consistent- no trend

HERAPDF2.0 NNLO

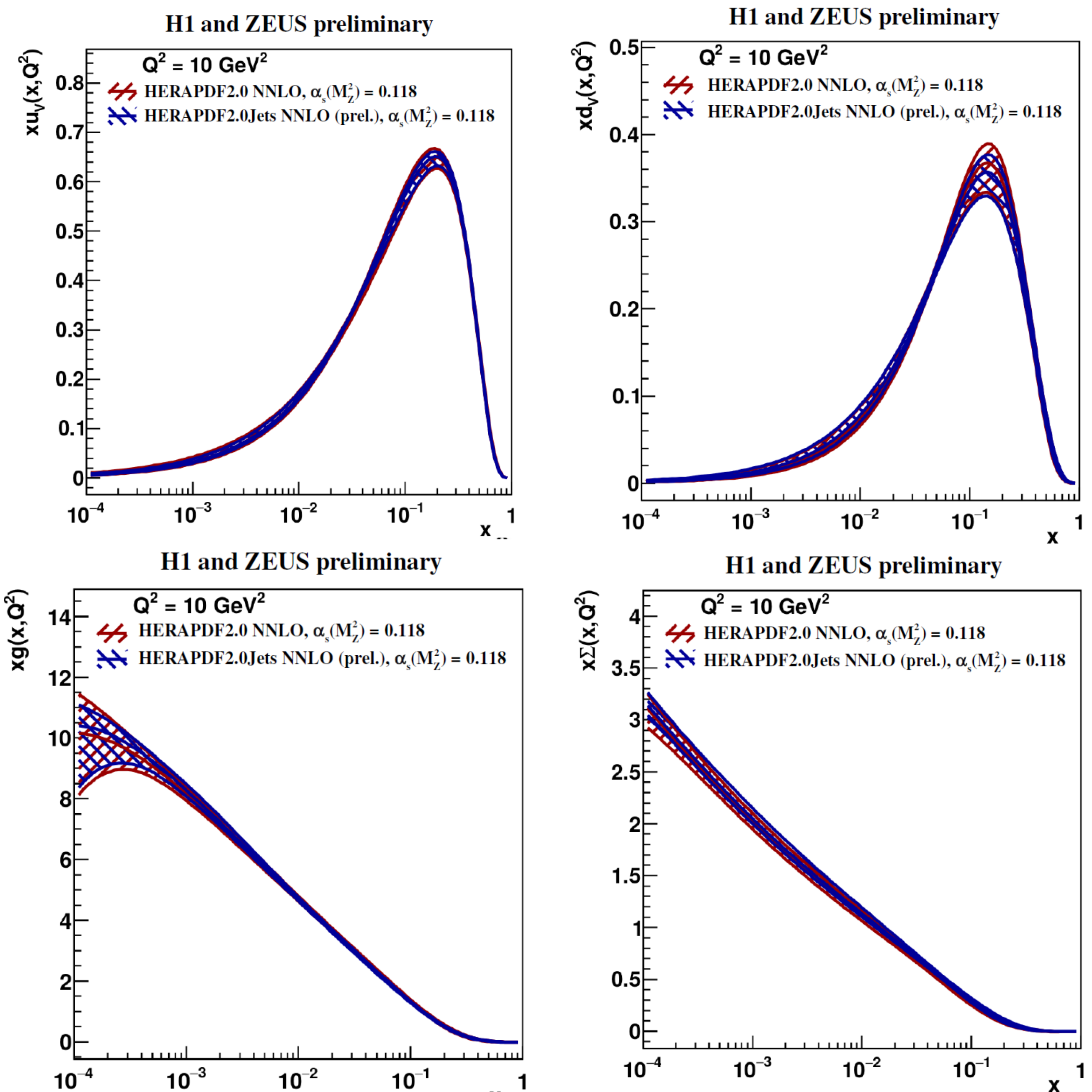
HERAPDF2.0Jets NNLO (fixed alpha_s)

REQUEST Preliminary

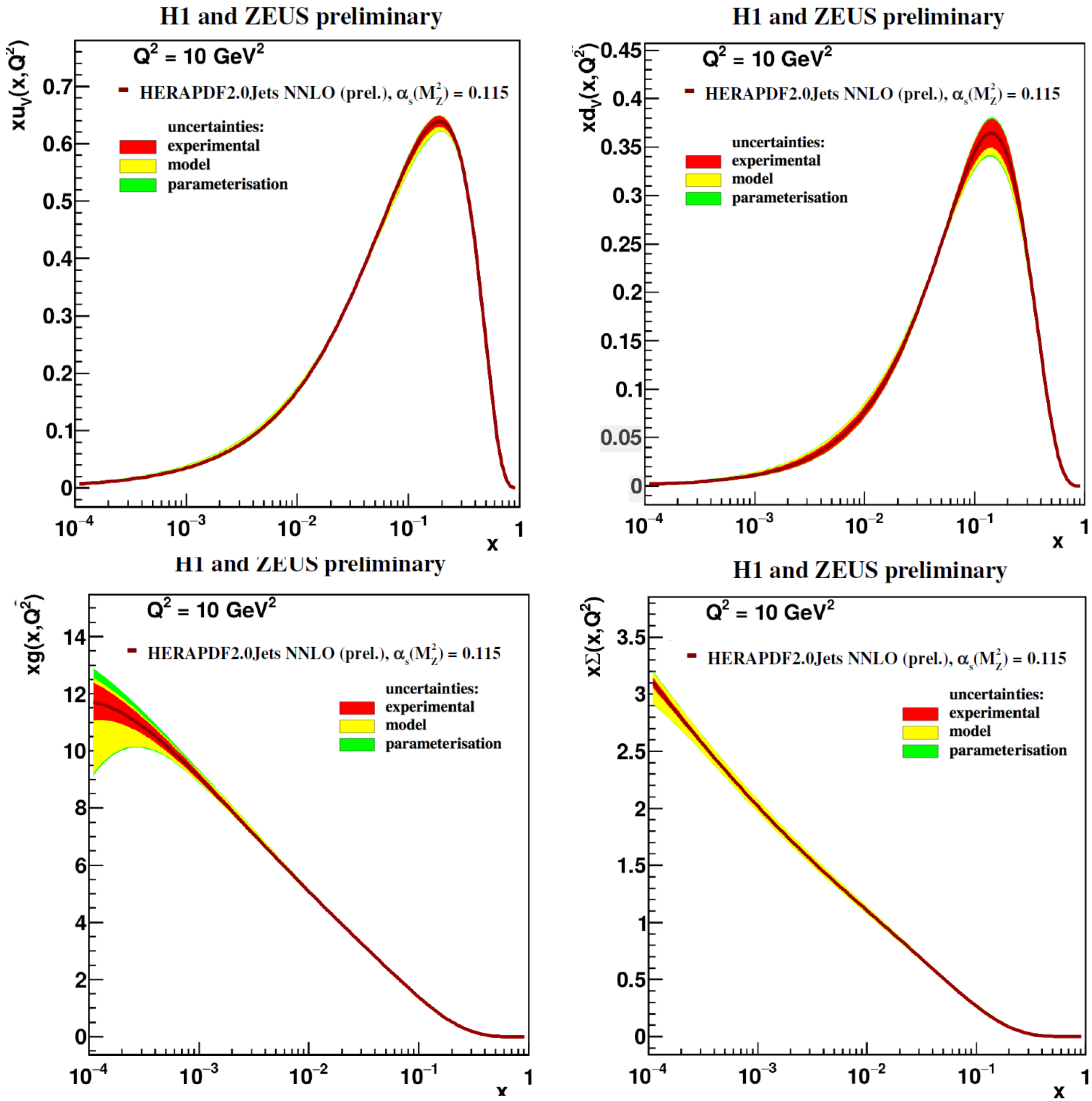
HERE for alpha_S =0.118

Full uncertainties are included

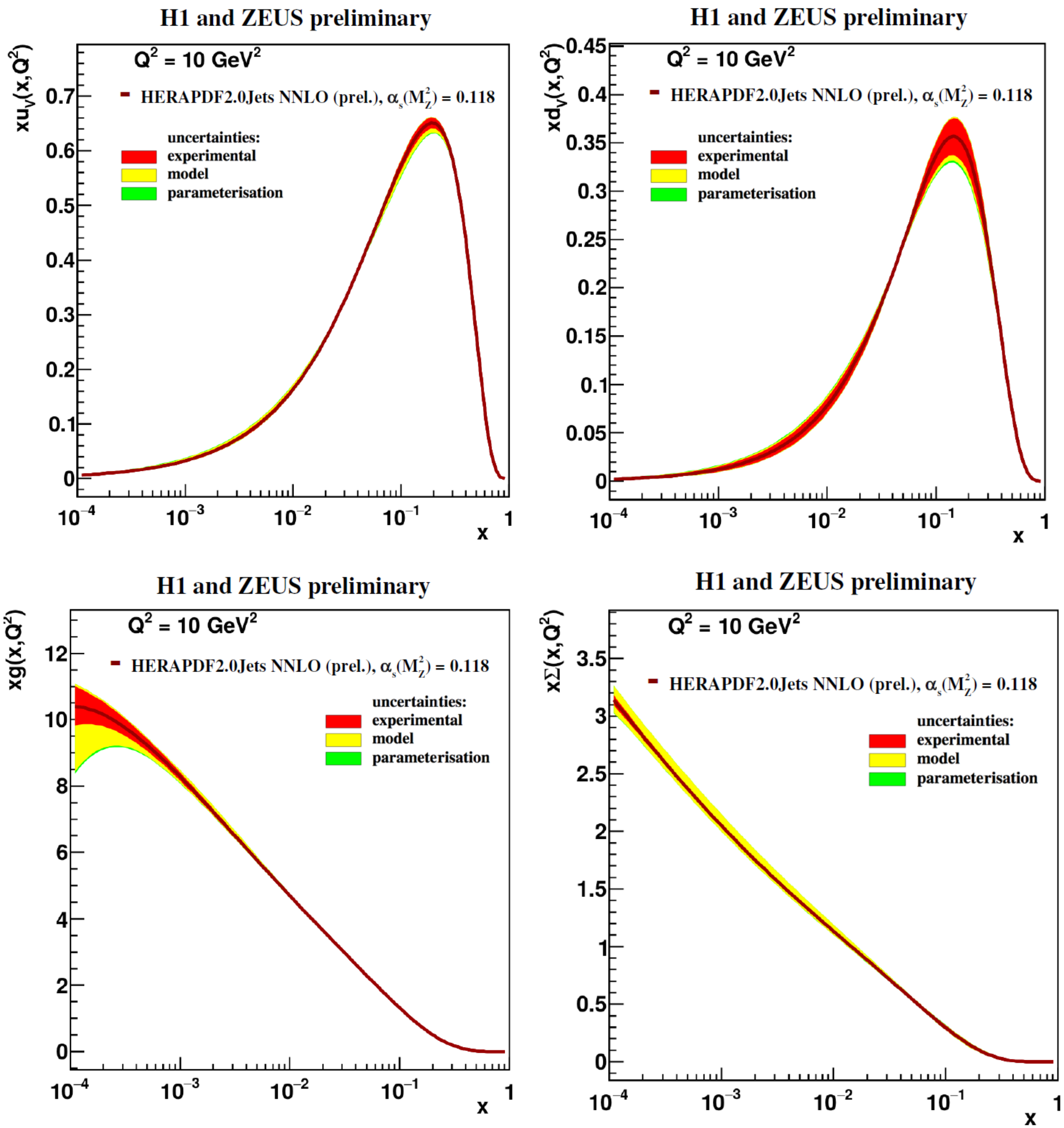
Exp+model+param



REQUEST Preliminary
As=0.115

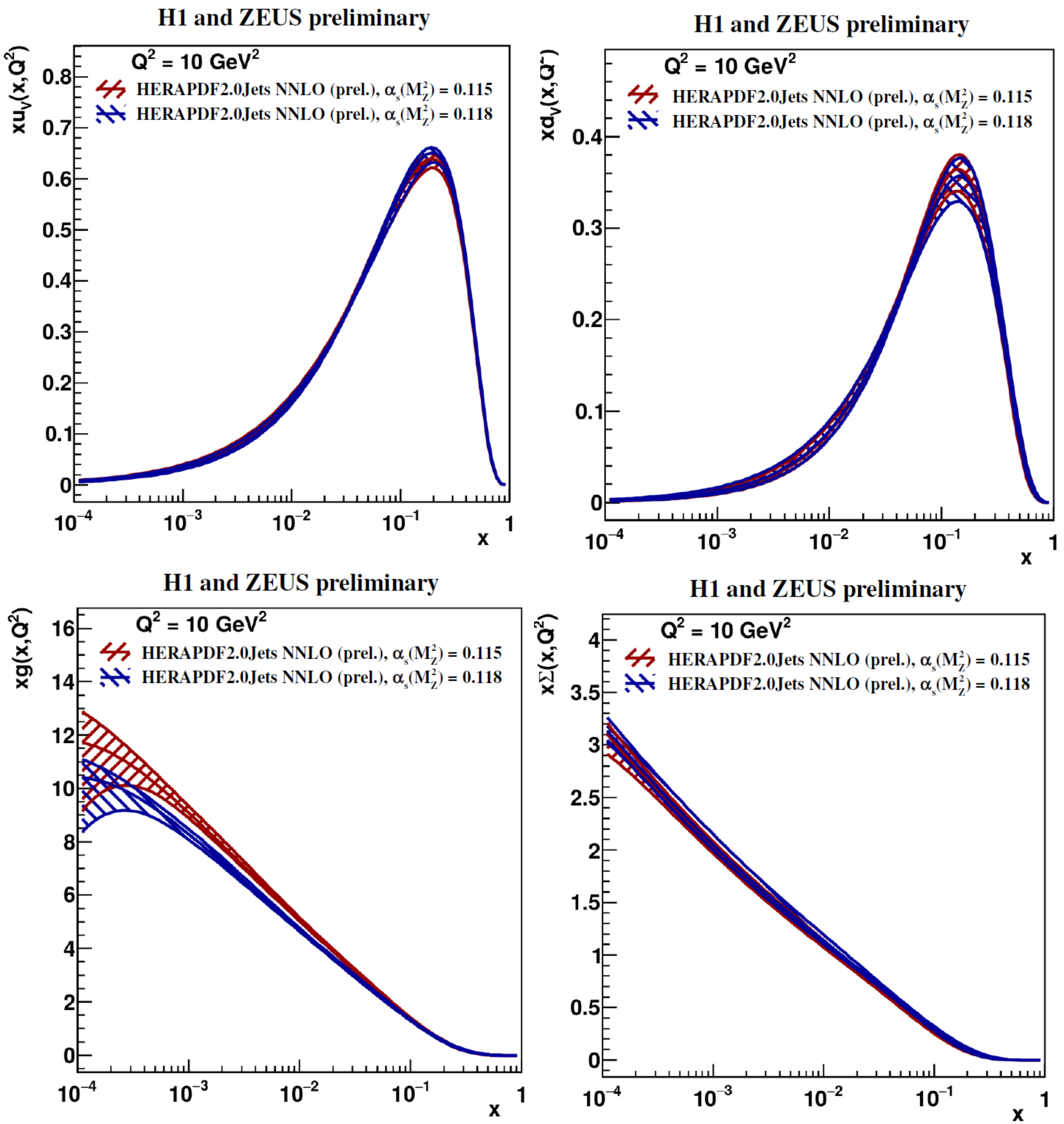


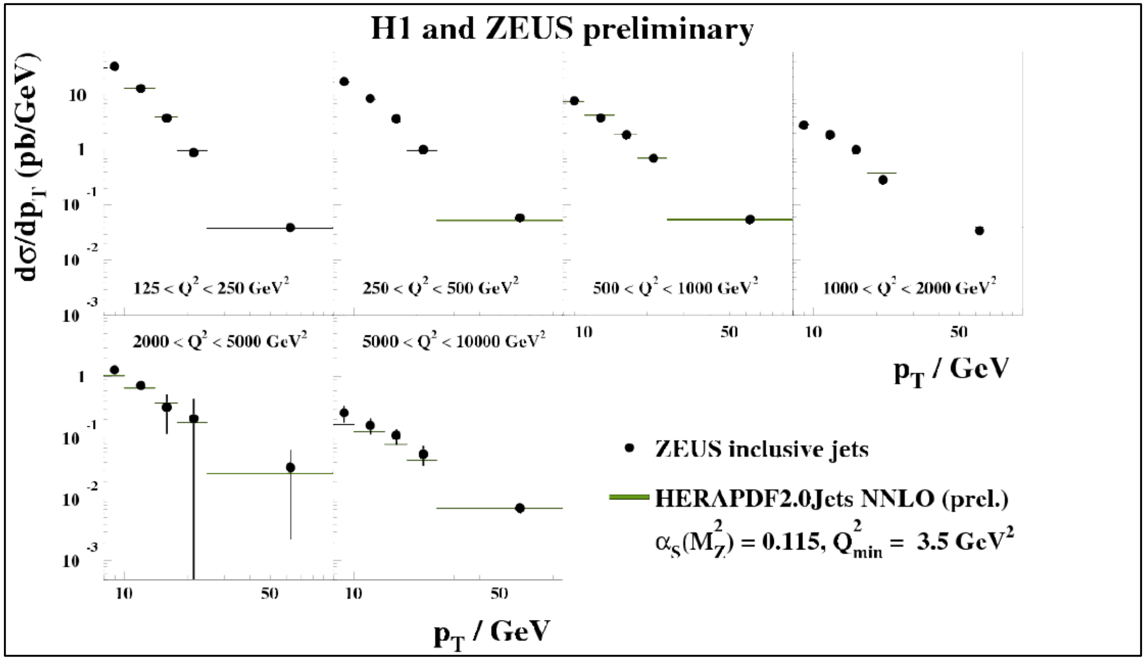
REQUEST Preliminary
As=0.118

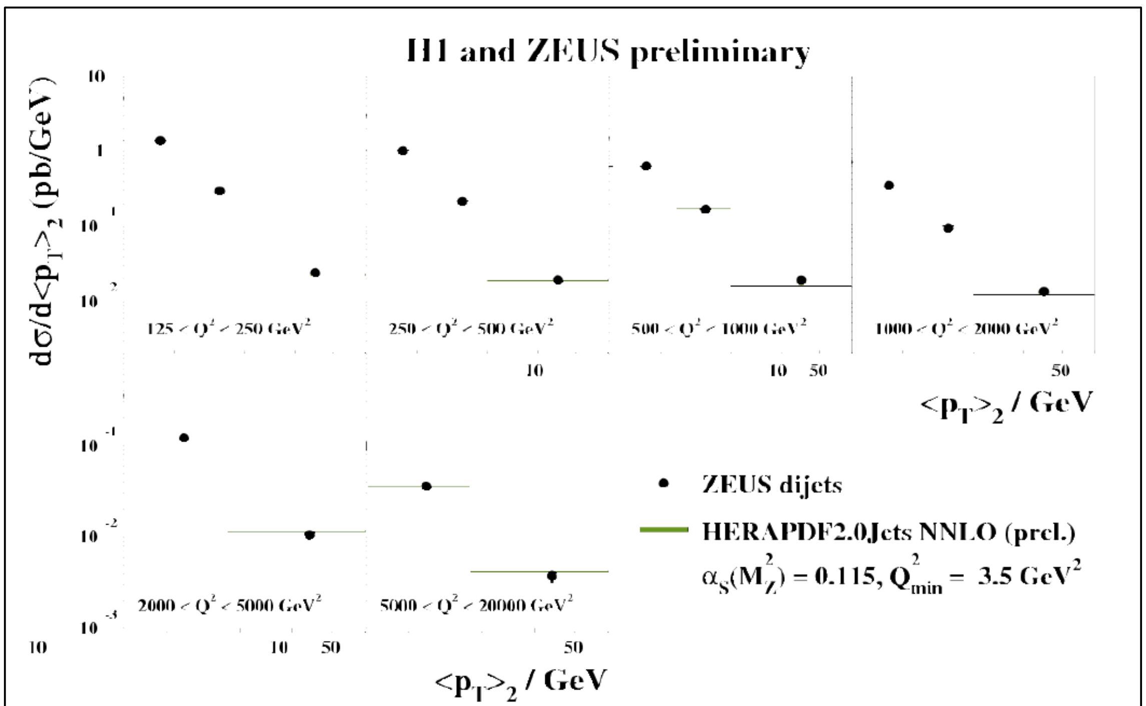


NOW compare fixed alphas=0.118 with 0.115
We think this is better than a free alphas fit

REQUEST Preliminary

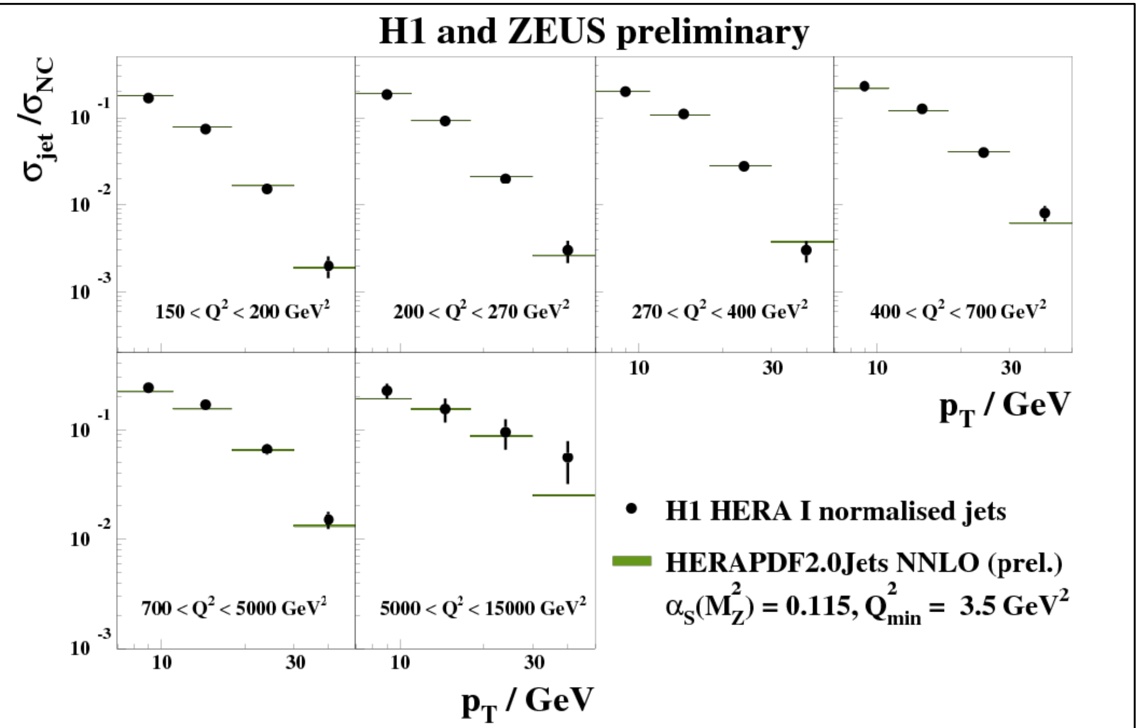


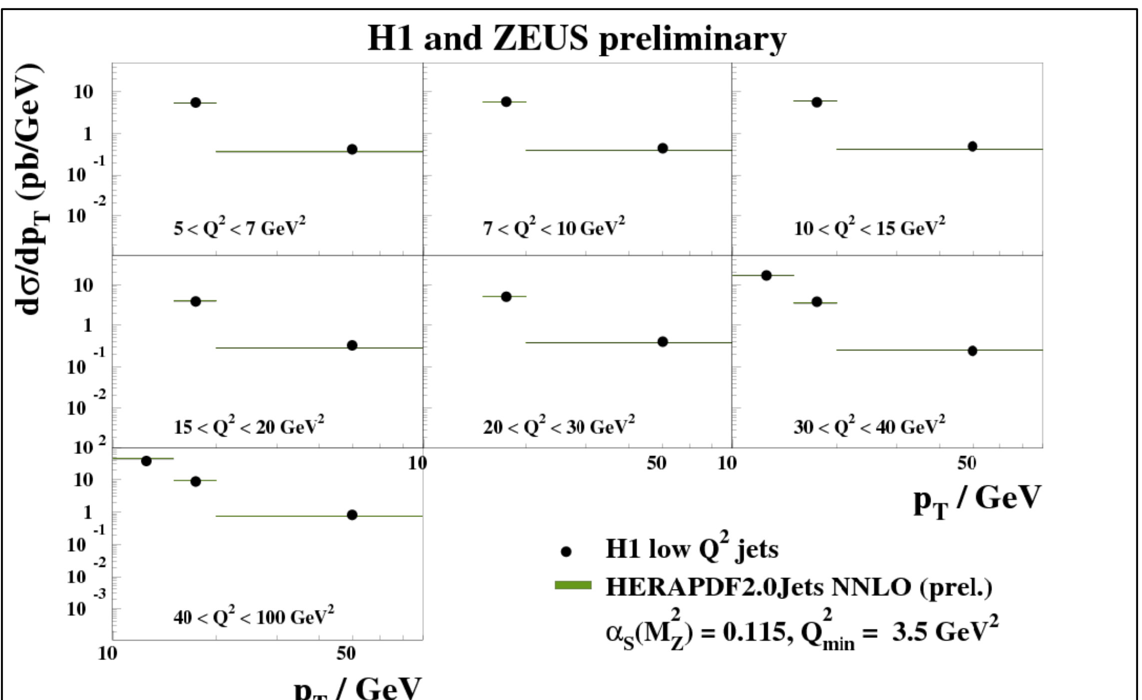




Now compare the NNLO fit with $\alpha_s(M_Z)$=0.115 to the jet data

REQUEST Preliminary





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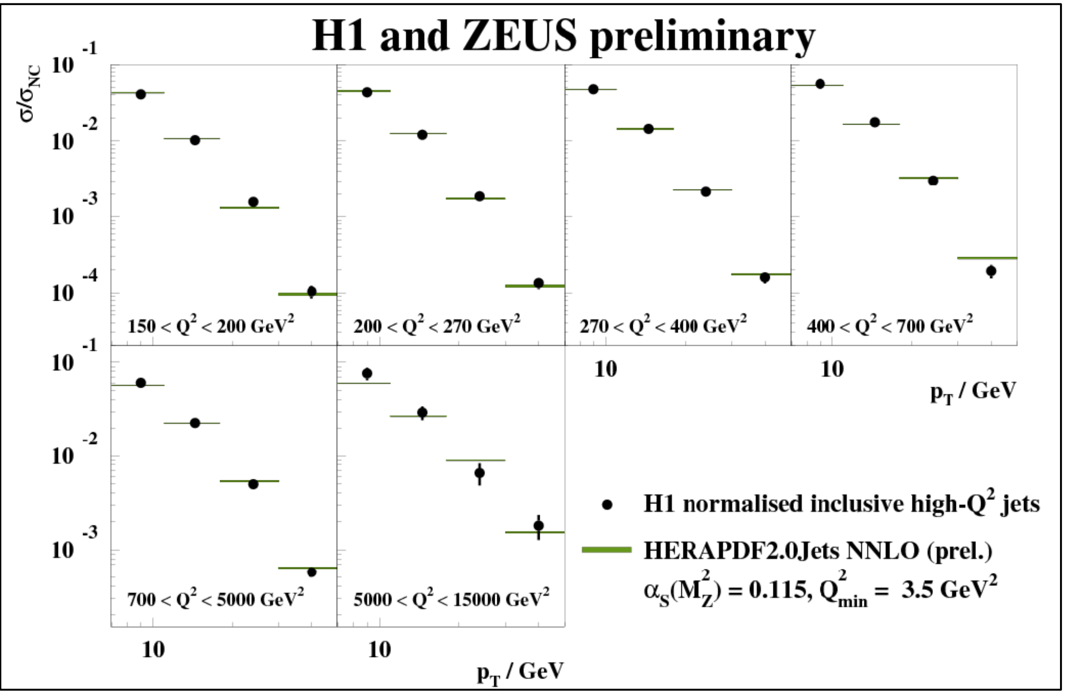

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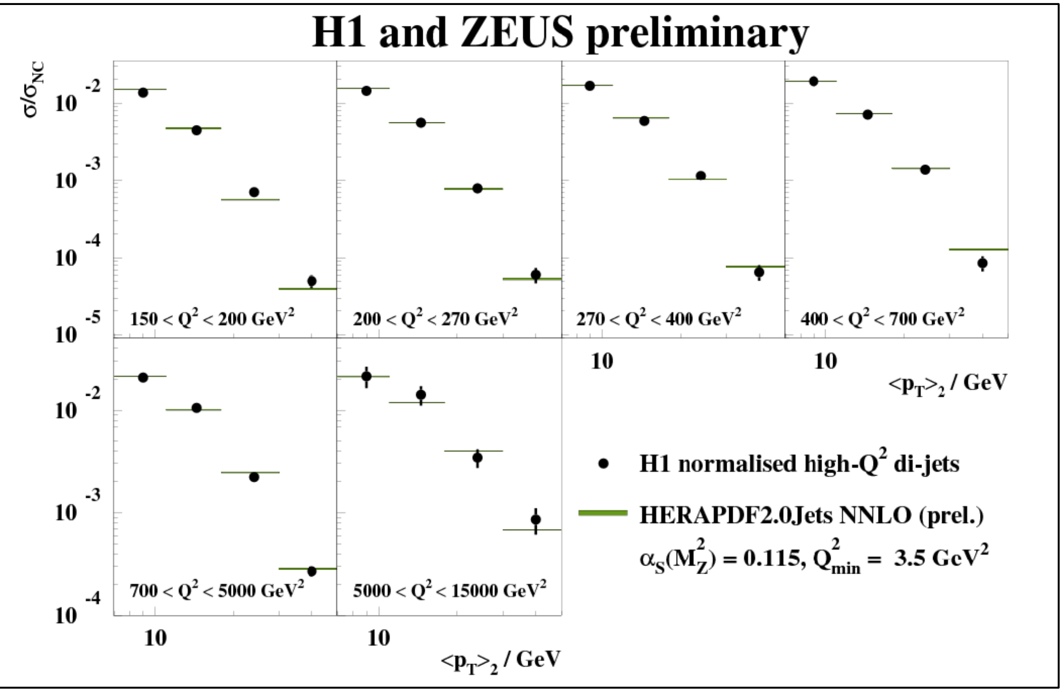
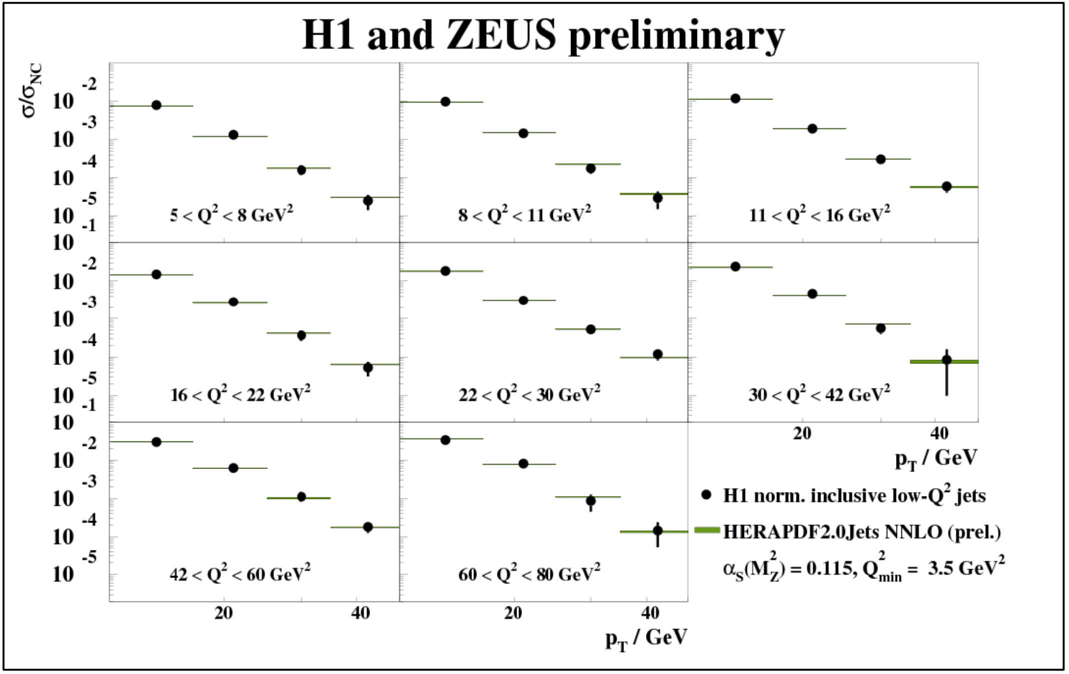


REQUEST Preliminary



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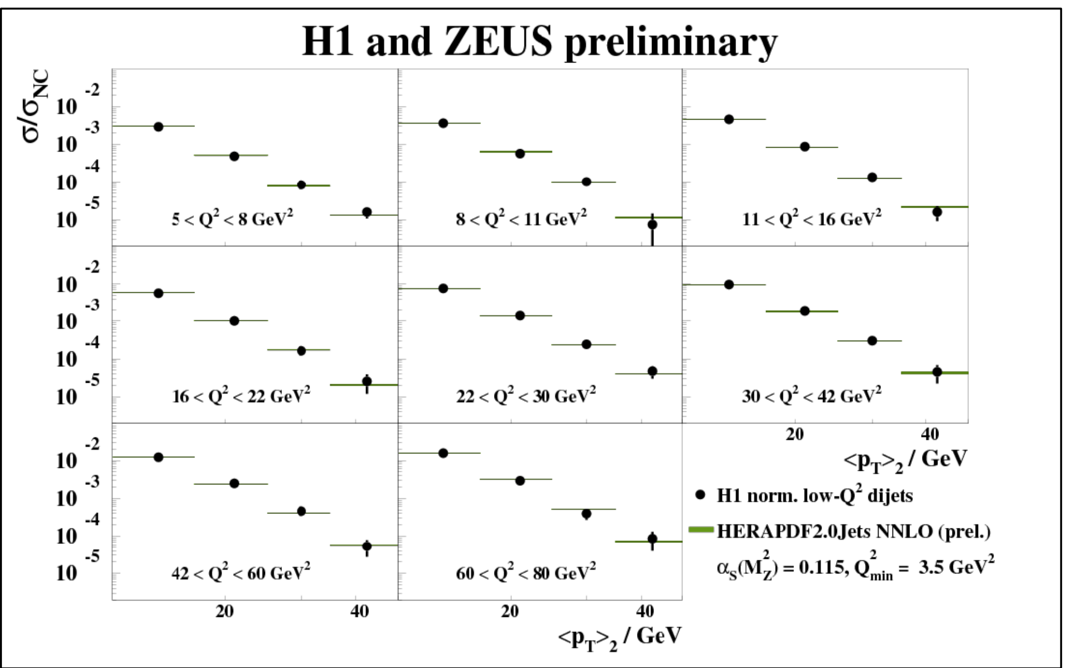
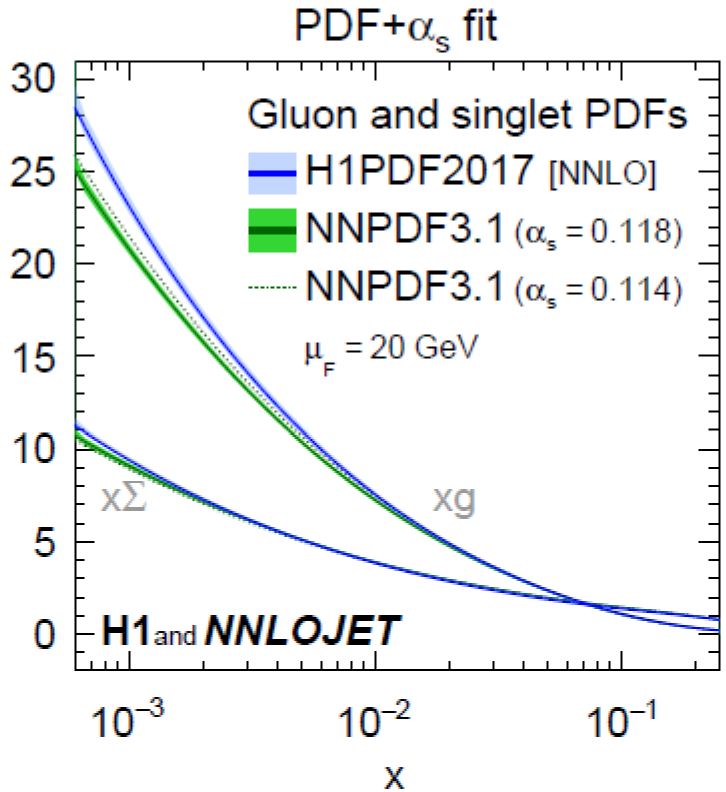


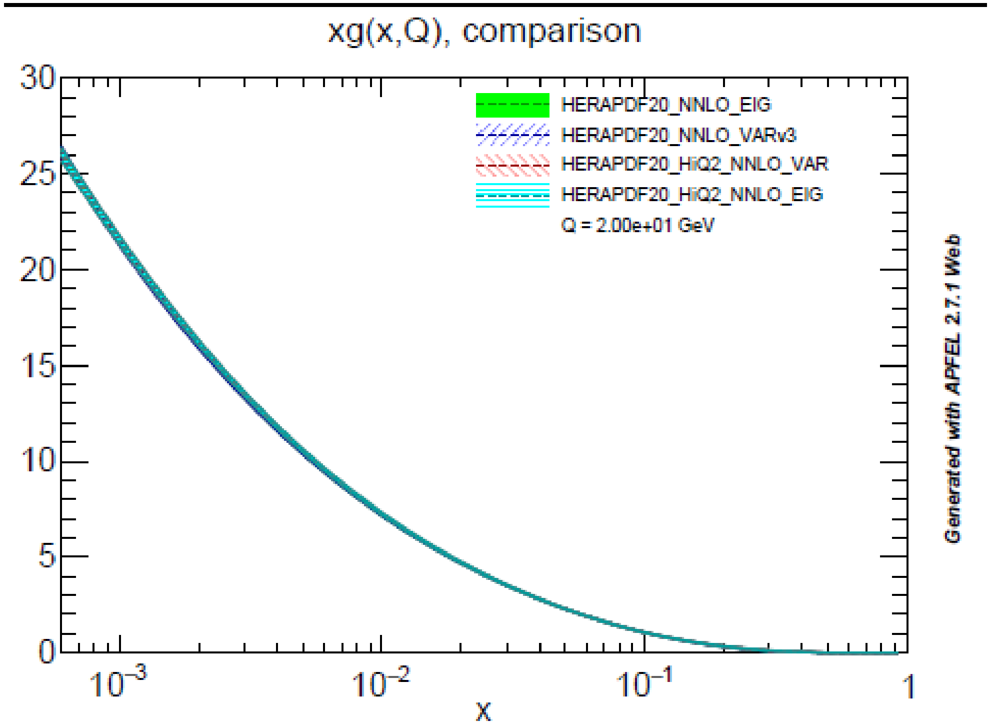
Back up

Short interlude on low-x, low-Q2 issues

But we were also asked to investigate the effect of the low-x, Q2 region on these fits

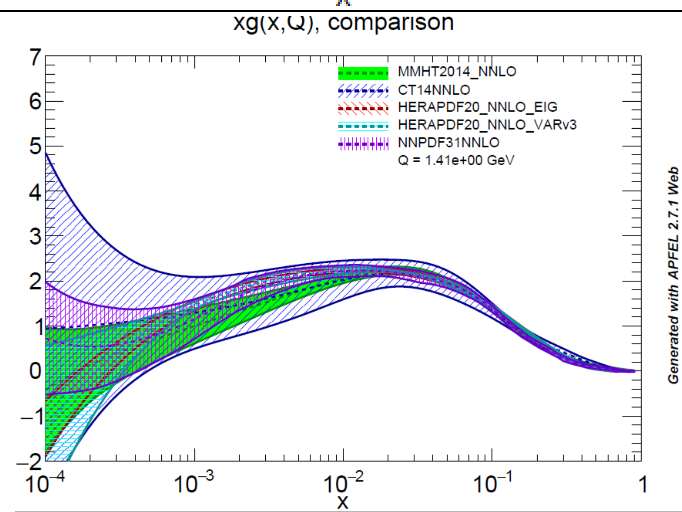
I think this was partly due to a misunderstanding- a perception that the HERAPDF2.0 gluon and the H1PDF gluon are very different- due to a negative gluon term**. But they are not IF you look at the same scale Q2=400**

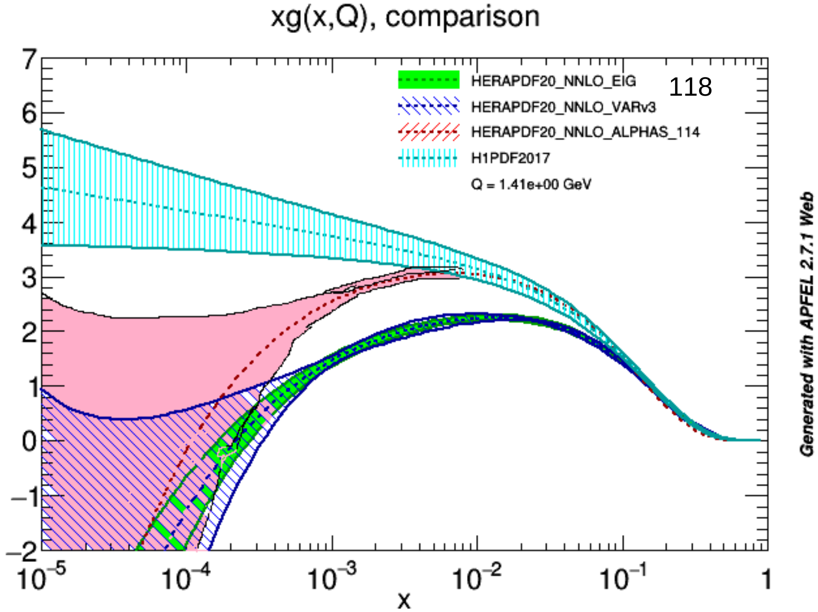




If we look at low scale then the HERAPDF gluon turn over at low x,Q2 is also seen by world PDFs – and note CT14 does not have a negative gluon term. You do not need a negative term for it to turn over it comes from QCD evolution--particularly at NNLO

How fast it turns over at low-x will depend on the value of alphas—all of these are at 0.118





Now compare at $\alpha_s(M_Z)$ =0.114 at low scale

- HERAPDF and H1PDF at $\alpha_s(M_Z)$ =0.114 are hard to compare because there are no uncertainties on the 0.114 HERAPDF2.0 off the shelf
- If we look at the uncertainties for 0.118 we can see them widen out at low-x
- Translate this level of uncertainty to 0.114 (in pink) and we are not so far apart
- WHY are our uncertainties at low-x larger? It is because of the negative term. (It is not because we have no jets) **Indeed this is WHY the negative term was introduced**

$xg(x, Q_0^2) \sim x^{\delta_g}$, i.e. is controlled by a single power. This means that

$$g \pm \Delta g \sim g\,[1 \pm \Delta\delta_g \ln(1/x)], \tag{63}$$

i.e. the uncertainty grows linearly with $\ln(1/x)$ and there is no scope for a rapidly expanding uncertainty as data constraints run out. This is much more of an issue for the gluon than for valence quarks, as the momentum sum rule offers a far less direct constraint than the number sum rules as $x \to 0$. However, there is another complication to consider, namely

$$\Delta g(x, Q_0^2) \sim g(x, Q_0^2)\,\Delta\delta_g \ln(1/x), \tag{64}$$

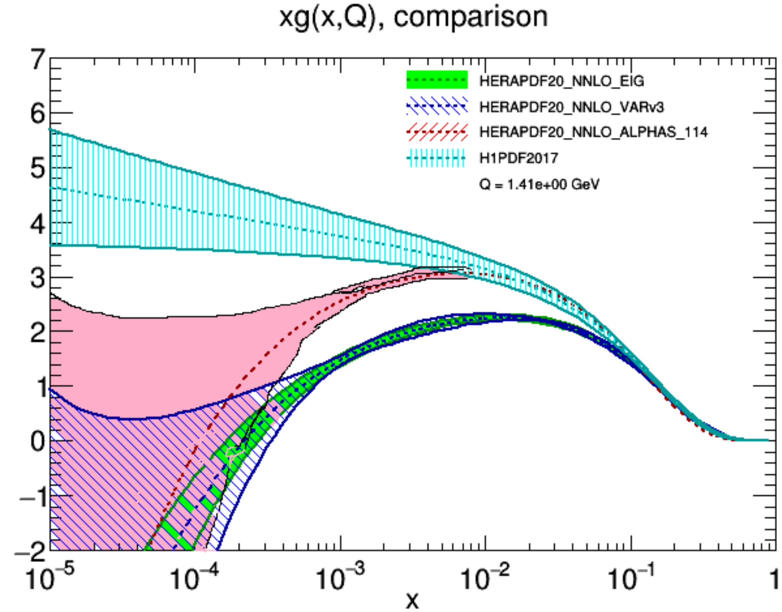
and so as $g(x, Q_0^2)$ becomes smaller then so does $\Delta g(x, Q_0^2)$. If $g(x, Q_0^2)$ is very small, then the absolute input uncertainty for the gluon is very small, and at higher Q^2 the uncertainty is therefore determined entirely by evolution from higher-x, i.e. by the region where the gluon distribution is better determined. Most PDF fitting groups find that $xg(x, Q^2)$ is indeed small at low Q^2 and small x. In this region the MRST (since 2001) and MSTW gluon distributions have the form,

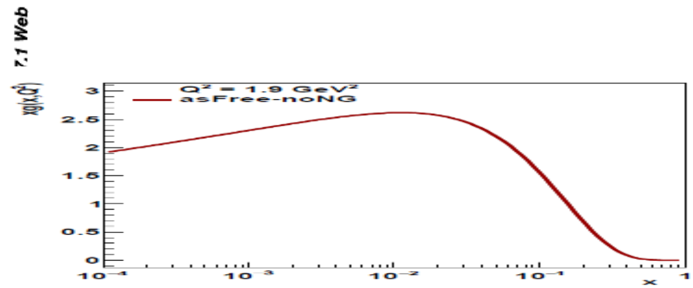
$$xg(x, Q_0^2) = xg_1(x, Q_0^2) + xg_2(x, Q_0^2) \sim A_g x^{\delta_g} + A_{g'} x^{\delta_{g'}}, \tag{65}$$

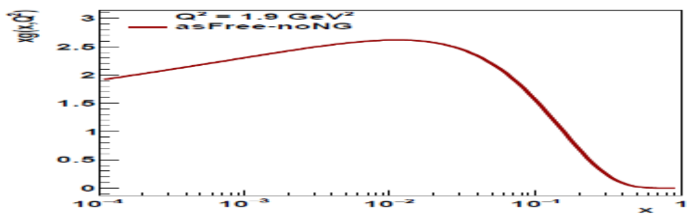
which is more flexible than a single power. Not only does it allow the gluon to become negative at very small x, but it is also particularly important for the uncertainty,

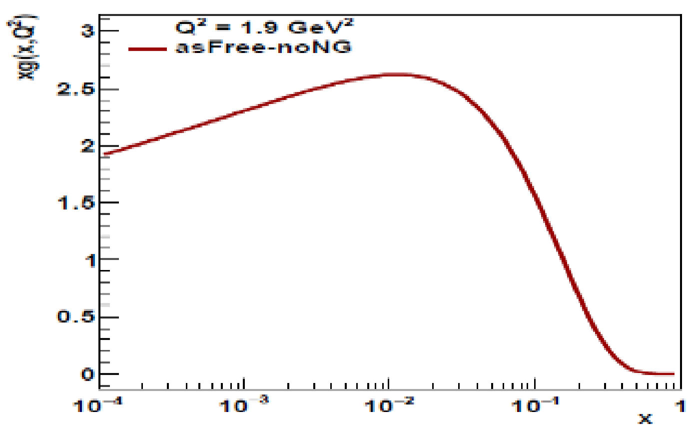
$$\Delta g(x, Q_0^2) \sim \pm g_1(x, Q_0^2)\,\Delta\delta_g \ln(1/x) \pm g_2(x, Q_0^2)\,\Delta\delta_{g'} \ln(1/x), \tag{66}$$

where g_1 and g_2 represent the two independent terms in the gluon parameterisation. The interplay between the two terms allows for a large uncertainty at $x \lesssim 10^{-4}$ where the data constraint, from the Q^2 dependence of $F_2(x, Q^2)$ at HERA, diminishes rapidly.









For further comparison here is the HERAPDF2.0NNLO Jets with no negative gluon term alpha_s=0.1148, free alphas fit

\Without the negative gluon we are even closer to the H1 result and alpha-s remains almost the same as our main result.

Back to the main presentation

We are working to Iris' plan – with a few necessary modifications- we have got as far as point 4

1) keep ALL settings as for HERAPDF2.0
throw the heavy flavour data out for the fit
--> HERAPDF2.5NLO-Jets-only
compare HERAPDF2.0Jets to HERAPDF2.5Jets-only
message: it makes no difference

2) produce the exactly same fit in NNLO --> HERAPDF2.5NNLO-Jets-only
MAJOR MESSAGE:
What does NNLO do?
How does alphas_s change?
Is the scale uncertainty less?

Cannot quite do this because some data/sets and points must be cut

3) add new jet data and produce [with everything else still as HERAPDF2.0]
HERAPDF3.0NLO-Jets-only
HERAPDF3.0NNLO-Jets-only
==> Message: what do low Q^2 jets do.

Also we answer these questions in a slightly different order

4)-- do new mass parameter scans with new HF data and produce
HERAPDF3.5NLO-Jets-only
HERAPDF3.5NNLO-Jets-only
==> message: mass parameters are insignificant at this level

5)-- add the HF data to the fit and produce
HERAPDF3.5NLO-Jets
HERAPDF3.5NNLO-Jets with full error analysis
==> message: using the HF data explicitly doesn't do anything,
but everything is consistent.

ZEUS-dijets There are 22 data points differential in ET and Q2 .
The data points are distributed as 4/4/4/4/3/3 in increasing Q2..and within each group they are ordered in ET.
I report here percentage changes under scale variation for NLO and NNLO—for the largest change, which is μ_R up by factor of two.
Changes are given fractionally so 0.044 means 4.4%

NLO Mur=2
0.044,0.079,0.064,0.03/ 0.019,0.069,0.055,0.026 /
0.0018, 0.056,0.044,0.019/ 0.008,0.04,0.036,0.014/
0.00,0.036,0.016/0.01,0.04,0.022
NNLO Mur=2
0.073,0.05,0.026,0.23/ 0.044,0.027,0.026,0.01/
0.007,0.002,0.03,0.002/0.014,0.028,0.005,0.002/
0.016,0.007,0.012/0.013/0.023,0.017

There is a worrying tendency for the scale variation to be larger at NNLO than at NLO for the first Et bin of each Q2 group. These are the same 6 bins we were asked to cut -on grounds of unreliability- and this seems like a good reason why.
For ALL other bins the scale variation is less at NNLO

old H1 low Q2 inclusive jets data set h109-162.

There are 28 data points grouped as 7 groups of 4, where the 7 groups are of increasing Q2 and the 4 points within each groups are of increasing ET

The scale variations can be large both at NLO (46%) and at NNLO(28%), but are **always** smaller at NNLO. I discuss the large size at NLO as a basis for cuts.

I will present the largest changes- which are for μ_R down by factor of two

NLO Mur=1/2

0.46*,0.31*,0.24,0.17/0.46*,0.29*,0.22,0.17/0.40*,0.27,0.22,0.16/ 0.36*,0.25**,0.21,0.15/0.32**,0.24**,0.20,0.14/ 0.27**,0.21,0.18,0.13 / 0.20**,0.18,0.15, 0.12**

NNLO Mur=1/2

0.28*,0.13*,0.096,0.065 /0.26*,0.13*,0.087, 0.068 /0.23*,0.12,0.086,0.066 / 0.21*,0.11**,0.08, 0.06 /0.19**,0.11**,0.08, 0.06 /0.16**,0.10, 0. 077, 0.056 / 0.12**, 0.09,0.068,0.055/**

Ratio NLO/NNLO

1.64*,2.38*,2.5,2.83/ 1.77*,2.23*,2.52,2.5/ 1.74*, 2.25, 2.56, 2.42/ 1.71*, 2.27**, 2.625, 2.27/1.68**,2.18**,2.5, 2.33/ 1.69**,2.1,2.33,2.32/ 1.66**, 2.0, 2.21, 2.18/**

The * indicates points that we have always- cut even- at NLO using a k-factor criterion
The ** indicates the extra cut from using a kinematic cut μ > 13.5GeV
This cuts NLO scale variations >~24% and NNLO scale variations > ~10%

The **stands for those points that were already cut at NLO because their NLO/LO k-factors are >2.5. This was points 1,2,5,6,9,13.

If we increase this k factor requirement to cutting NLO/LO k-factor >2.2
we would cut **1,2,3,5,6,7,9,10,13,14,17.** This is **step 6.i**

If instead we put a cut on μ = sqrt(ptave^2+Q^2) > 13.5,
We would cut **1,2,5,6,9,10,13,14,17,18,21,25.** This is **step 6.ii**

Or we could chose to cut on large scale variations if we said the NLO scale variation should be less than 24% (and a cut NNLO scale variations of less than 11% gives the same points)
We would cut **1,2,3,5,6,9,10,13,14,17,18,21** This is **step 6.iii**
All of these give very similar results as you have seen

I am of the strong opinion that a kinematic cut is the simplest

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All of these give very similar results as you have seen

I am of the strong opinion that a kinematic cut is the simplest

The only other jet data set which is affected by ANY of these suggested cuts is the new H1 lowQ2 2016 inclusive and dijets which has similar large scale variations at NLO. These come as 48 data points in 8 groups (increasing in Q2) of 6 points (increasing in ET)

I had already suggested the cut μ = sqrt(ptave^2+Q^2) > 13.5 for these data, but one could equally well cut on the size of scale variation—it would hit much the same points just as it does for the older low Q2 data.

H1_lowq2_2016 standard Q^2+pt2/2=mur,Q^2=muf

NLO Mur=1/2

0.47*,0.35*,0.25,0.20,0.15,0.09/ 0.44*,0.33*,0.24,0.18,0.14,0.087/ 0.40*,0.31*,0.23,0.18,0.13,0.08/ 0.36*,0.29*,0.22,0.17,0.13,0.077/ 0.32*,0.26*,0.21,0.17,0.12,0.073 /0.28*,0.24*,0.19,0.15,0.11,0.067/0.23*,0.21*,0.17,0.15,0.11,0.06/ 0.18*,0.18*,0.16,0.14,0.10,0.055

NNLO Mur=1/2

0.31*,0.19*,0.11,0.077,0.052,0.024/ 0.29*,0.18*,0.11,0.076,0.051,0.022/ 0.26*,0.17*,0.09,0.075,0.050,0.026/ 0.24*,0.16*,0.10,0.07,0.05,0.023/ 0.22*,0.14*,0.10,0.075,0.044,0.025 /0.18*,0.13*,0.09,0.07,0.043,0.022/ 0.14*,0.11*,0.094,0.068,0.043,0.022/ 0.13*,0.10*,0.087,0.063,0.047,0.023

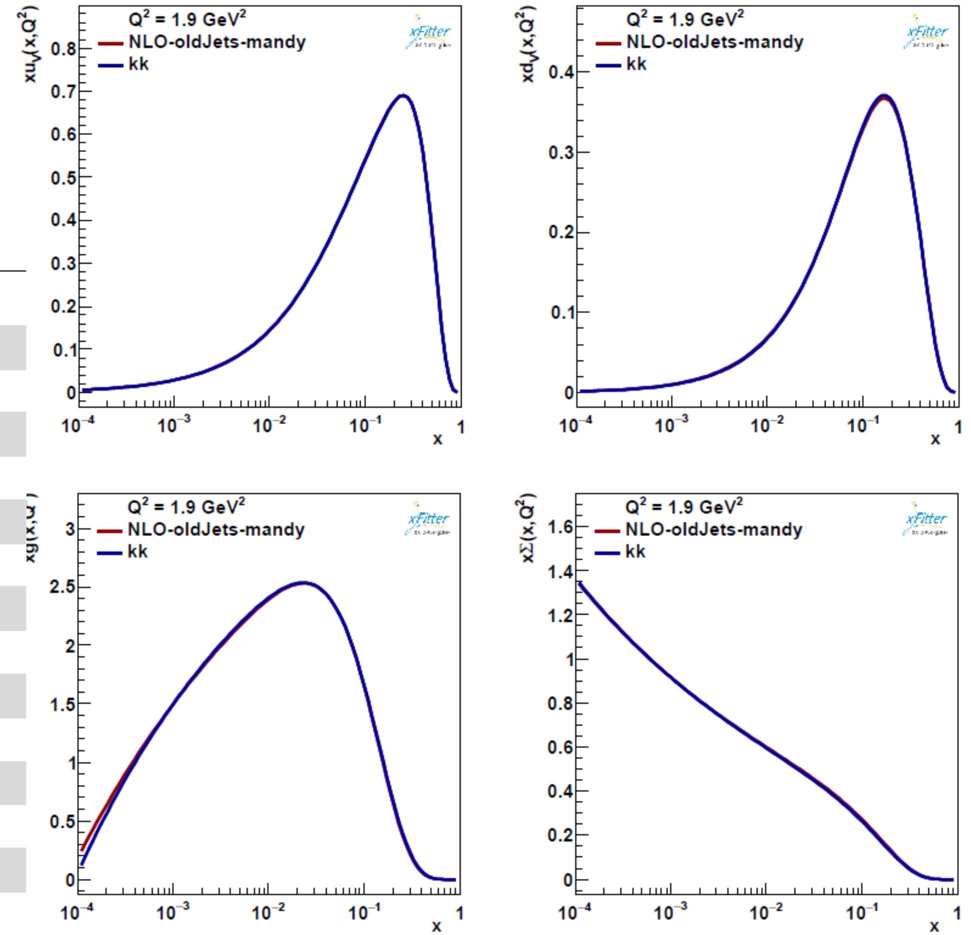
Ratio NLO/NNLO

1.51*,1.84*,2.26,2.6,2.88,3.75/ 1.51*,1.83*,2.18,2.36,2.74, 3.95 /1.54*,1.82*,2.55,2.4,2.6,3.08/ 1.5*,1.81*,2.2,2.42,2.6,3.5/ 1.45*, 1.85*,2.1,2.27,2.72,2.92/ 1.55*,1,85*, 2.1,2.14,2.56,3.05/ 1.64*,1.91*,1.81,2.2,2.56,2.72/ 1.38*,1.8*,1.84,2.22,2.12,2.39

The * indicates points cut by the kinematic cut

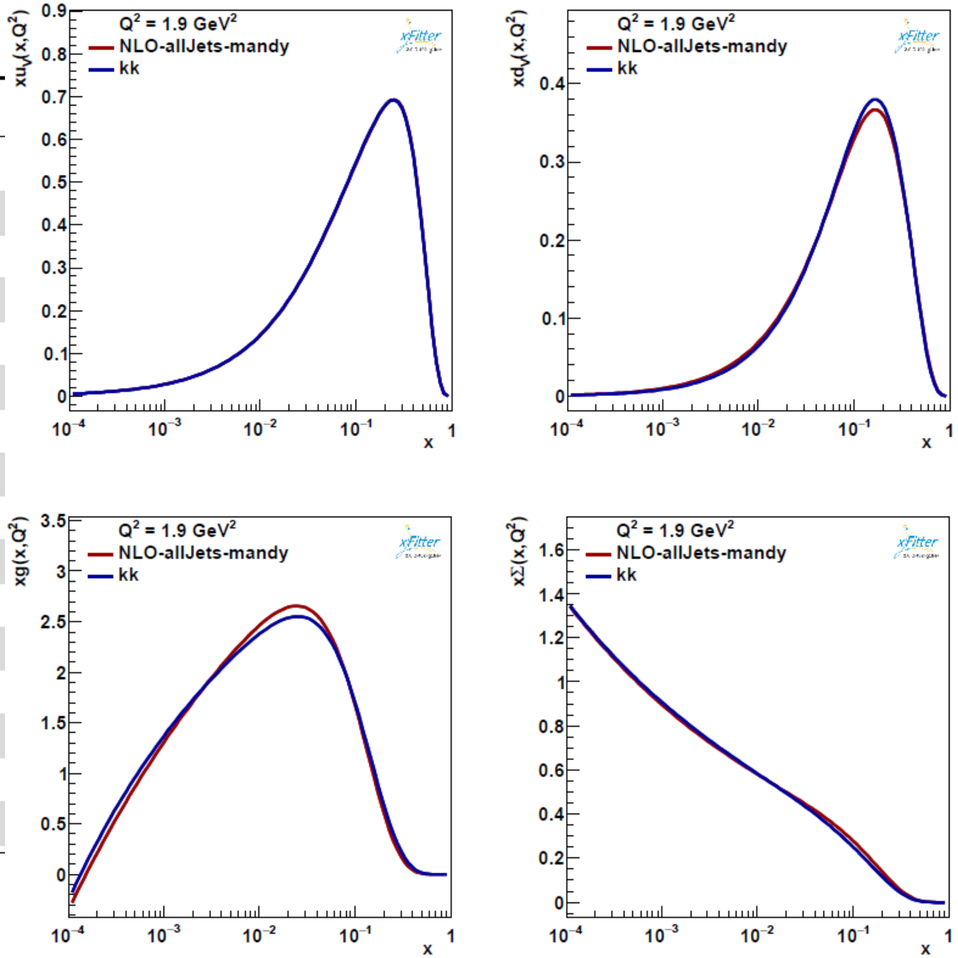
Comparison Katarzyna/me at NLO on final data selection old jets

Parameter	NLO-oldJets-mandy	kk
'Bg'	−0.01 ± 0.16	−0.02 ± 0.17
'Cg'	8.2 ± 1.2	7.89 ± 0.78
'Aprig'	0.9 ± 1.0	0.79 ± 0.81
'Bprig'	−0.172 ± 0.082	−0.191 ± 0.068
'Cprig'	25.00	25.00
'Buv'	0.722 ± 0.038	0.719 ± 0.035
'Cuv'	4.781 ± 0.088	4.817 ± 0.087
'Euv'	12.3 ± 2.3	12.7 ± 2.1
'Bdv'	0.858 ± 0.097	0.873 ± 0.097
'Cdv'	4.26 ± 0.40	4.35 ± 0.41
'CUbar'	7.45 ± 0.84	7.42 ± 0.86
'DUbar'	9.2 ± 3.0	9.4 ± 2.7
'ADbar'	0.176 ± 0.011	0.174 ± 0.011
'BDbar'	−0.1708 ± 0.0072	−0.1726 ± 0.0074
'CDbar'	6.3 ± 1.4	6.9 ± 1.8



Comparison Katarzyna/me at NLO on final data selection old +new jets

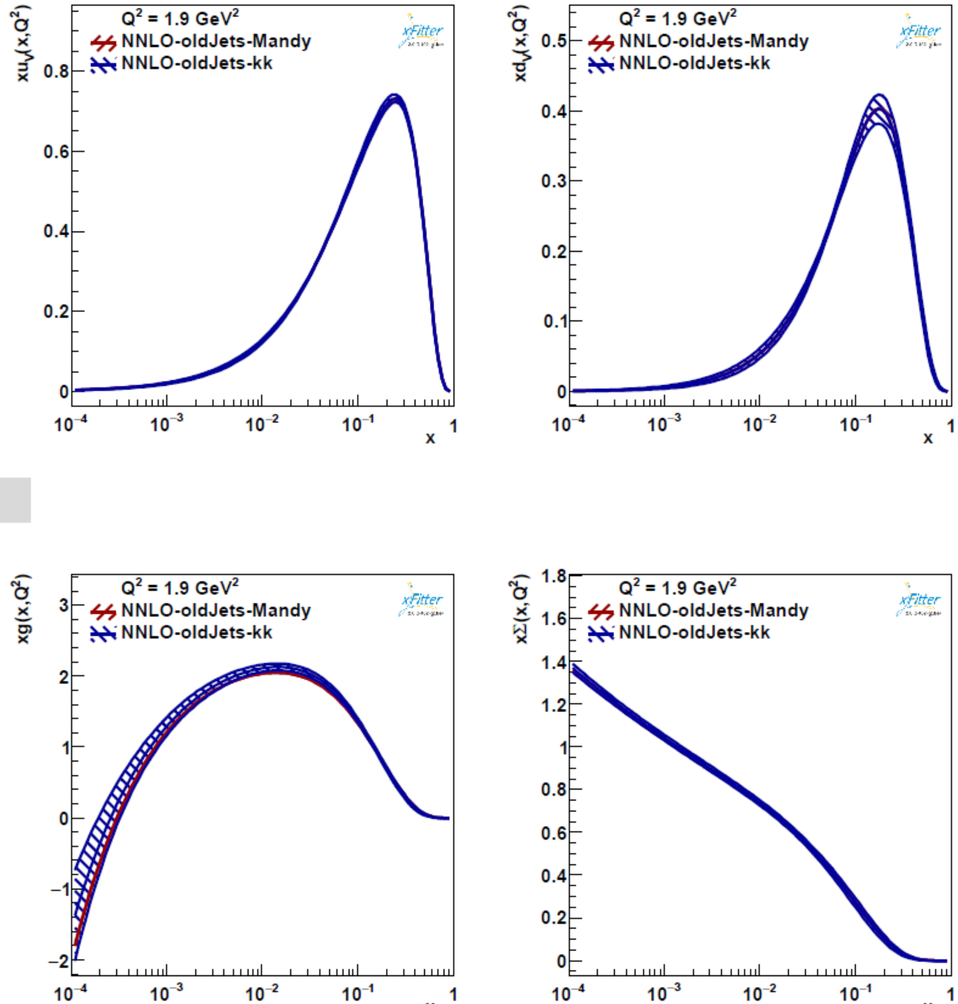
Parameter	NLO-allJets-mandy	kk
'Bg'	−0.00 ± 0.16	−0.04 ± 0.14
'Cg'	9.1 ± 1.2	7.92 ± 0.71
'Aprig'	1.1 ± 1.0	0.97 ± 0.62
'Bprig'	−0.170 ± 0.082	−0.193 ± 0.063
'Cprig'	25.00	25.00
'Buv'	0.730 ± 0.038	0.733 ± 0.032
'Cuv'	4.778 ± 0.088	4.792 ± 0.086
'Euv'	12.0 ± 2.3	11.7 ± 1.8
'Bdv'	0.858 ± 0.097	0.910 ± 0.093
'Cdv'	4.29 ± 0.40	4.54 ± 0.39
'CUbar'	7.95 ± 0.84	7.34 ± 0.91
'DUbar'	12.2 ± 3.0	9.0 ± 2.6
'ADbar'	0.160 ± 0.011	0.1685 ± 0.0094
'BDbar'	−0.1814 ± 0.0072	−0.1762 ± 0.0066
'CDbar'	5.3 ± 1.4	7.3 ± 1.8
'alphas'	0.1180	0.1180



And now some NEW results

Katarzyna and myself agreement at NNLO first for old jets only

Parameter	NNLO-oldJets-Mandy	NNLO-oldJets-kk
'Bg'	−0.097 ± 0.073	−0.076 ± 0.044
'Cg'	5.02 ± 0.54	5.48 ± 0.50
'Aprig'	0.13 ± 0.12	0.142 ± 0.040
'Bprig'	−0.426 ± 0.060	−0.402 ± 0.030
'Cprig'	25.00	25.00
'Buv'	0.802 ± 0.027	0.811 ± 0.029
'Cuv'	4.812 ± 0.083	4.851 ± 0.084
'Euv'	10.3 ± 1.4	10.3 ± 1.5
'Bdv'	0.998 ± 0.091	0.996 ± 0.088
'Cdv'	4.65 ± 0.39	4.67 ± 0.39
'CUbar'	6.7 ± 1.8	7.2 ± 1.3
'DUbar'	1.7 ± 2.5	1.4 ± 1.5
'ADbar'	0.285 ± 0.012	0.287 ± 0.012
'BDbar'	−0.1196 ± 0.0051	−0.1200 ± 0.0052
'CDbar'	9.2 ± 1.5	8.8 ± 1.5
[illegible]	[illegible]	[illegible]



Some remarks on chisq
Numbers are partial chisq plus relevant part of correlated chisq

	NNLO		NLO	no of pts
H1 norm jets old	24.3	||	18.4	24
H1 lowQ2 old	12.0	||	13.5	16
ZEUS inclusive	30.0	||	29.5	30
ZEUS dijets	22.9	||	18.7	16

All these jets have similar NLO and NNLO chisq

H1 2013 highQ2 inclusive				
H1 2013 highQ2 dijets	90.8	||	70.4	48

The h1 high Q2 jets have larger NNLO chisq

H1 2016 lowQ2 inclusive				
H1 2016 lowQ2 dijets	58.8	||	141.8	64

But the h1 low Q2 jets have smaller NNLO chisq

As already presented in previous H1/ZEUS meetings these figures are broadly in agreement with the findings of the H1 jet studies

As an aside the hadronisation systematic uncertainty—which is ONLY used for the new 2016 jets (it was offset in the past) ---contributes a much larger amount to the NLO correlated chisq than it does to the NNLO correlated chisq

For NNLO alphas free and old+new jets

Parameter	asFree-NNLO-allJets-scales	asFree-NNLO-allJets
'Bg'	−0.109 ± 0.013	−0.087 ± 0.012
'Cg'	6.37 ± 0.16	6.16 ± 0.14
'Aprig'	0.117 ± 0.021	0.128 ± 0.014
'Bprig'	−0.443 ± 0.031	−0.422 ± 0.021
'Cprig'	25.00	25.00
'Buv'	0.7606 ± 0.0081	0.7815 ± 0.0063
'Cuv'	4.919 ± 0.040	4.889 ± 0.033
'Euv'	10.76 ± 0.42	10.39 ± 0.32
'Bdv'	0.988 ± 0.032	1.002 ± 0.026
'Cdv'	4.99 ± 0.17	4.92 ± 0.14
'CUbar'	7.30 ± 0.27	7.32 ± [illegible]
'DUbar'	2.75 ± 0.45	2.39 ± [illegible]
'ADbar'	0.2744 ± 0.0052	0.2731 [illegible]
'BDbar'	−0.1234 ± 0.0025	−0.12[illegible]
'CDbar'	11.38 ± 1.00	10.43 ± 0.74
'alphas'	0.11328 ± 0.00058	0.11505 ± 0.00056

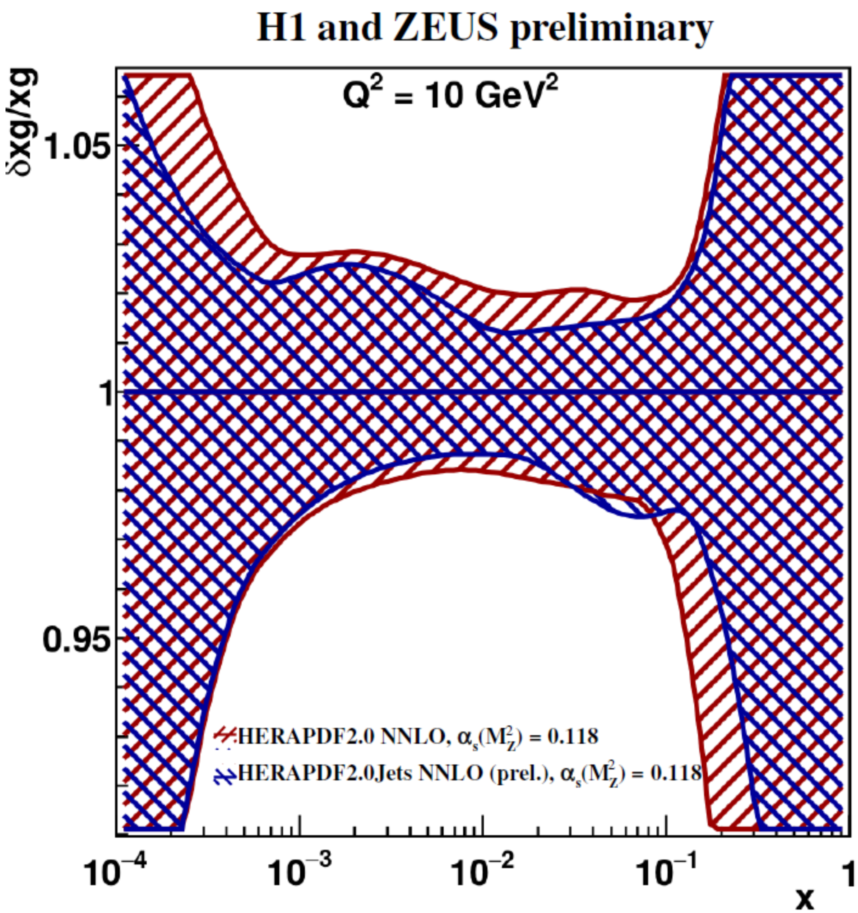
	Old Scale choice (Q2+pt2)/2	Our scale choice Q2+pt2

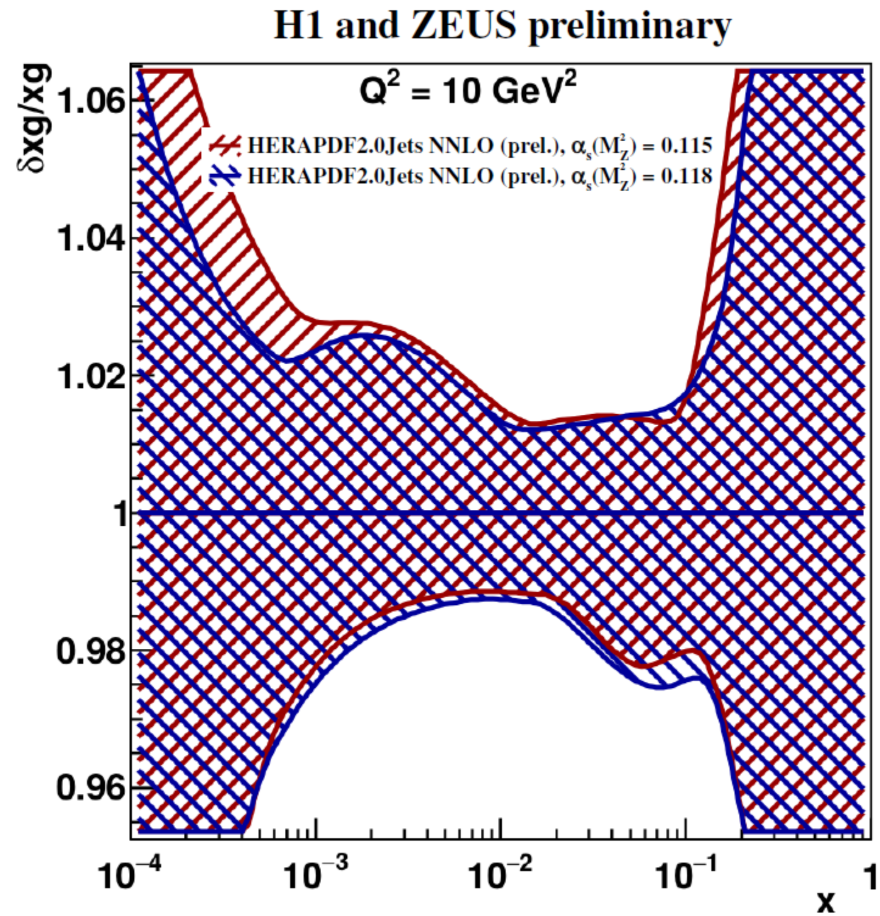
OLD results not fully checked

For NLO alphas free and old+new jets

Parameter	NLO-allJets-asFree-testScales	NLO-nominal-scales
'Bg'	0.009 ± 0.025	0.019 ± 0.025
'Cg'	7.97 ± 0.35	7.30 ± 0.34
'Aprig'	0.78 ± 0.13	1.14 ± 0.15
'Bprig'	−0.184 ± 0.020	−0.139 ± 0.017
'Cprig'	25.00	25.00
'Buv'	0.726 ± 0.016	0.775 ± 0.016
'Cuv'	4.798 ± 0.061	4.698 ± 0.061
'Euv'	13.41 ± 0.96	11.77 ± 0.87
'Bdv'	0.799 ± 0.053	0.852 ± 0.055
'Cdv'	3.98 ± 0.26	4.08 ± 0.26
[illegible]	[illegible] 0.46	7.50 ± 0.52
[illegible]	[illegible] 1.4	8.8 ± 1.4
[illegible]	[illegible] ± 0.0061	0.1656 ± 0.0060
[illegible]	[illegible]5 ± 0.0045	−0.1842 ± 0.0045
'CDbar'	4.16 ± 0.69	3.76 ± 0.63
'alphas'	0.12056 ± 0.00067	0.12390 ± 0.00065

	Old Scale choice (Q2+pt2)/2	Our scale choice Q2+pt2


H1 and ZEUS preliminary
Q^2 = 10 GeV^2
δxg/xg
1.05
1
0.95
HERAPDF2.0 NNLO, αs(M_Z^2) = 0.118
HERAPDF2.0Jets NNLO (prel.), αs(M_Z^2) = 0.118
10^-4
10^-3
10^-2
10^-1
1
x


H1 and ZEUS preliminary
Q^2 = 10 GeV^2
δxg/xg
HERAPDF2.0Jets NNLO (prel.), αs(M_Z^2) = 0.115
HERAPDF2.0Jets NNLO (prel.), αs(M_Z^2) = 0.118
1.06
1.04
1.02
1
0.98
0.96
10^-4
10^-3
10^-2
10^-1
1
x

But if you want to see what
an alpha_s free fit looks like
then it looks like this