HERAPDF2.0 NNLOJets

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H1/ZEUS November 2019

- Reminder of DIS2019 result, decisions on data sets, cuts, scale and further checks
- Account for new c, b combination – new values of optimal pole masses for RTVFN obtained at NNLO with $\alpha_S(M_Z)$ =0.115 (within old uncertainties)
- **NOT including c,b data in fit**
- Final recheck of parametrisation with new settings, mb,mc, $\alpha_S(M_Z)$ =0.115 and jet data
- Repeat $\alpha_S(M_Z)$ free fits obtaining 01151 compatible to what we had for DIS2019 no need to iterate mc,mb, param
- Decisions on treatment of Q20 and mc in model variations

- Redo $\alpha_S(M_Z)$ =0.115 and =0.118 fixed fits with all model/param uncertainties
- Redo $\alpha_S(M_Z)$ free fit with model/param/hadronization/scale uncertainties

- Do we re visit the NLO Jets fit with new settings for mc, mb and new jets- h1 lowQ2 2016 jets?
- My proposal is NO: the mc,mb have not changed significantly
- the lowQ2 2016 jets are BADLY fitted at NLO, they NEED NNLO
-

REMINDER The HERAPDF2.0NLOjets contains

ZEUS di-jets = 22 --cut to 16 for new NNLO fit
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 needed 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 Q^2 jets $\mu = \sqrt{(ptave^2+Q^2)} > 13.5$ GeV
And the removal of 6 points from ZEUS dijets for which NNLO predictions are unreliable
on the basis of large scale variations both at NLO and NNLO

This work established that **scale variations** of predictions for a fixed set of PDF parameters are **MUCH smaller at NNLO.**
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

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

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

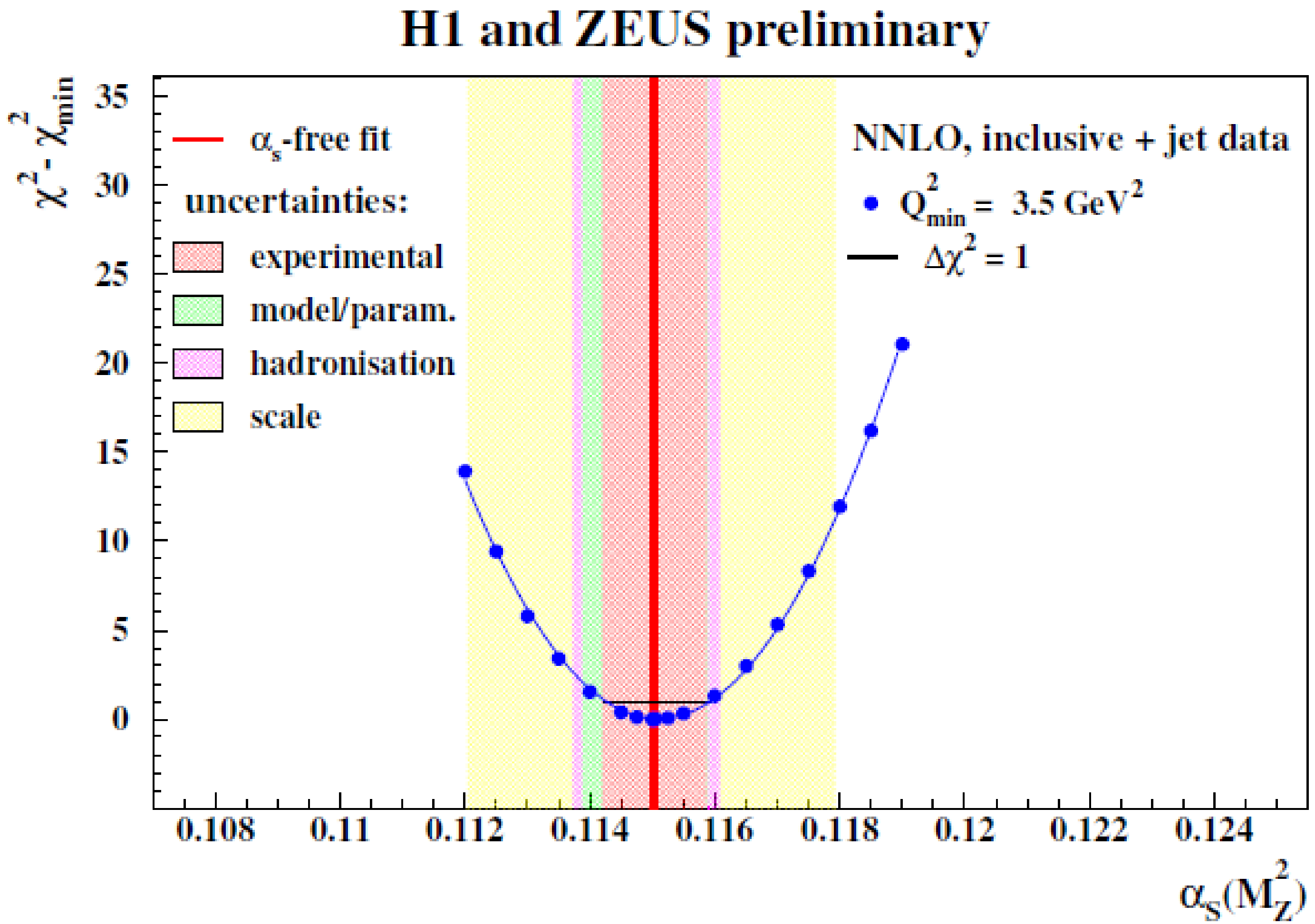
In fact the 'optimal' scale choice for NLO and NNLO is different – if optimal means lower chisq. (NLO has lower chisq $\Delta\chi 2\sim -15$ for the old scale choice)
Since we are concentrating on NNLO we will use
Renormalisation= Q^2 +pt^2,
Factorisation=Q^2+pt^2
(in practice using Q^2 or Q^2+pt^2 for high Q^2 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 lowQ^2 jets have some systematic correlations to the older 2013 high Q^2 jets– this does not change things much **but it is done**
- There is an extra low pt bin for the high Q^2 set, which was published along with the newer low Q^2 set. We chose not to use this.
- All statistical correlation matrices for 2013 and 2016 H1 jets are used by default

The result for alphas

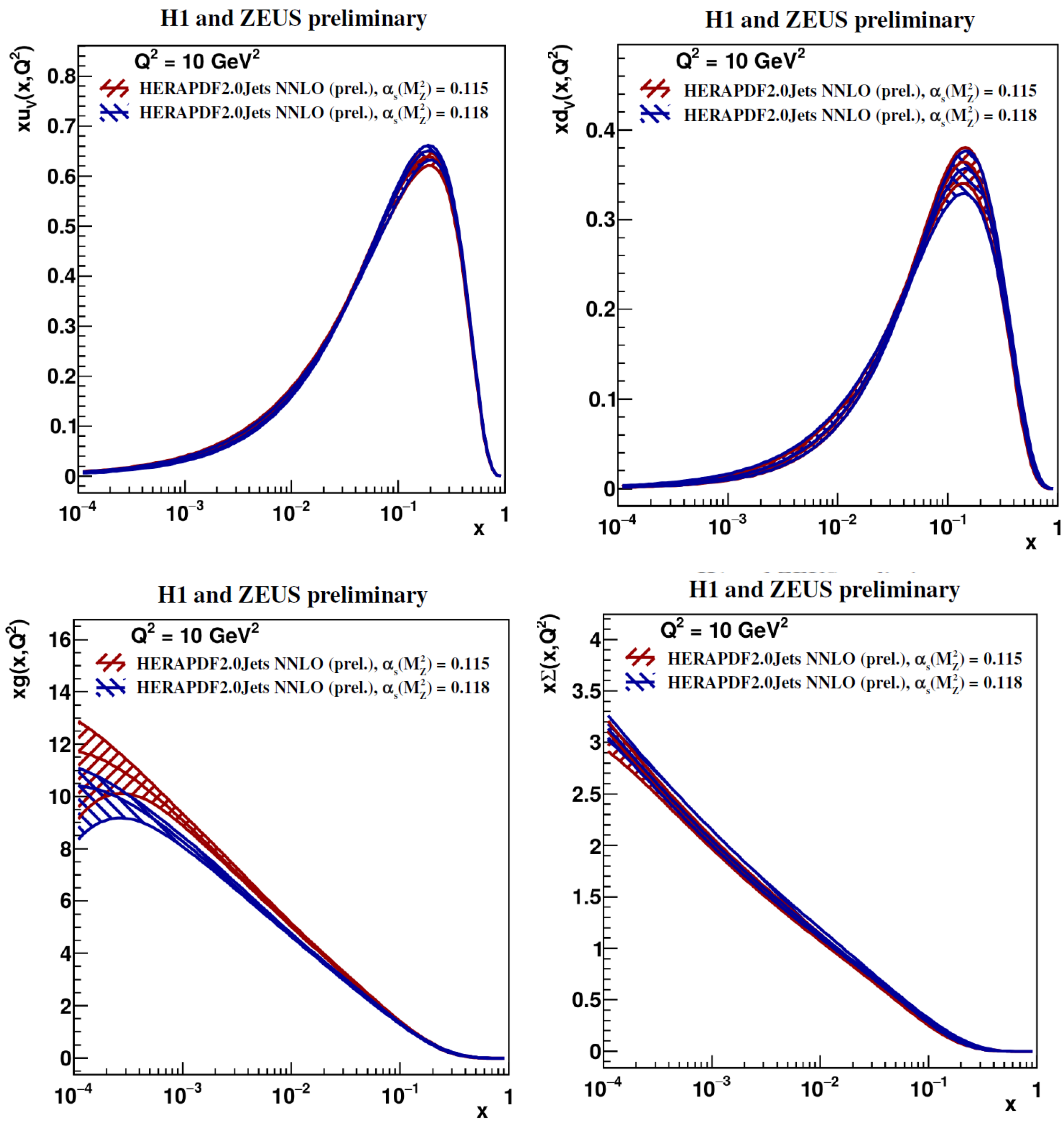
- Free $\alpha_s(M_Z)$ fit at NNLO

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

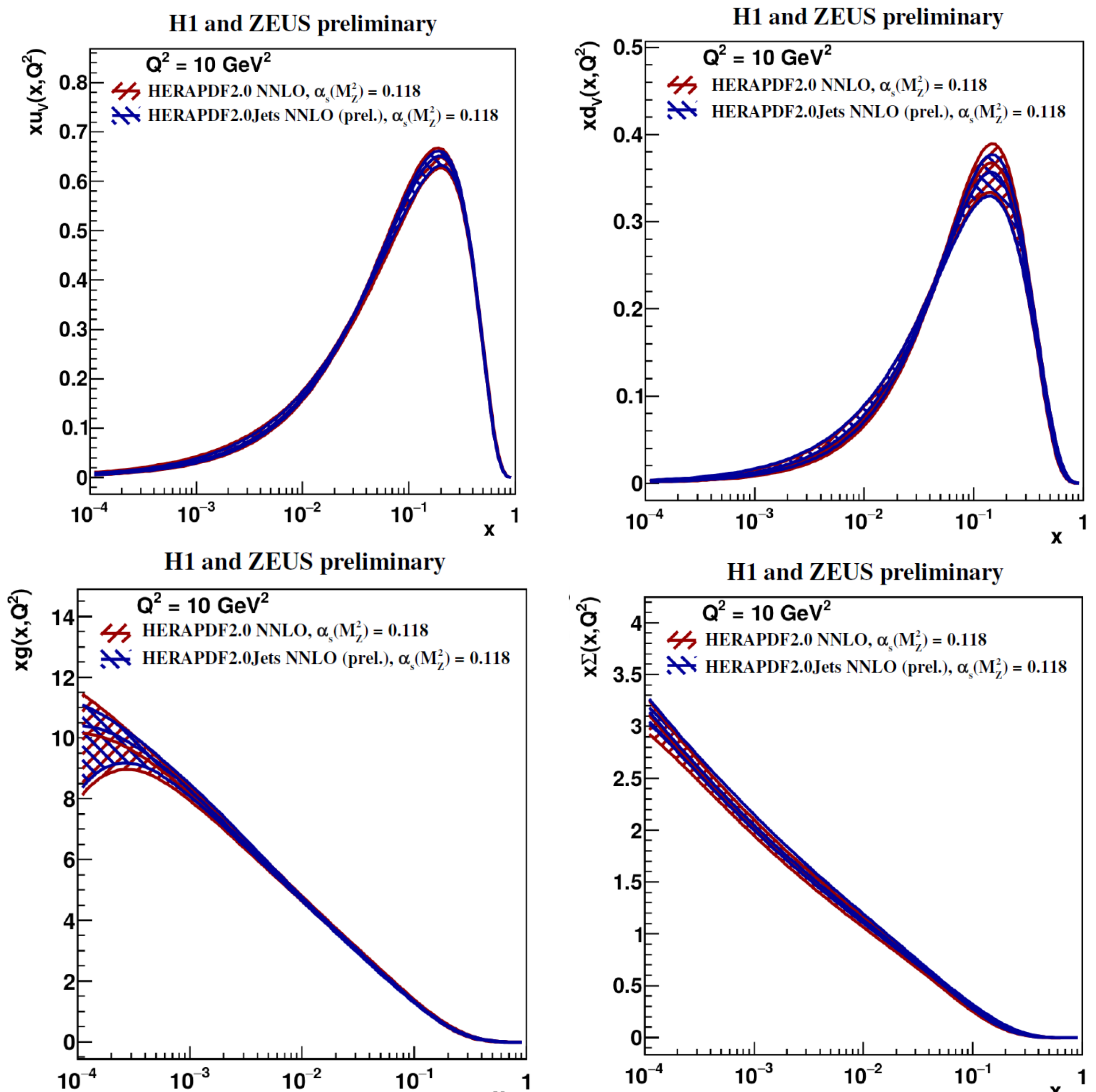


The result for the PDFs for

$\alpha_s(M_Z)$ =0.115 and
$\alpha_s(M_Z)$ =0.118



And compare HERAPDF2.0 NNLO and HERAPDF2.0Jets NNLO both with $\alpha_s(M_Z)$ =0.118



Let’s size of the experimental error on alphas caused some discussion

$\alpha_s(M_Z) = 0.1150 \pm 0.0008$ $Q^2>3.5$ GeV^2

How much comes from H1 and ZEUS separately?

$\alpha_s(M_Z) = 0.1149 \pm 0.0017$ $Q^2>3.5$ GeV^2 **ZEUS**

$\alpha_s(M_Z) = 0.1148 \pm 0.0009$ $Q^2>3.5$ GeV^2 **H1**

Daniel was worried that the H1 result is more accurate than the results issued by H1 themselves BUT the cuts used on the data are not the same
He proposed use $Q^2>10$ GeV^2 and use common cuts on μ ($=\sqrt{(pt^2 + Q^2)}$) >13.5 GeV)

In fact we had already done this in part of our studies and we obtained:

$\alpha_s(M_Z) = 0.1144 \pm 0.0010$ $Q^2>10$ GeV^2 if the cut is made only on inclusive data

$\alpha_s(M_Z) = 0.1140 \pm 0.0011$ $Q^2>10$ GeV^2 if the cut is also made on the low Q2 normalised jet data

This size of experimental error already seems much closer to that of the H1 study

A further issue arose concerning normalised jets:
the γ/Z, ZZ and xF3 terms were not used in the NNLO jet predictions for the numerators, hence they also should not be used for the denominators for consistency.
This is a very small effect but has been checked.

One more change to note: I was given 'official grids'from Ploughshare, with higher statistics –these give *slightly* lower overall chisq mostly from H1 HERA-II high Q2 jets—PDFs not significantly changed

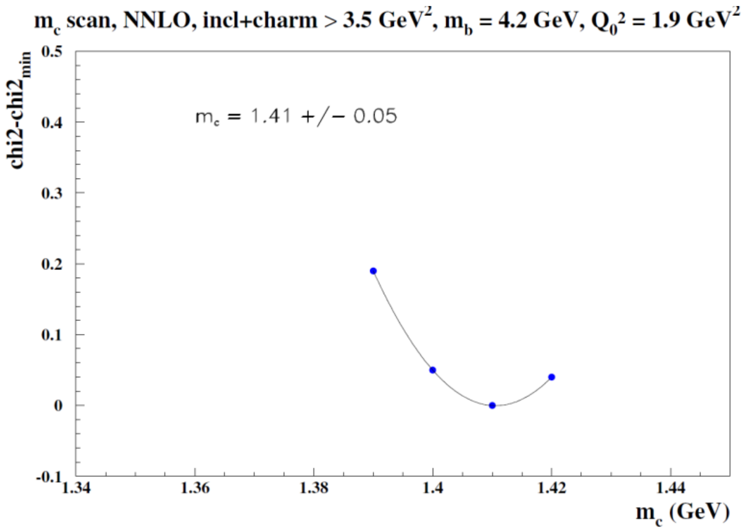
Remove the hadronization uncertainty from H1 HERA-II low Q2 jets so that it can be consistently offset as with other data sets—again no significant change

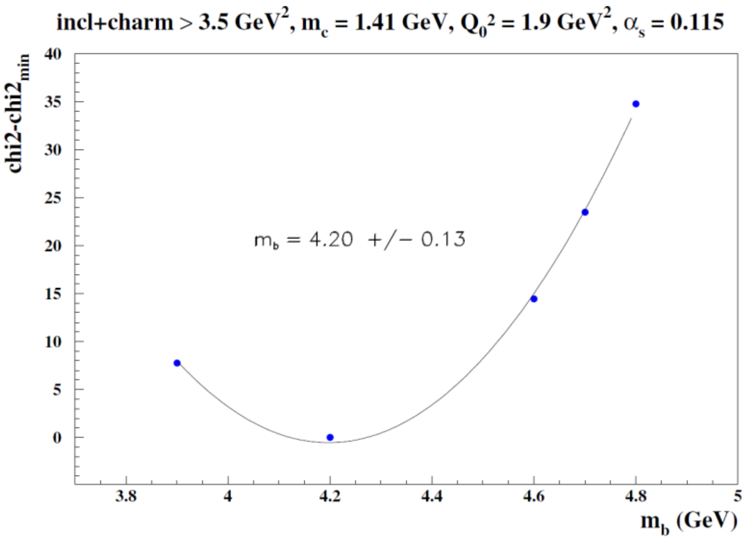
Now on with the plan

The next stage is to consider the **NEW combined charm and beauty data**

First how it may affect the optimal charm and beauty masses

THEN adding these data into the fit– NO we are no longer doing that treatment of heavy flavour is not consistently NNLO—anyway it makes rather little difference

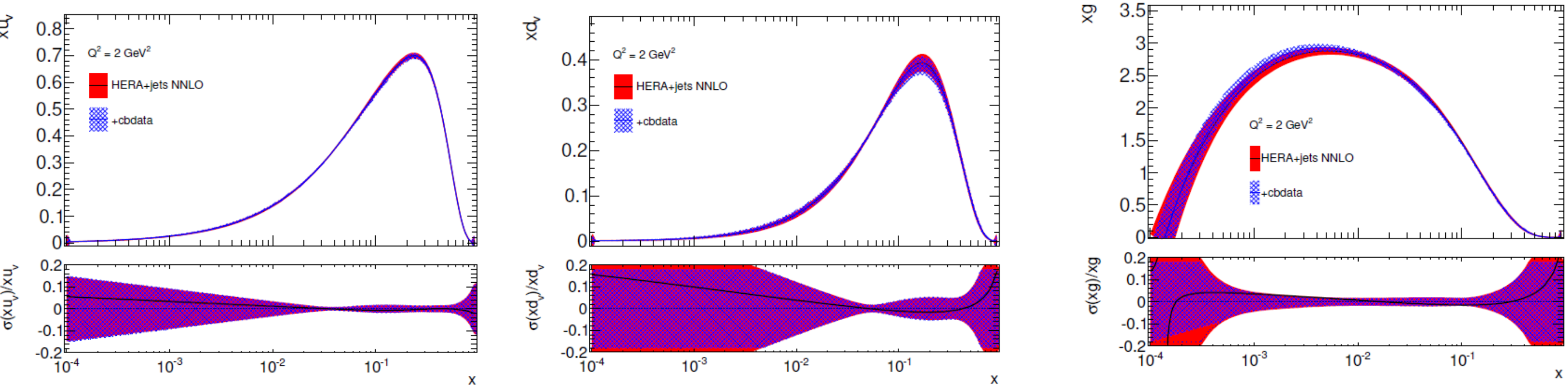


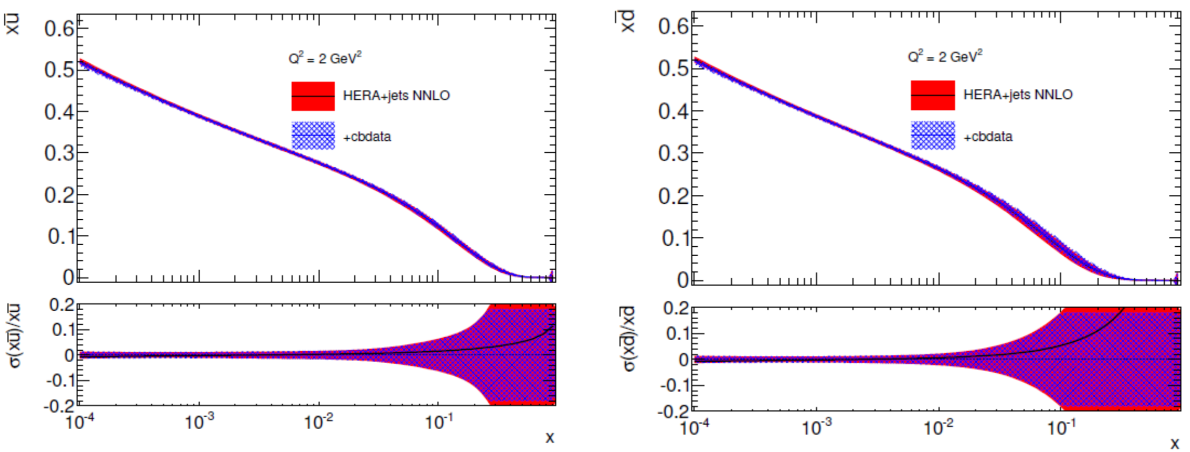


New mc,mb scans with $\alpha_S(M_Z)$ =0.115

- Then refit for $\alpha_S(M_Z)$ using these new mb, mc value – 0.115 still favoured
- Then re-check parametrisation scan with new mc,mb, $\alpha_S(M_Z)$ =0.115 AND jet data added—after all there are 198 jet data points
- Previous parametrisation confirmed
- **Hence no further iterations needed**

JUST for the record: we show the difference in PDFs with /without charm and beauty data





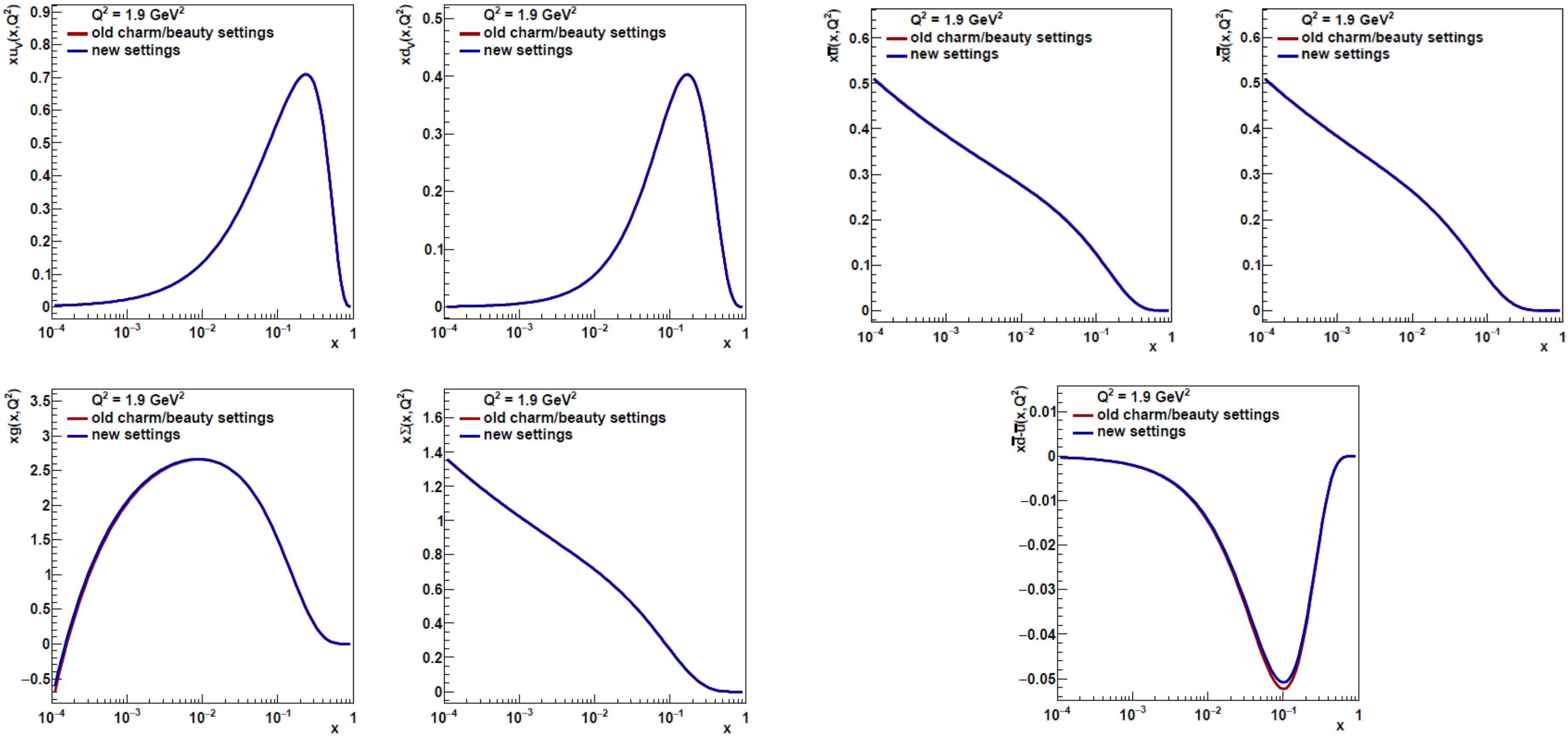
Only the gluon shows a visible but small difference

Note these two fits both have $\alpha_S(M_Z)$ =0.115

Message:

- Adding charm and beauty data has small effect on gluon
- Fits to data in back-up--- very similar to those from charm/beauty data paper

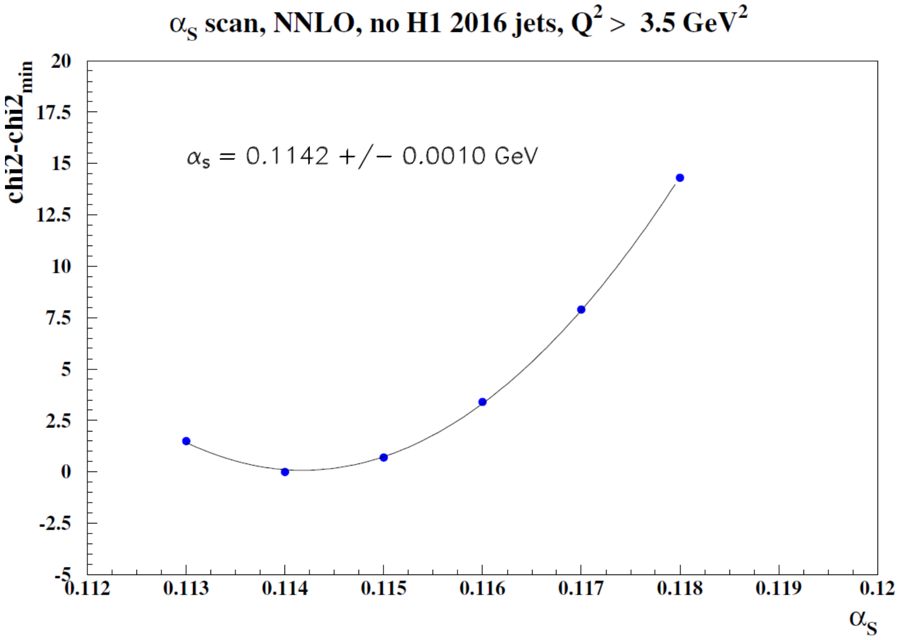
Compare PDFs fit to inclusive +jets at NNLO with new/old values of mc,mb settings.

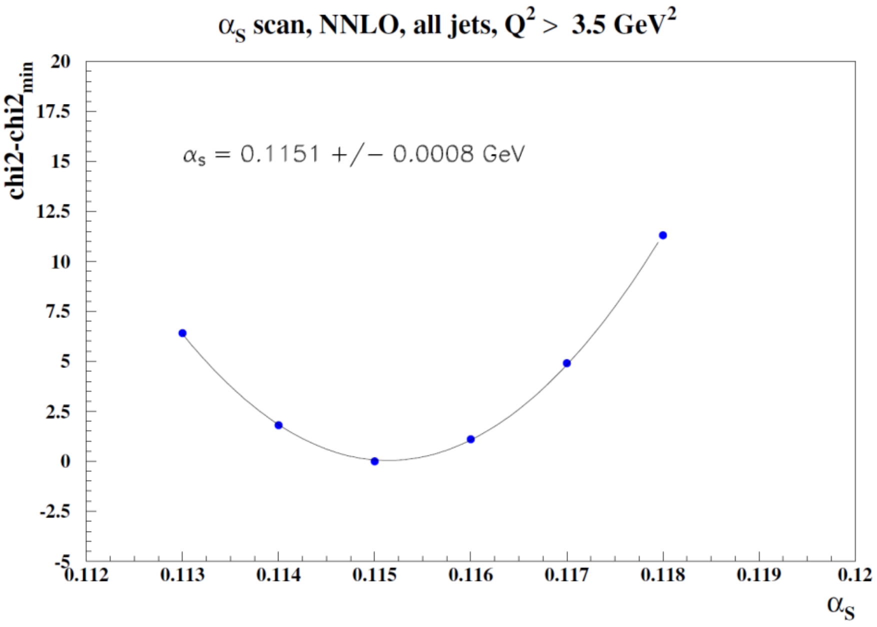


Message:

- New settings have negligible effect on PDFs

Now redo the $\alpha_S(M_Z)$ scan with the new settings

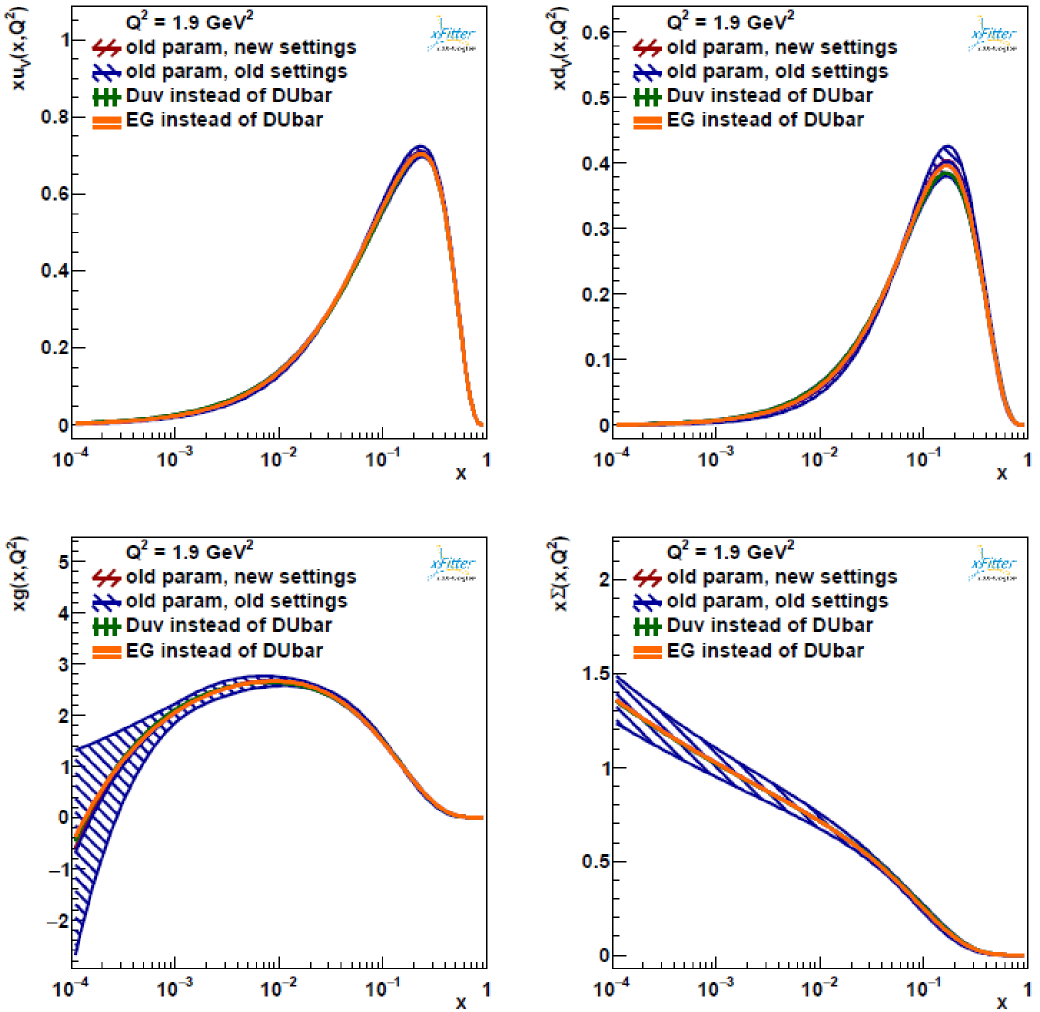




We obtain the same value as before- good- we will do all the work of evaluating the final Model/param/hadronisation/scale uncertainties once this meeting agrees our policy

This confirms $\alpha_S(M_Z)$ =0.115 is the favoured value and so we stick with the DIS19 procedure to show PDFs at $\alpha_S(M_Z)$ =0.115 and $\alpha_S(M_Z)$ =0.118 (the PDG value)

NOTE in passing that with/without new H1 low Q^2 jets we get compatible values



Parametrisation scan…

follows the same path until the choice of the 14th parameter where Dubar, Duv and Eg all give almost the same χ2

However, all these parameter values are small and consistent with zero within 1σ, hence PDFs very similar. Thus we stick with Dubar—the usual parametrisation

Addition of 15th parameter(s) does not improve chisq further and will thus be used only for the parametrisaton uncertainties

Some remarks on model/param uncertainties

We vary mc (model) and Q^2_0 (param) but these two are coupled since we require $Q^2_0 < mc^2$

With Q^2_0=1.9 GeV^2 and mc=1.41, mc^2=1.9881 GeV^2 central choices this is fine

Q^2_0 down to 1.6 GeV^2 variation is fine

Q^2_0 up variation up to 2.2 GeV ^{2} is not fine – we USED to combine this with the upper variation of mc BUT the new value of mc and its uncertainty make the upper variation of mc=1.46, mc^2=2.1316..so this will not work. (Older values were mc=1.43 central, 1.49 upper limit, which did work.)

Propose vary Q^2_0 down ONLY and symmetrise

Mc up variation to mc=1.45, mc^2=2.1025 is fine

Mc down variation is now down to mc=1.37, mc^2=1.8769 is NOT FINE

Propose vary Mc up ONLY and symmetrise

These proposals were circulated in July and agreed by all those who replied.

Ever onward

Next steps proposed:

- Now do all model/parametrisation study for fixed $\alpha_S(M_Z)$ =0.115 and 0.118 NNLO jobs, as suggested on the previous page
- Then do all model/parametrisation study for free alphas NNLO jobs adding hadronisation –by offset--and scale variations- by the usual ½ correlated and ½ uncorrelated procedure that we used before
- THEN WE are finished at NNLO

Now we did think that we MIGHT also:

- Redo the NLO jet fits with new settings: mc,mb, scale, including H1 2016 jets and refit for NLO alphas
- Then do all model/parametrisation/hadronisation/scale study for free alphas NLO jobs keeping track of correlations of all variations to the NNLO, so we can evaluate $\Delta\alpha_S$
- Possibly also redo fixed alphas NLO with all new settings

But I now think we should NOT revisit the NLO fit in such detail—WHY?

Because H1 2016 low Q^2 jets are NOT well fitted at NLO.

I think they should not be used at NLO- and if we do not use them there is little change with the new mc,mb,scale—it is all within previous uncertainties

At most we could quote the $\alpha_S(M_Z)$ value =0.121 with the new scale, for the old analysis for comparison, in fact we already did so in our public talks.

no H1 2016 jets **H1 2016 jets** → 64 extra data points

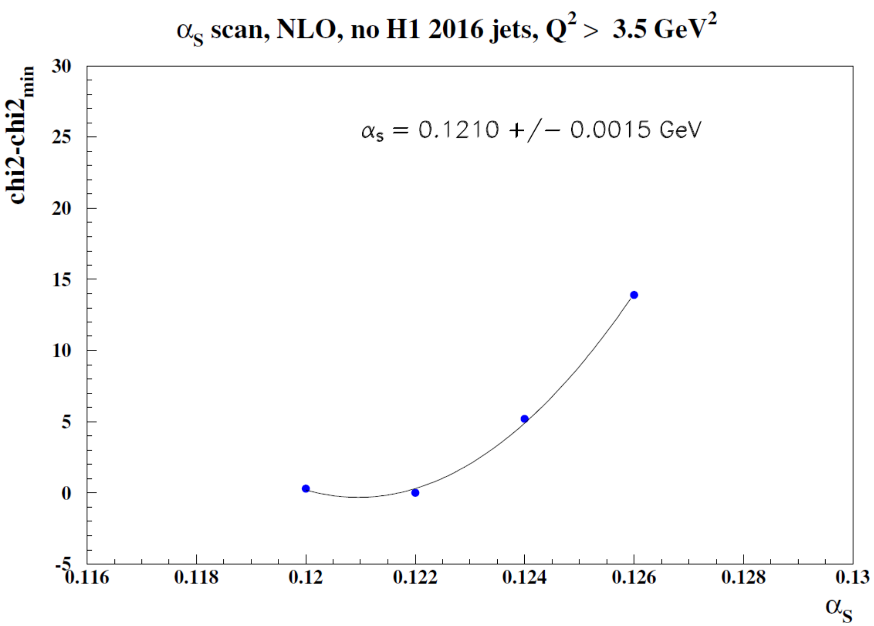
NLO $\alpha_S(M_Z)$ =0.118 χ2 = 1517 χ2 =1696 →+179 χ2

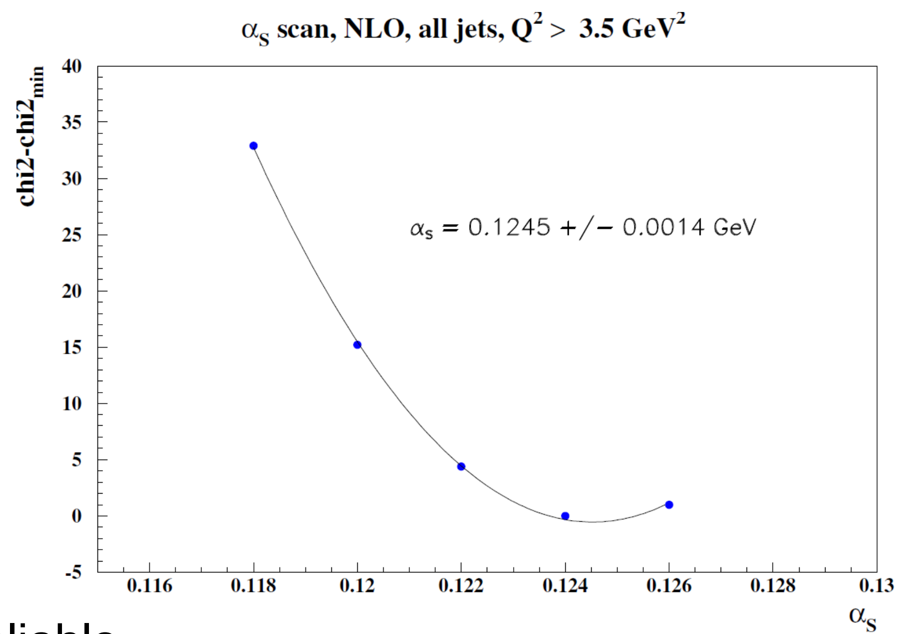
NLO $\alpha_S(M_Z)$ free χ2 = 1510, $\alpha_S(M_Z)$ =0.121 χ2 =1663, $\alpha_S(M_Z)$ =0.1245 →+153 χ2

NLO $\alpha_S(M_Z)$ =0.118 χ2 = 1502 χ2 =1684 →+182 χ2
Old scale

Compare NNLO

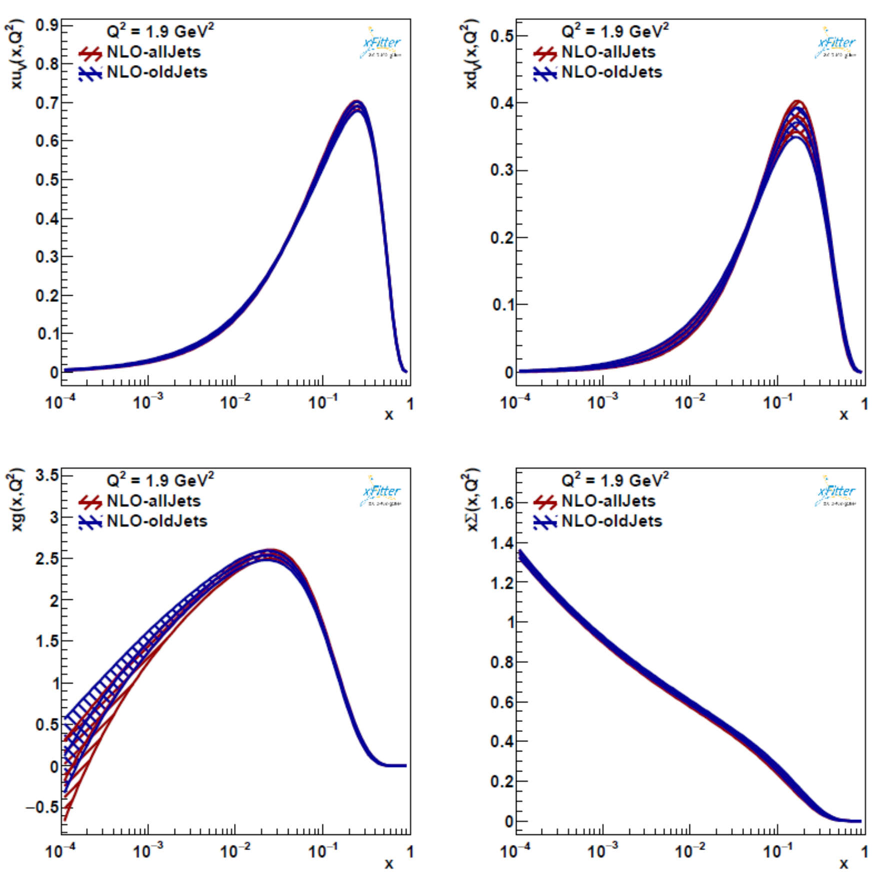
NNLO $\alpha_S(M_Z)$ =0.115 χ2 =1525 χ2 =1599 →+ 74 χ2

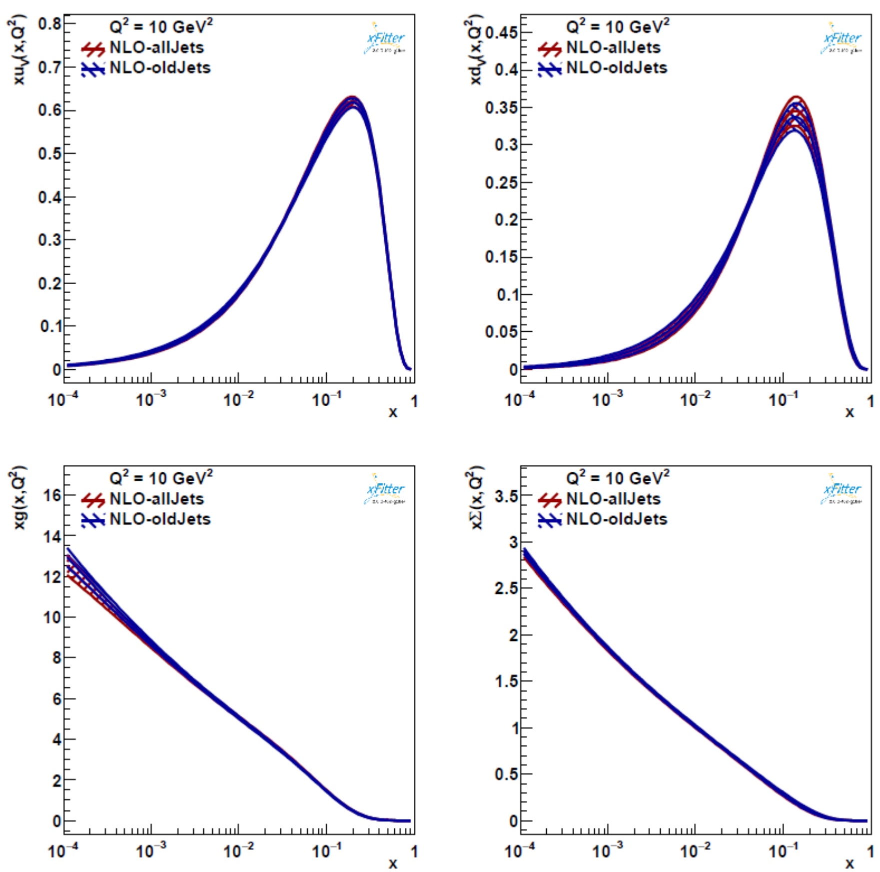


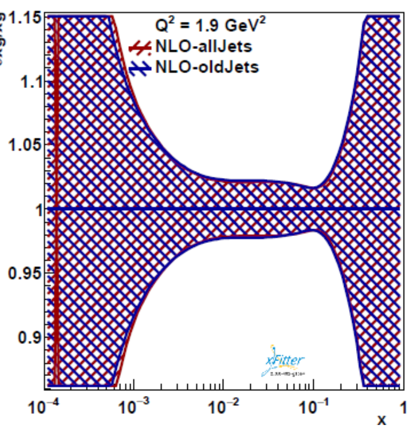


Hence I think this change in $\alpha_S(M_Z)$ is unreliable

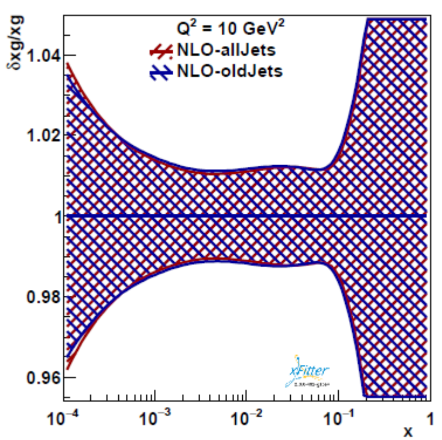
But with fixed alphas there is no advantage: What do new jets do? NLO







The answer is: not a lot when $\alpha_S(M_Z)$ is fixed



SUMMARY

- Finish the NNLO analysis much in the way that the DIS19 preliminary was done but with new mc,mb settings accounting for the new c,b data
- Using the same data sets, same cuts, same scale choice, same parametrisation
- $\alpha_S(M_Z)$ =0.115
- $\alpha_S(M_Z)$ =0.118
- Free alphas
- All model parametrisation uncertainties treated as agreed
- Hadronisation by offset consistently
- Scale uncertainty ½ correlated , ½ uncorrelated as for HERAPDF2.0NLOJets

- Do not revisit NLO other than to say that the current scale choice would have resulted in $\alpha_S(M_Z)$ =0.121 rather than 0.118
- Maybe also say not revisiting it because the most significant new data set—H1 low Q2 jets 2016 is not well fitted at NLO

Back-up

Back-up about cuts

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

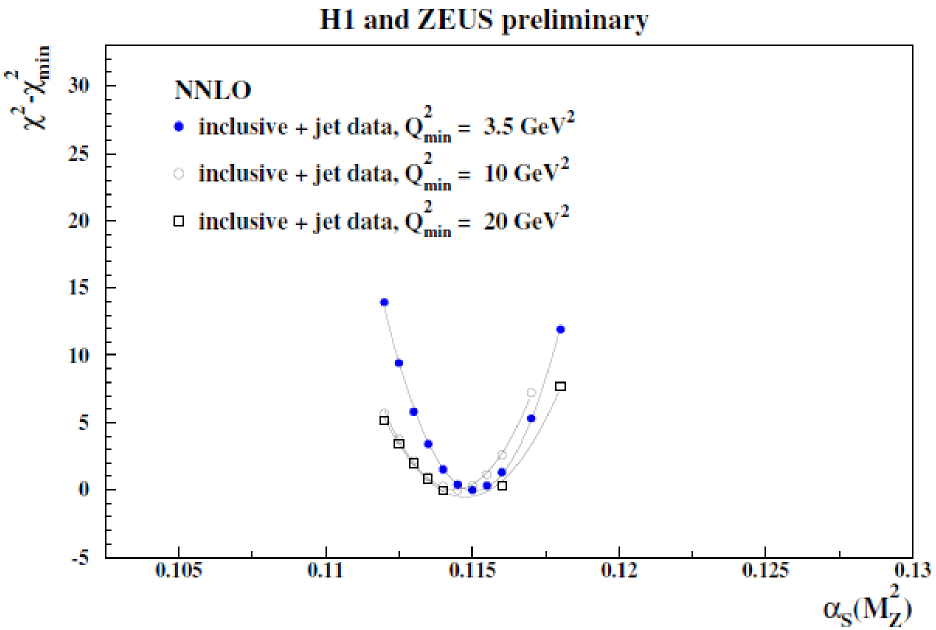
The three criteria above cut much the same points
The kinematic cut is simplest
This cuts NLO scale variations >~24% and NNLO scale variations > ~10%

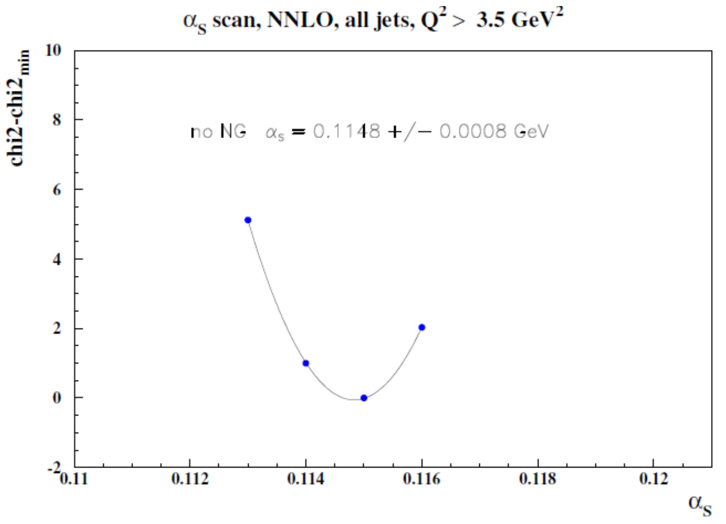
Back-up on checks

Since it is well known that HERA data at low x and Q^2 may be subject to the need for ln(1/x) resummation or higher twist effects we also perform scans with Q^2 cuts

The Q2 cuts do not result in any significant change to the value of $\alpha_s(M_Z)$ that is determined

We also did a check—not made public on the effect of the negative gluon term





The central values from the three scans are:

$\alpha_s(M_Z) = 0.1150 \pm 0.0008$ Q^2>3.5 GeV^2

$\alpha_s(M_Z) = 0.1144 \pm 0.0010$ Q^2>10 GeV^2

$\alpha_s(M_Z) = 0.1148 \pm 0.0010$ Q^2>20 GeV^2

With no negative gluon term

$\alpha_s(M_Z) = 0.1148 \pm 0.0008$

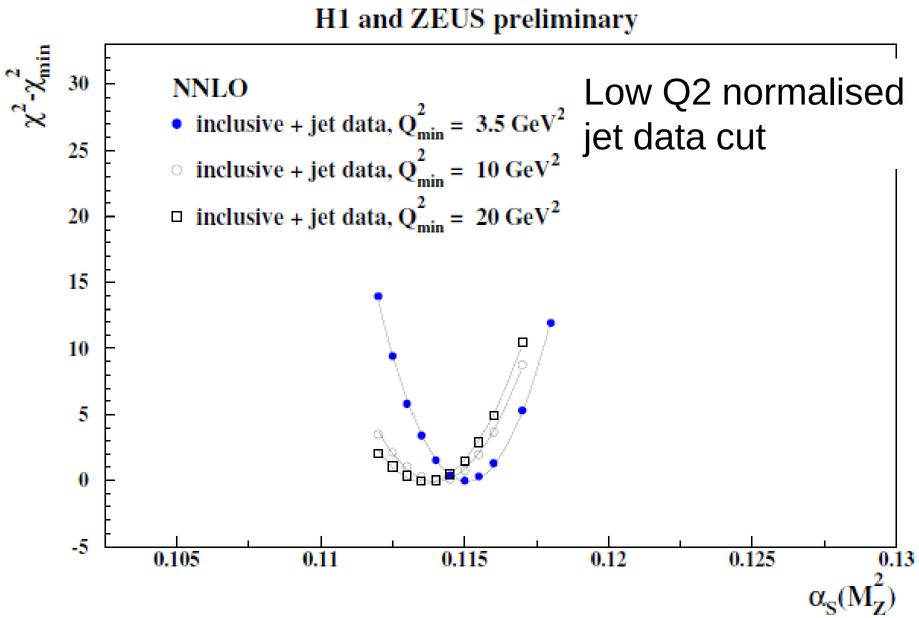
Compatible with standard result

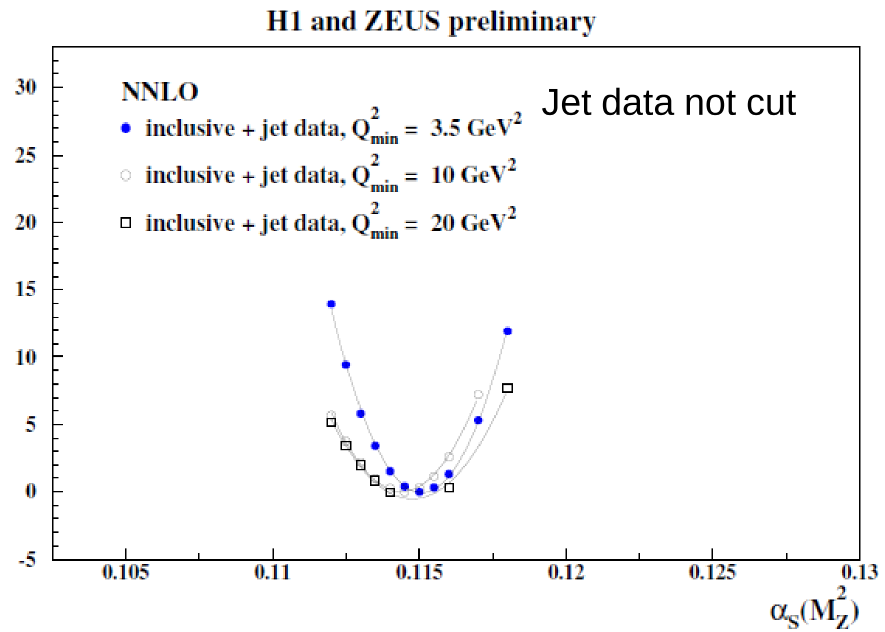
Back-up on checks

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

compare back to not doing it





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

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

Back-up on checks

Daniel also suggested looking at only H1 data and making two fits with the $Q^2 > 10\ GeV^2$ cut on both inclusive and normalised jet data

H1-HERA-I only:

H1 HERA-I high-Q2 norm. incl. jets

H1 HERA-I low-Q2 abs. incl. jets

---for this we get $\alpha_s(M_Z) = 0.1181 \pm 0.0021$

+ H1-HERA-II only:

H1 HERA-II high-Q2 norm. incl. jets

H1 HERA-II high-Q2 norm. dijets

H1 HERA-II low-Q2 norm incl. jets

H1 HERA-II low-Q2 norm. dijets

-----for this we get $\alpha_s(M_Z) = 0.1131 \pm 0.0012$

Daniel said he would run his programme for these cuts and data selection.
Hopefully we have a reasonable agreement.
This has not been done—but I don't think its very important
We have similar uncertainty values when we use similar cuts already.

JUST for the record
here are the χ2 for an NNLO fit with inclusive+jets+charm and beauty, as=0.115

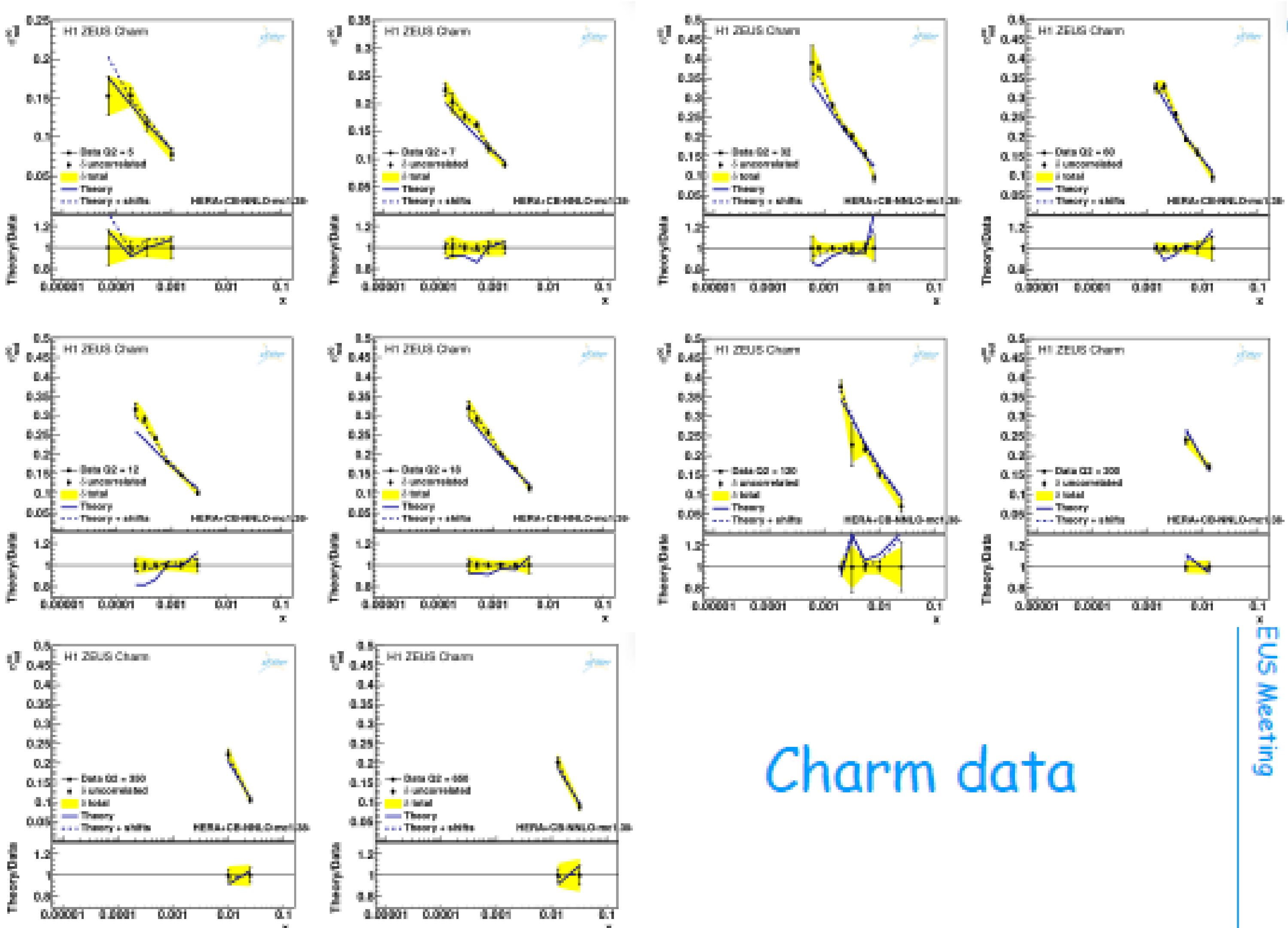
sumsqhinc= 91.9
sumsqhjet= 20.2
sumsqcb= 46.95
X/N CCEP = 39 46.13
X/N CCEM = 42 53.45
X/N NCEP 920= 377 454.27
X/N NCEP 820= 70 64.47
X/N NCEM= 159 221.13
X/N NCEP 460 = 204 215.0
X/N NCEP 575 = 254 218.93
ZEUS di-jets = 16 15.15
ZEUS inc 96/97 = 30 30.65
H1norm highQ2 99/00 = 24 15.81
H1 low-Q2 = 16 18.02
H1 HERA2 highq2 incl = 24 22.5
H1 HERA2 highq2 dijet = 24 39.0
H1 HERA2 lowq2 incl = 32 48.02
H1 HERA2 lowq2 dijet = 32 24.10
newsigcharm = 47 43.7
newsigbeauty = 27 22.4

The charm/beauty χ2 are similar to those when jet data is not included
The jet χ2 are similar to those when charm/beauty data are not included
The inclusive χ2 are similar to those when neither of these data sets are included

There is no tension

This is just for the record
We carry ON with inclusive+jet data only and new settings of mc,mb

NNLO



Charm data

EUS Meeting

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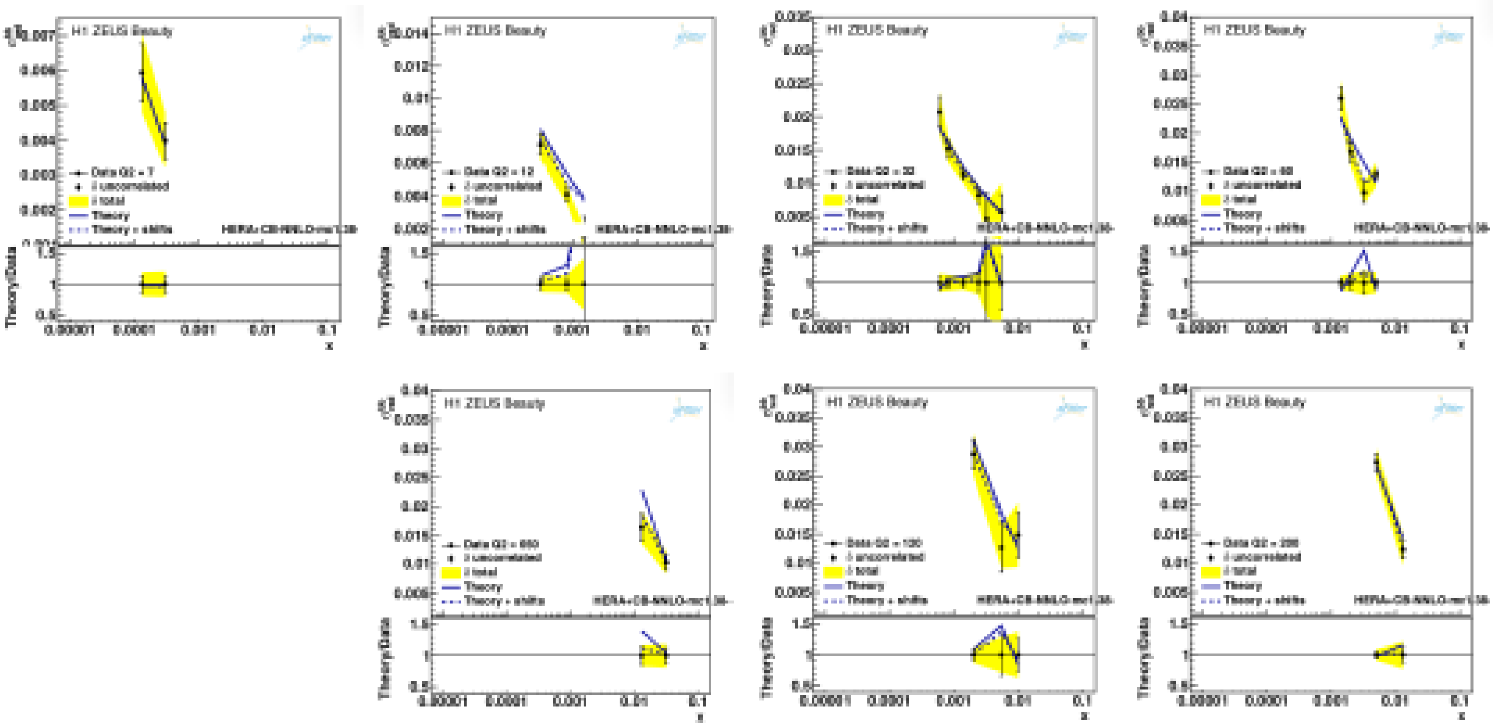
NNLO

Beauty data

K. Wic

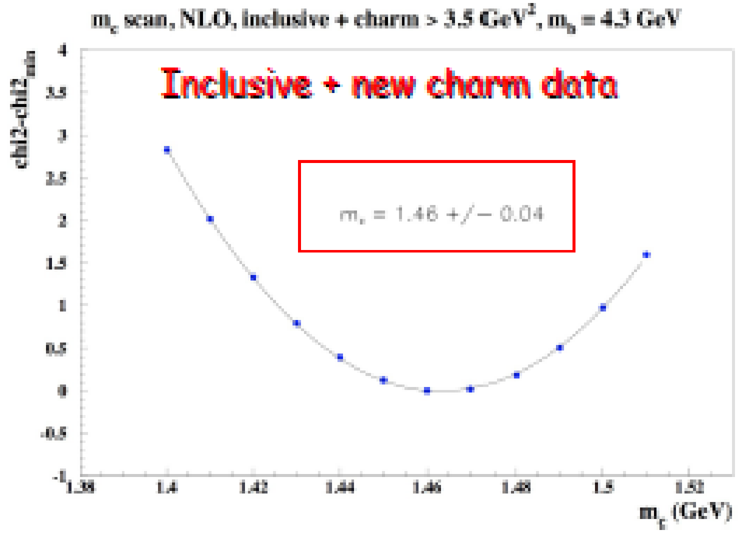


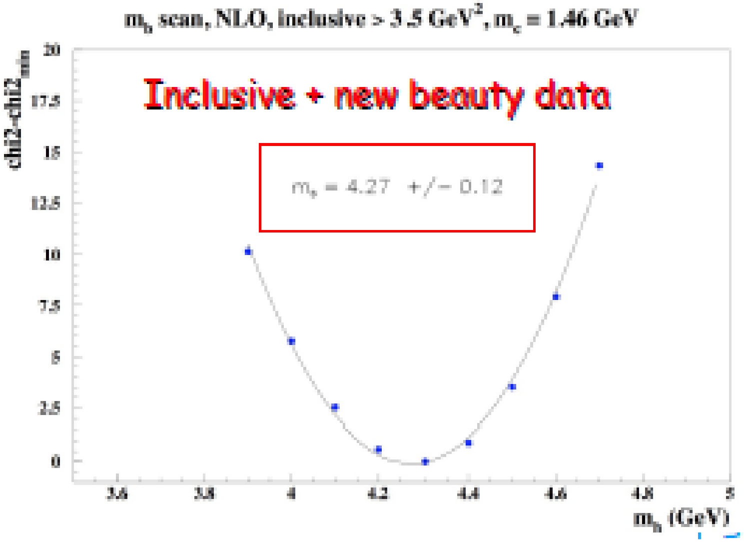
Scan of c/b mass @ NLO, inclusive and charm Q_{min}^2 >= 3.5 GeV^2

K. Wichmann

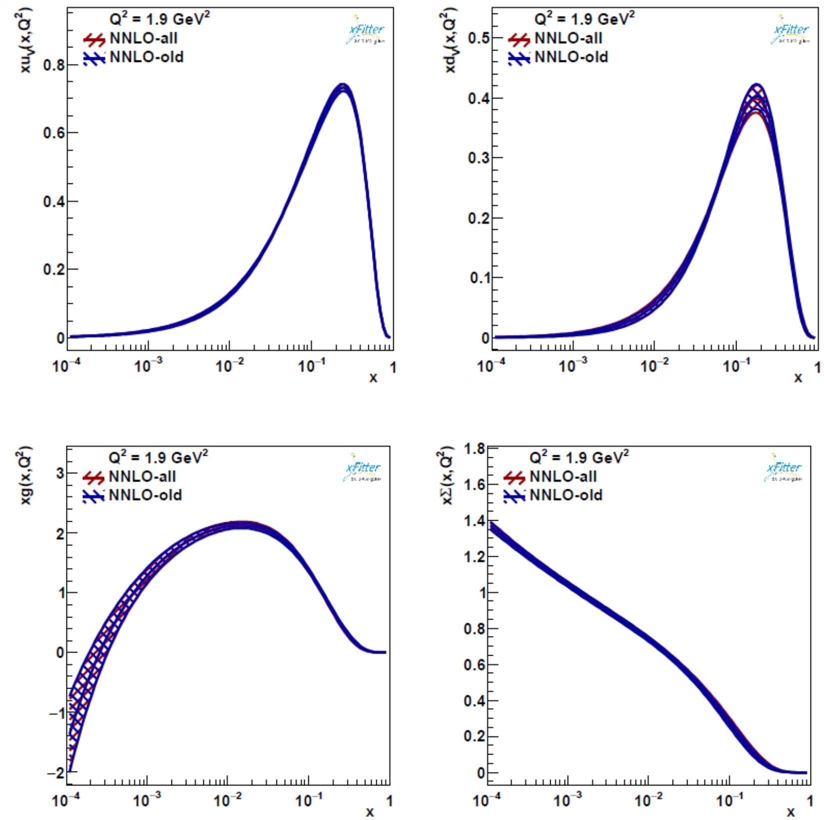
- New NLO values
  M_c = 1.46 +- 0.04 GeV
  M_b = 4.3 +- 0.1 GeV

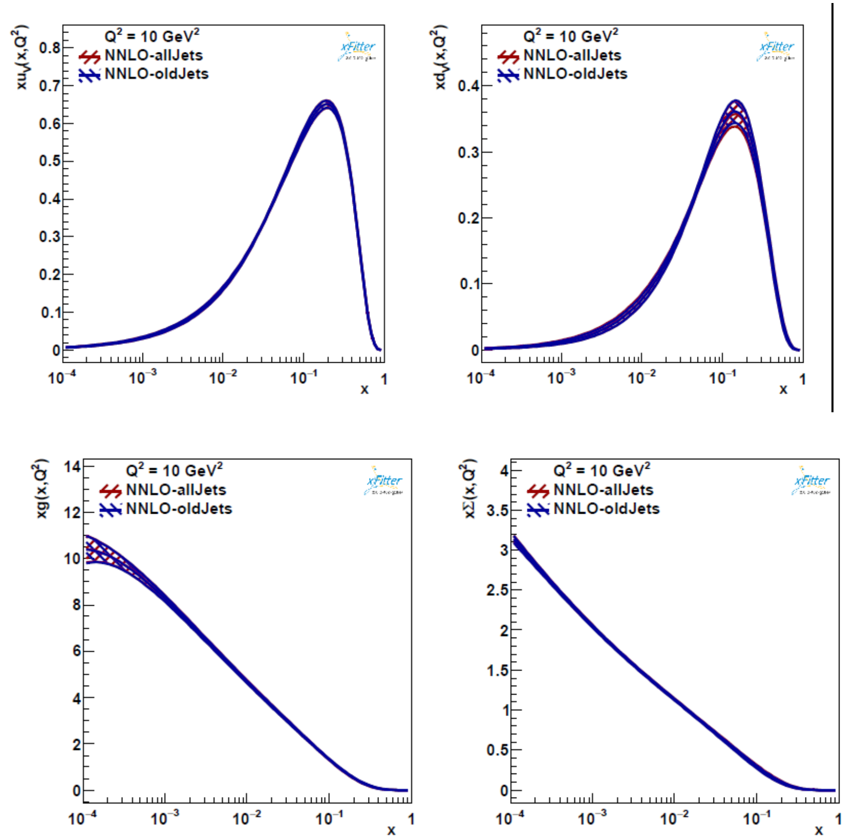
- HERAPDF2.0 values:
  M_c = 1.47 +- 0.06 GeV
  M_b = 4.50 +- 0.25 GeV

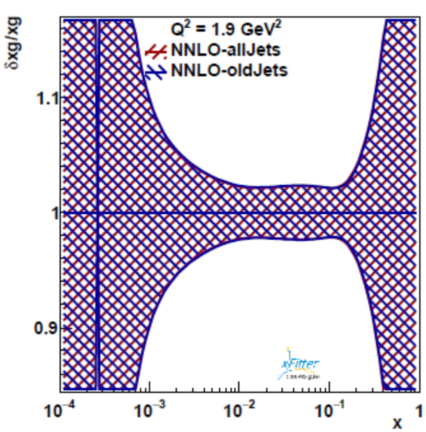




What do new jets do? NNLO







The answer is: not a lot when alphas is fixed
BUT AT LEAST YOU CAN fit them!