HERAPDF2.0 NNLOJets

A M Cooper-Sarkar and K Wichmann

H1/ZEUS June 2019

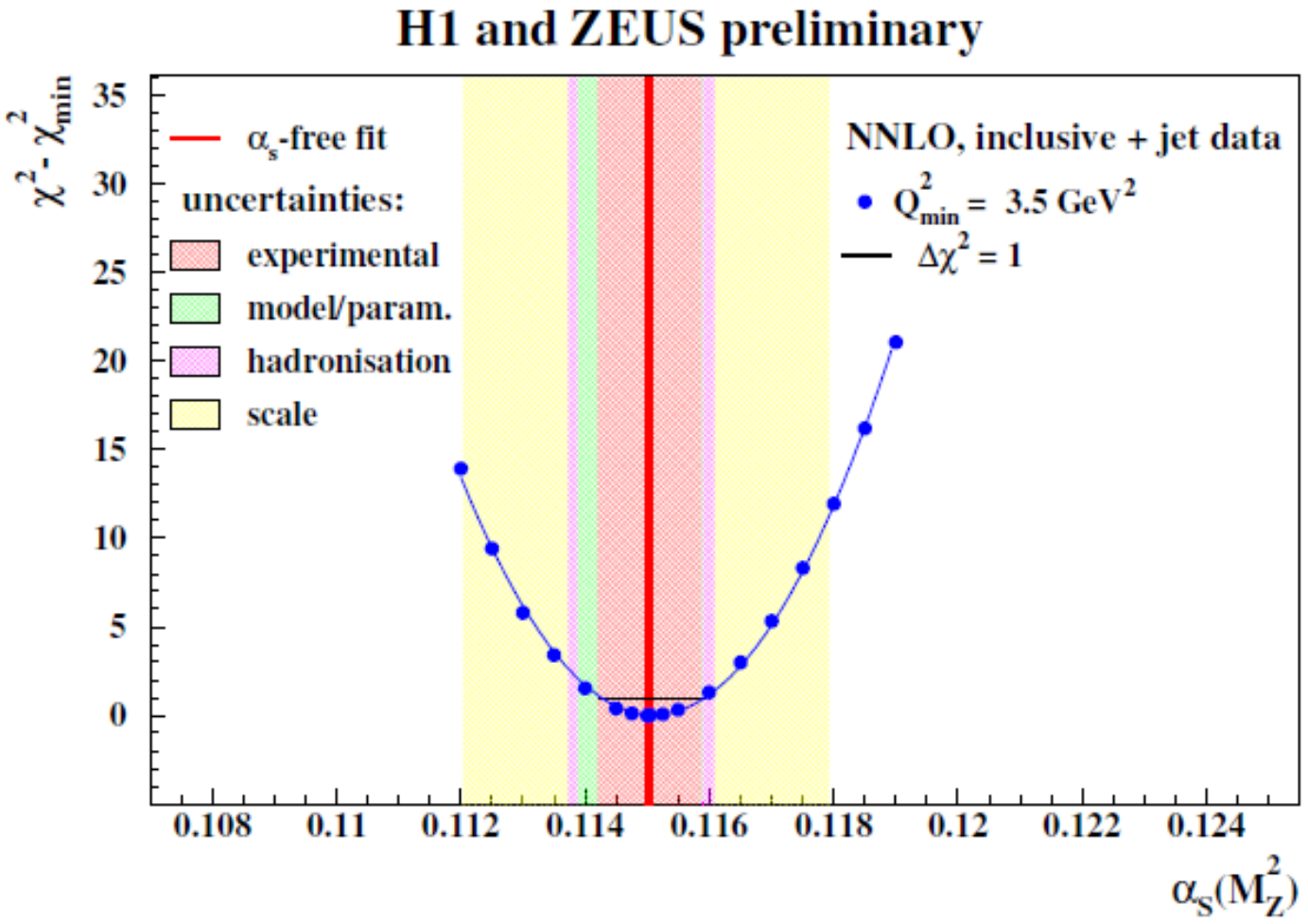
Updates post DIS

- Various questions regarding consistency of error on alphas
- Consistency of normalisation of jets
- NOW take into account the NEW charm and beauty combination data
- New scans for optimal mc and mb values
- Effect of adding the c, b data

The result for alphas

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

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



Let's concentrate on the experimental error

$\alpha_s(M_Z) = 0.1150 \pm 0.0008$ $Q^2>3.5$ 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 have already done this is 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

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.

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—here for the alphas=0.118 fixed fit

Parameter	old	new
'Bg'	-0.099±0.066	-0.076±0.065
'Cg'	5.09±0.50	5.32±0.50
'Aprig'	0.13±0.10	0.12±0.10
'Bprig'	-0.423±0.055	-0.429±0.055
'Cprig'	25.00	25.00
'Buv'	0.801±0.027	0.807±0.027
'Cuv'	4.819±0.084	4.809±0.083
'Euv'	10.4± 1.4	10.1± 1.4
'Bdv'	0.983±0.089	0.973±0.088
'Cdv'	4.58±0.39	4.52±0.38
'CUbar'	6.8± 2.7	6.7± 2.7
'DUbar'	0.77±3.5	0.71±3.5
'ADbar'	0.287±0.011	0.287±0.011
'BDbar'	-0.119±0.0049	-0.119±0.0049
'CDbar'	8.79± 1.67	8.47± 1.63

This sort of difference is complete negligible on plots

One more change to note: I was given 'official grids', which make no difference other than the coding for bin widths is tidier
BUT higher-stats official grids are also available now -- I have JUST updated– slightly lower overall chisq mostly from H1 HERA-II high Q2 jets—PDFs not significantly changed

Now on with the plan

The next stage is to consider the combined charm and beauty data
First how it may affect the optimal charm and beauty masses
THEN adding these data into the fit

Reminder: we have been here before

- From preliminary scans m_c tended to be below 1.39 GeV → Q_0^2 needs to be lowered (nominal: $Q_0^2 = 1.9\ GeV^2$)
  - Full scans confirm: we need $Q_0^2 = 1.8\ GeV^2$ for NNLO
  - <u>We should use it consistently for ALL fits</u>
  - Everything repeated with new settings, consistent

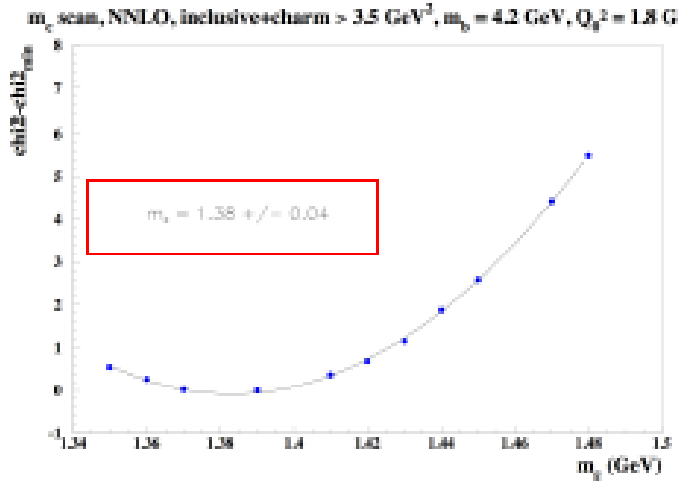
    → this is now setting @ NLO & NNLO: $Q_0^2 = 1.8\ GeV^2$

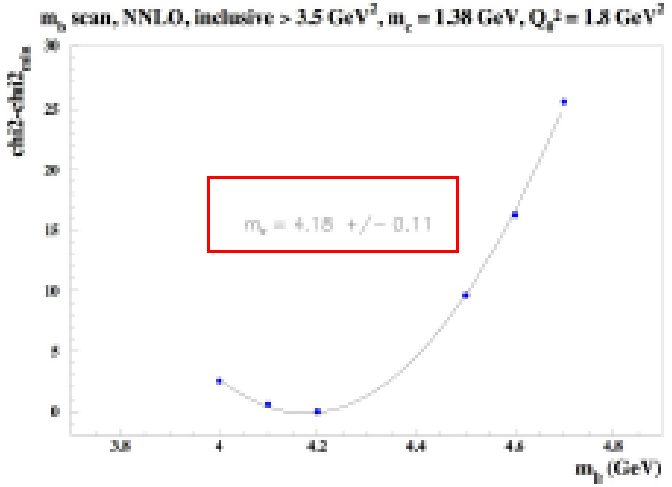
- Parameterisation scans repeated with these settings – w/wo charm&beauty

  → previous patameterisation confirmed for NLO and NNLO

Scan of c/b mass @ NNLO, incl Q^2_{min} >= 3.5 GeV², the same results w/wo 1st charm bin

- HERAPDF2.0 values:
  M_c = 1.43 +- 0.06 GeV
  M_b = 4.50 +- 0.25 GeV

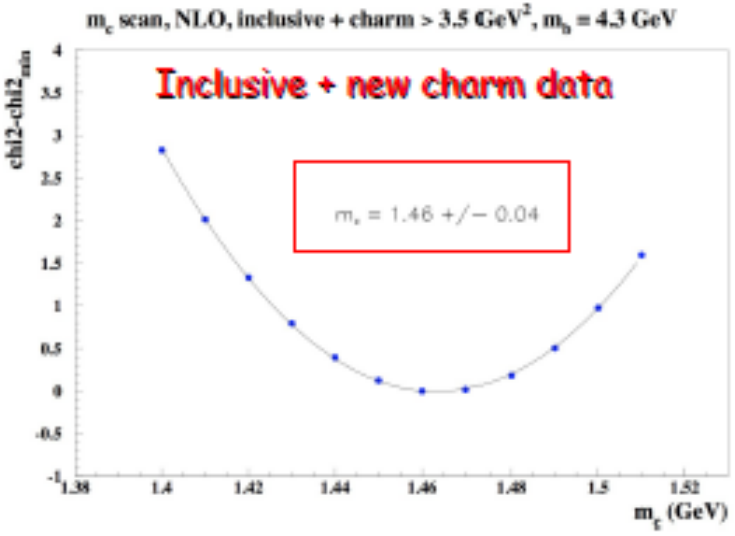


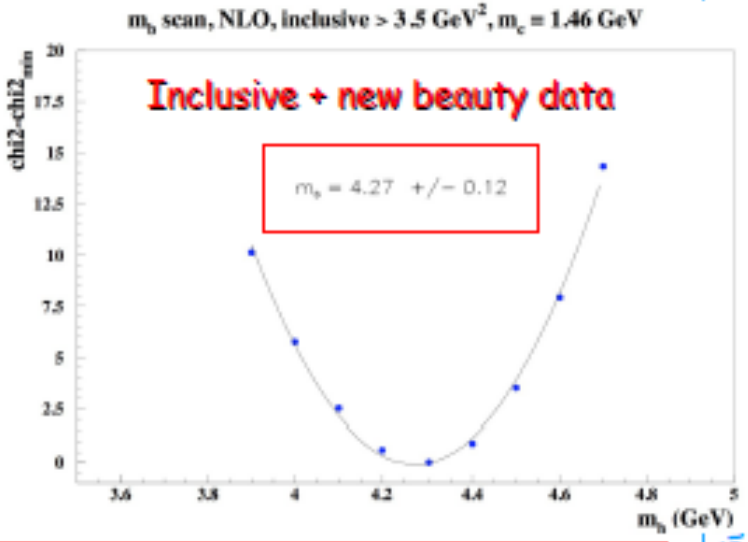


- **New NNLO values**
  M_c = 1.38 +- 0.04 GeV
  M_b = 4.2 +- 0.1 GeV

Scan of c/b mass @ NLO, inclusive and charm Q^2_{min} >= 3.5 GeV²

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





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

we want to use these results for default settings +
→ Q_0^2 = 1.8 GeV²
→ charm Q^2 >= 3.5 GeV²

K. Wichmann

19

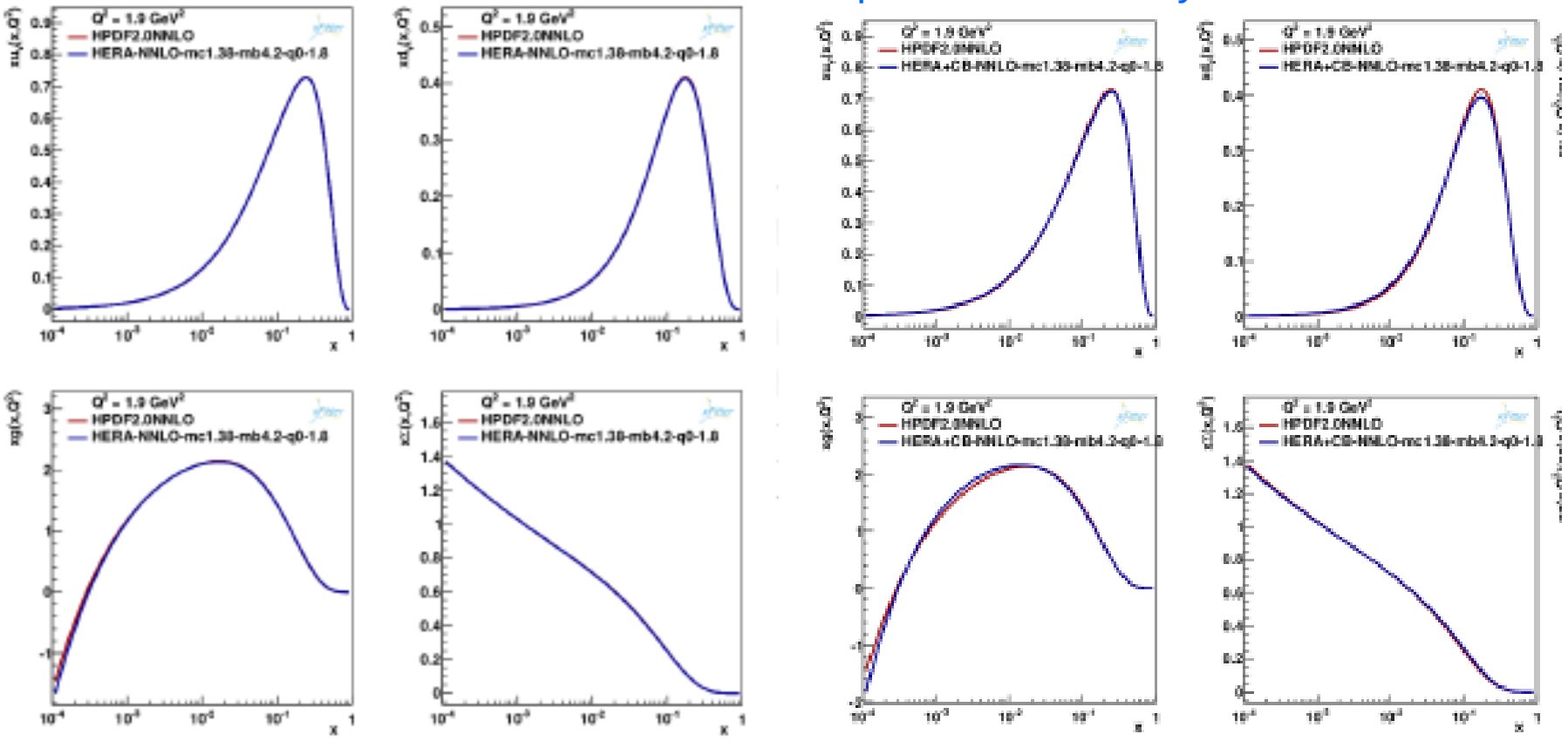
6

Results using the first charm mass bin in back-up

NNLO

Compare fits with new and old settings but no charm/beauty data

Compare fits old settings and no charm/beauty data to new settings plus charm beauty data



Message:

- New settings have negligible effect on PDFs
- Adding charm and beauty data has small effect on gluon
- Same message at NLO (in back-up)
- Fits to data in back-up--- very similar to those from charm/beauty data paper

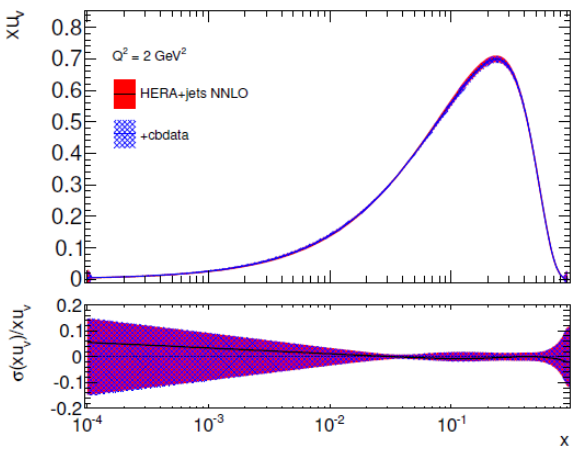
NEW

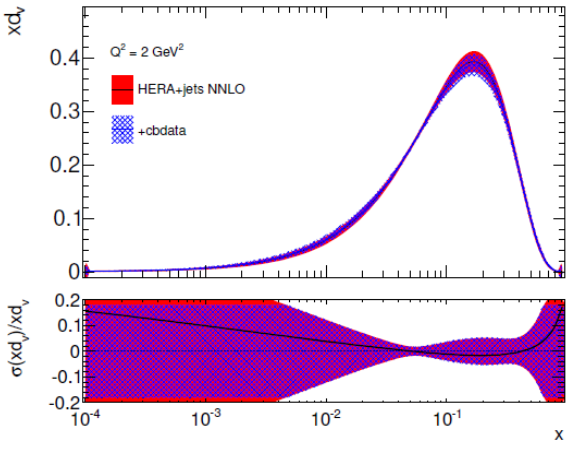
The NNLO fit with these new settings
And NNLO fit with new settings plus the charm and beauty data
Have now been performed including the jet data

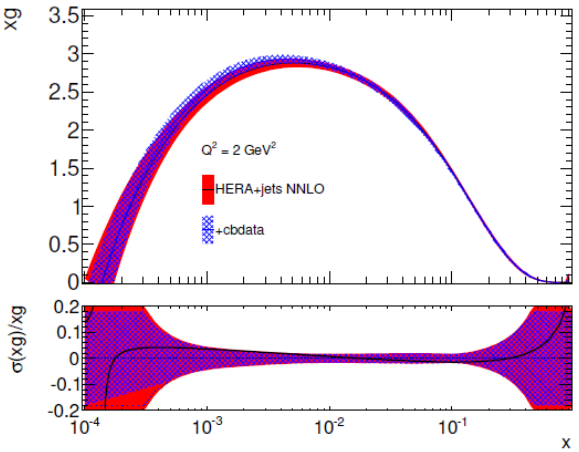
Parameter	Old settings	New settings
'Bg'	-0.076±0.065	-0.057±0.06
'Cg'	5.32±0.50	5.35±0.50
'Aprig'	0.12±0.10	0.11±0.10
'Bprig'	-0.429±0.055	-0.421±0.055
'Cprig'	25.00	25
'Buv'	0.807±0.027	0.809±0.028
'Cuv'	4.809±0.083	4.795±0.08
'Euv'	10.1± 1.4	10.1±1.4
'Bdv'	0.973±0.088	0.975±0.089
'Cdv'	4.52±0.38	4.55±0.38
'CUbar'	6.7± 2.7	6.75±2.7
'DUbar'	0.71±3.5	0.73±3.5
'ADbar'	0.287±0.011	0.280±0.011
'BDbar'	-0.119±0.0049	-0.119±0.005
'CDbar'	8.47± 1.63	7.97± 1.6

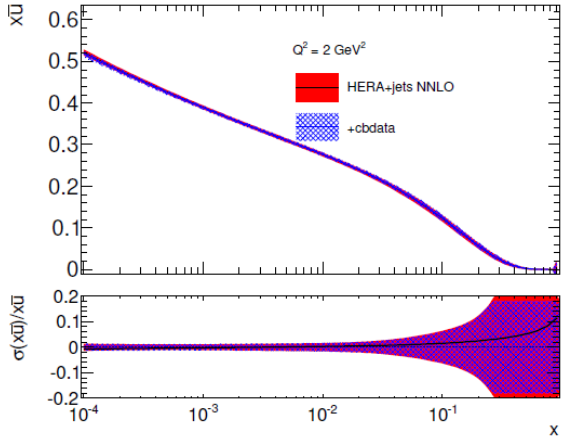
Negligible difference in PDFs due to change in settings --just as for fits without jets
This is shown here for fixed alphas=0.118 and results are similarly unchanged for 0.115

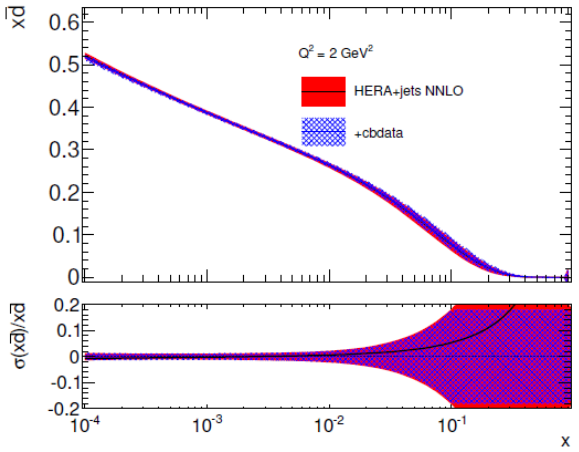
And here we show the difference in PDFs with /without charm and beauty data











Only the gluon shows a visible but small difference

BUT note these two fits both have alphas=0.115– because I have not yet got a converged job for any alphas value greater than 0.1165

And here are the χ2 for this fit with inclusive+jets+charm and beauty, alphas=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 27.75/22.5
H1 HERA2 highq2 dijet = 24 43.09/ 39.0
H1 HERA2 lowq2 incl = 32 48.02
H1 HERA2 lowq2 dijet = 32 24.10
newsigcharm = 47 43.7
newsigbeauty = 27 22.4

(blue jet values form high stats grids)

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

Currently scanning for alphas for this fit—preliminary indications are that alphas~0.114

Do we need to iterate on Mc, mb, parametrisation with a new value of alphas? We have so far used 0.118

Ever onward

Next steps:

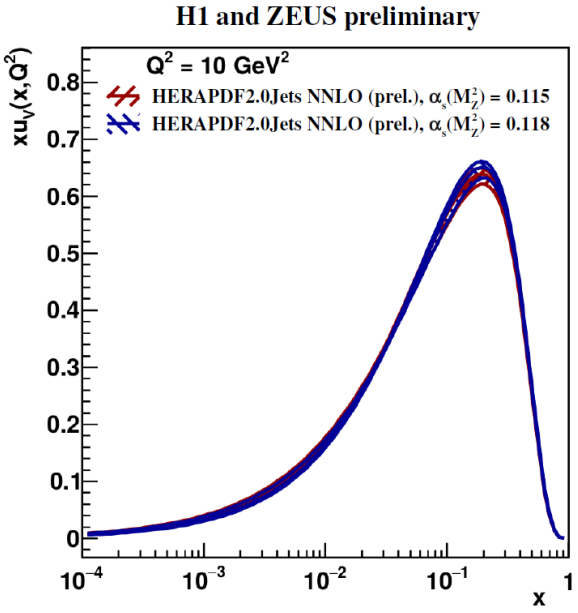
- Possible iteration of settings?
- Then do all model/parametrisation study for fixed alphas NNLO jobs
- Then do all model/parametrisation study for free alphas NNLO jobs adding hadronisation and scale varaiations

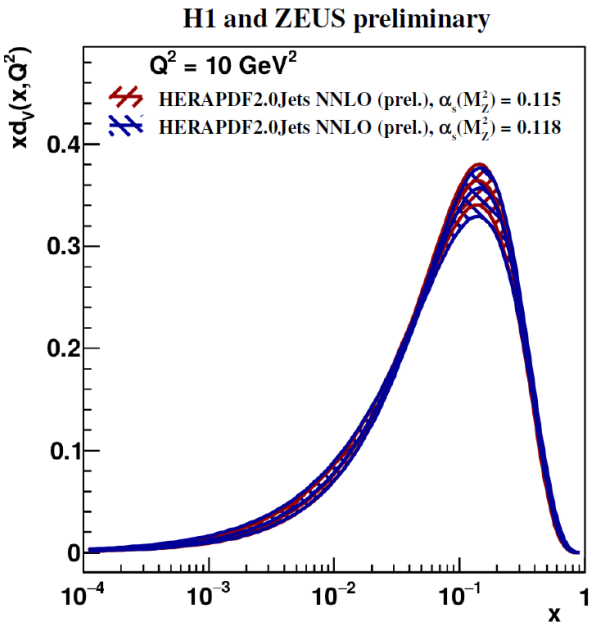
- Redo the NLO jet fits with new settings (including new scales) and charm/beauty, refit for NLO alphas
- Then do all model/parametrisation/hadronisation/scale study for free alphas NLO jobs keeping track of correlations of all variations to the NNLO, so we can evaluate $\Delta\alpha_S$
- Possibly also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

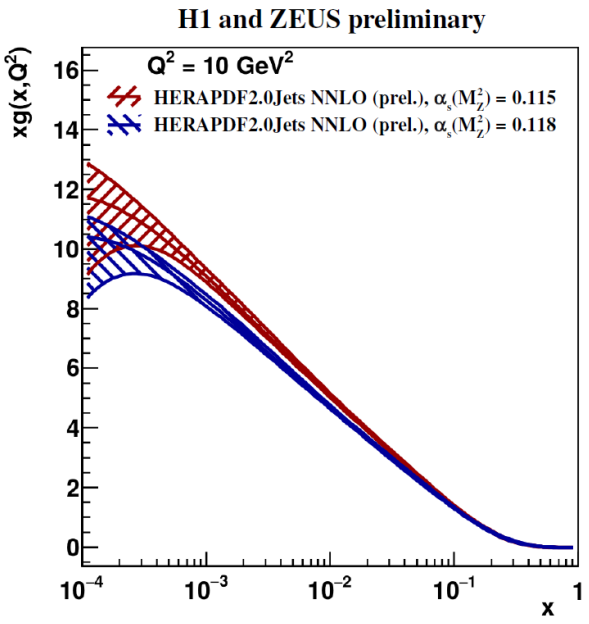
Back-up

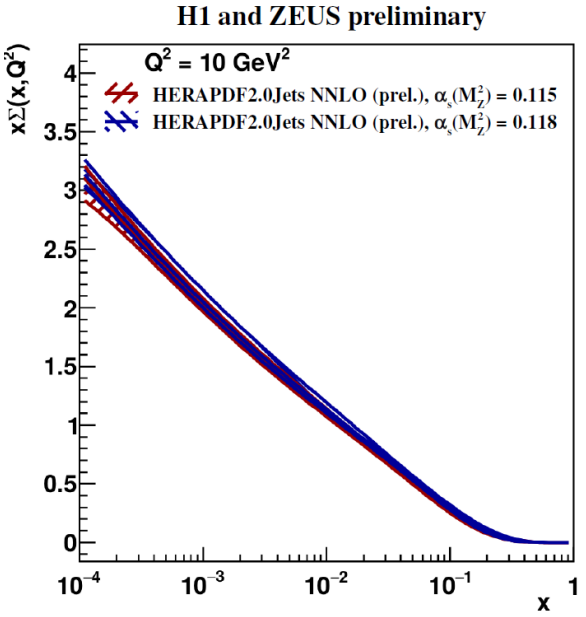
NOW compare PDFs for

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

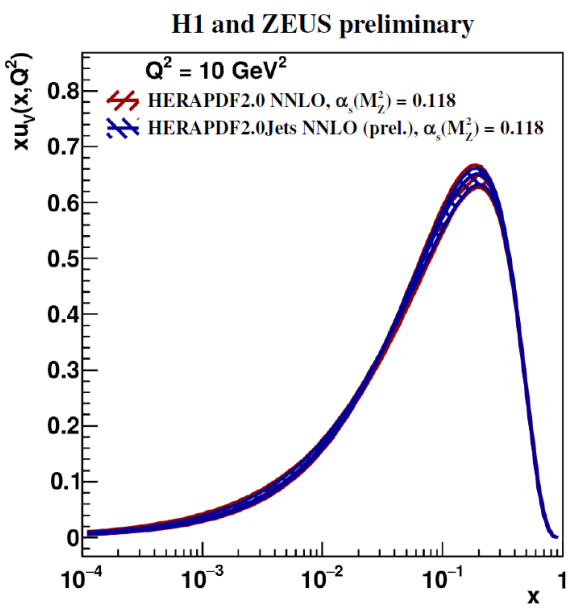


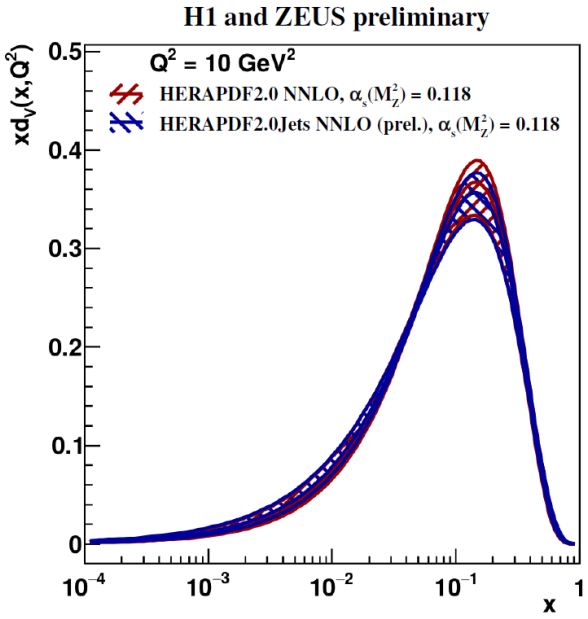


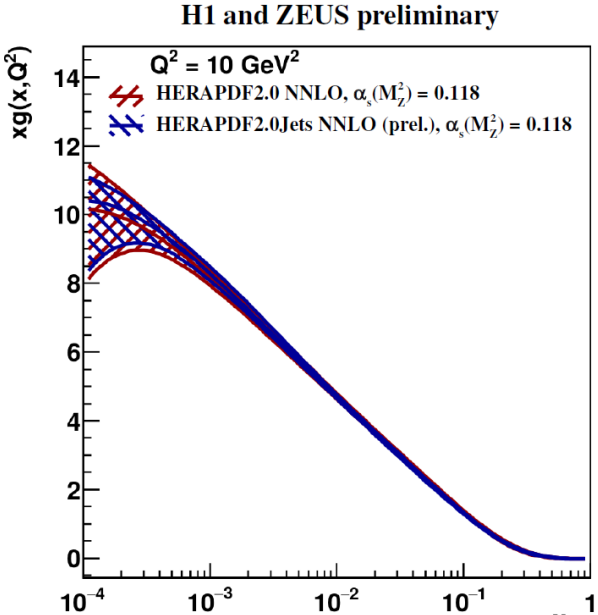


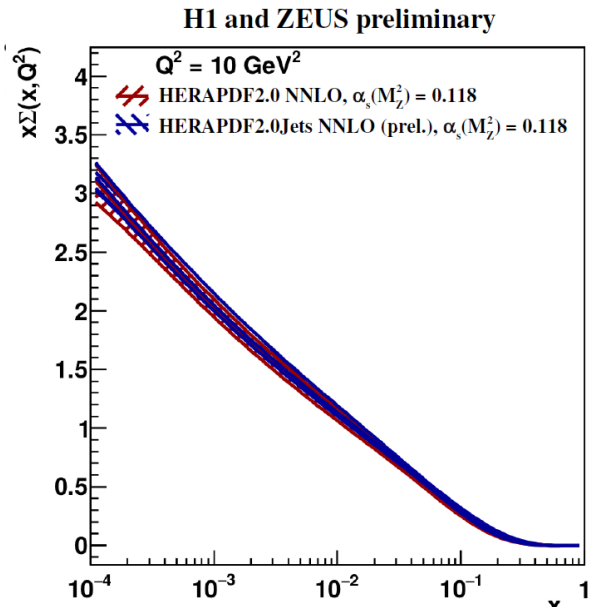


Now compare HERAPDF2.0 NNLO and HERAPDF2.0Jets NNLO both with $\alpha_s(M_Z) = 0.118$



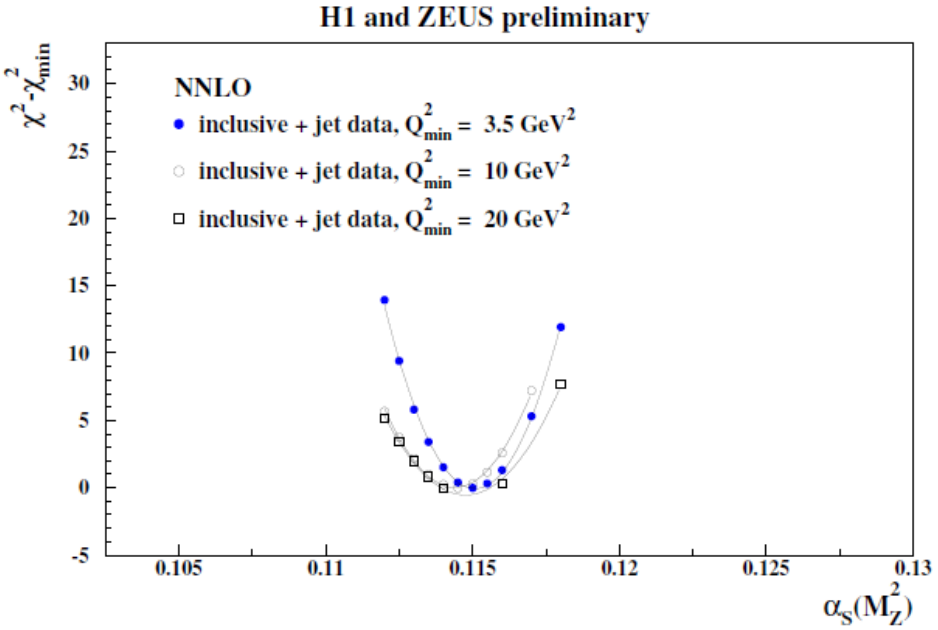




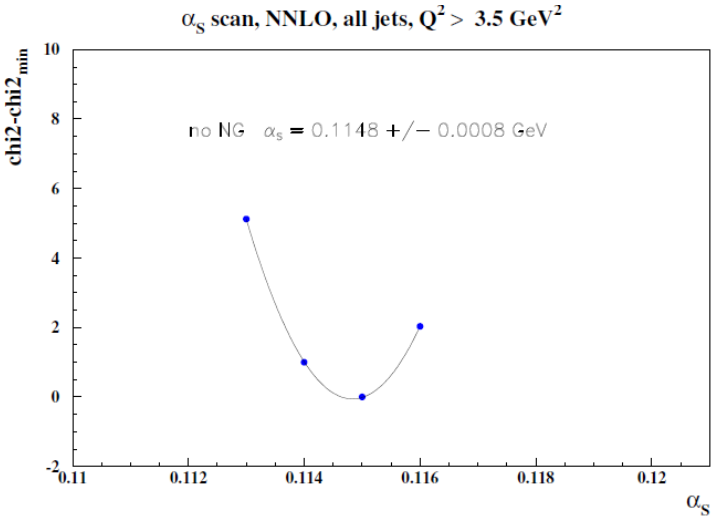


Since it is well known that HERA data at low x and Q^2 may be subject to the need for ln(1/x) resummation or higher twist effects we also perform scans with Q^2 cuts

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

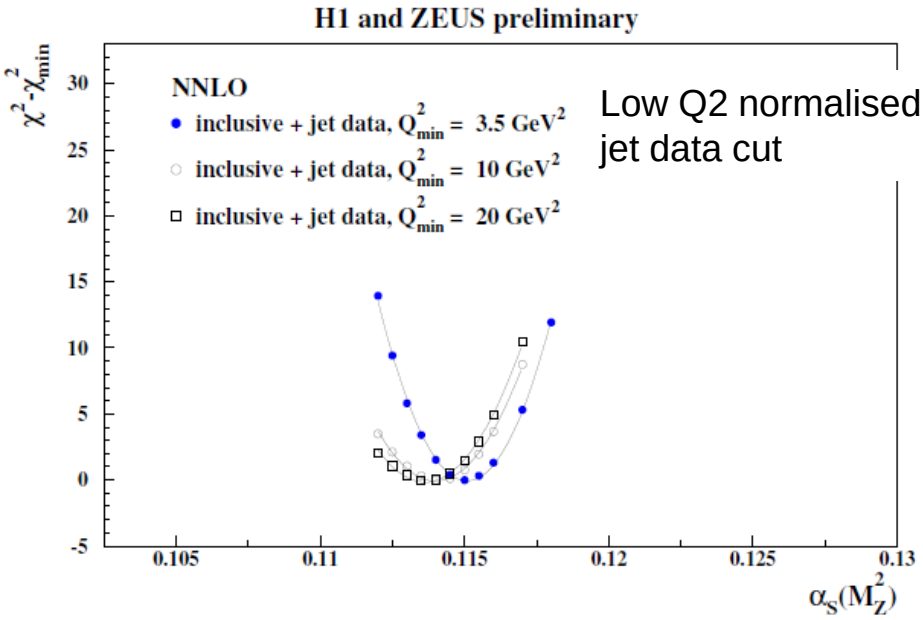
With no negative gluon term

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

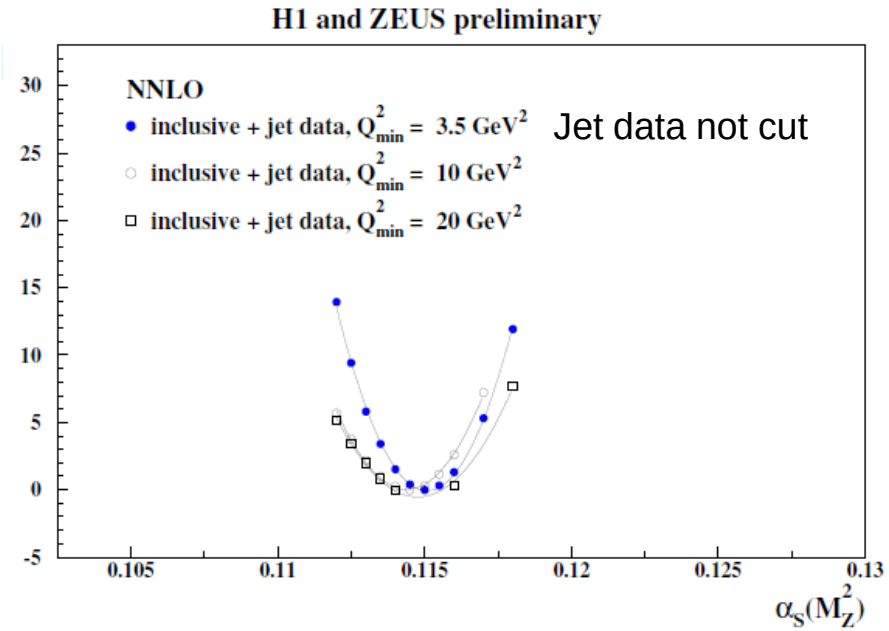
Compatible with standard result

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



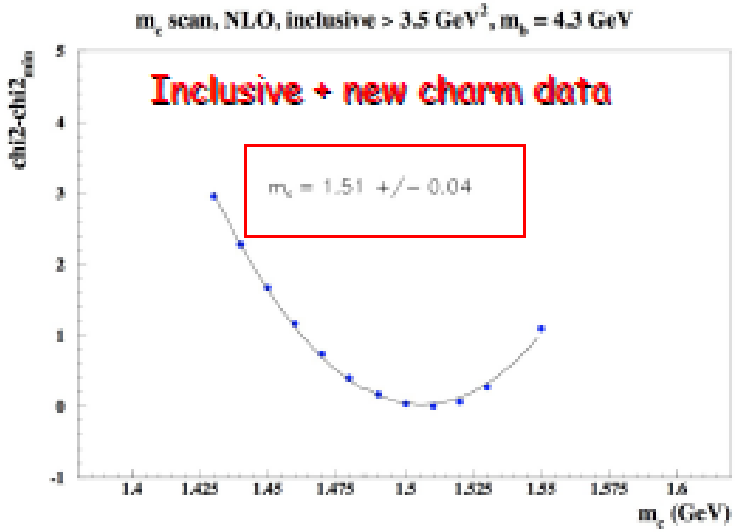
The central values from the three scans are:
0.1150 ± 0.0008 Q2>3.5
0.1140 ± 0.0011 Q2>10
0.1136 ± 0.0011 Q2>20

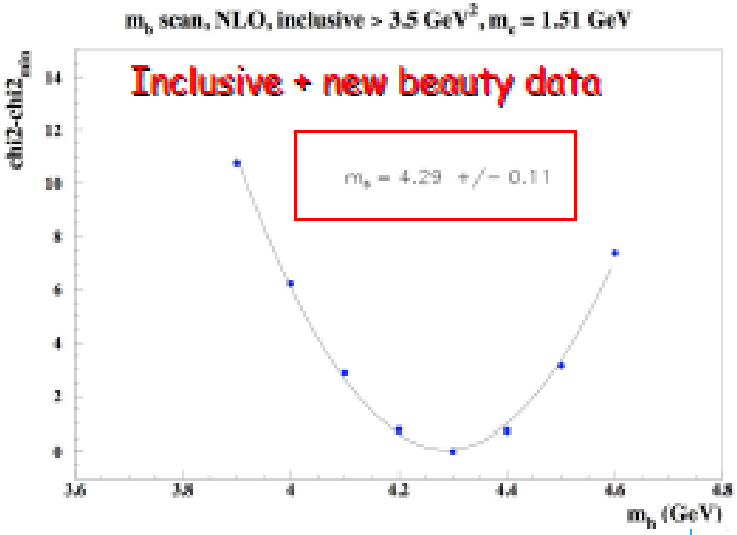
The central values from the three scans are:
0.1150 ± 0.0008 Q2>3.5
0.1144 ± 0.0010 Q2>10
0.1148 ± 0.0010 Q2>20

Scan of charm/beauty mass @ NLO, inclusive Q^2_{min} >= 3.5 GeV², all charm points

K. Wichmann

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





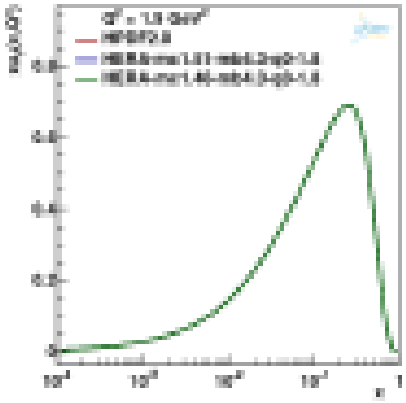
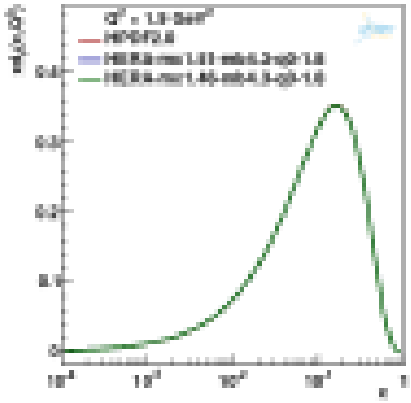
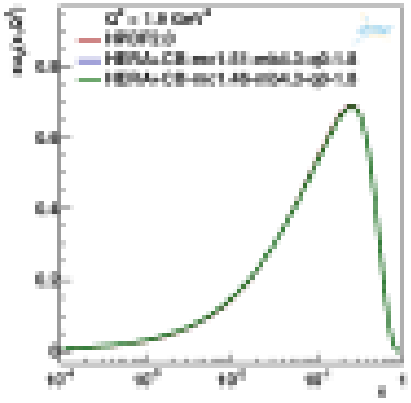
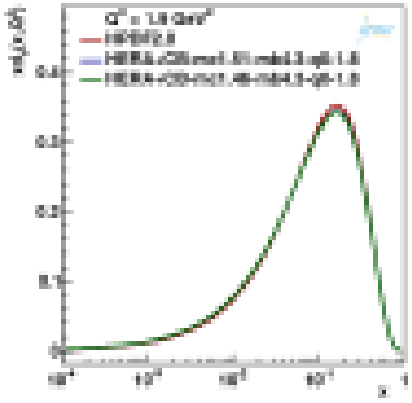
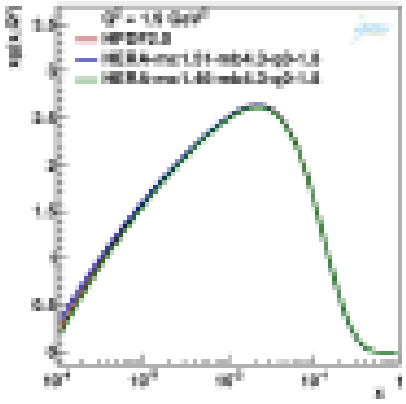
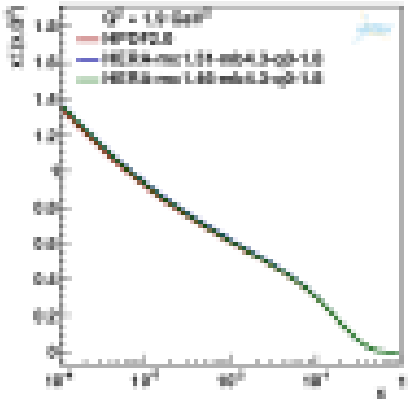
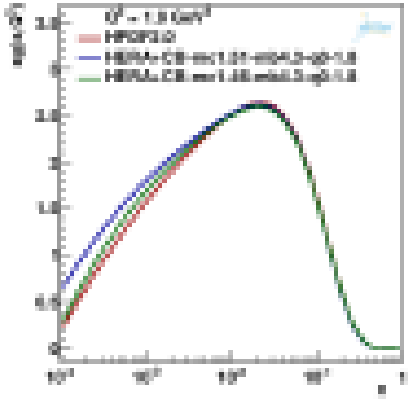
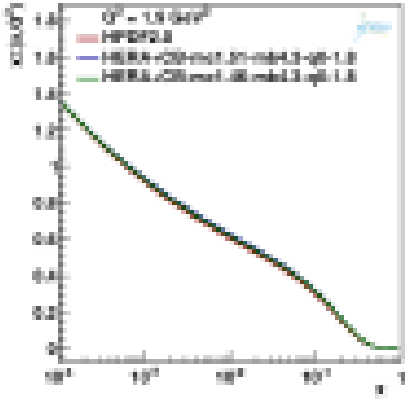
•New NLO values
M_c = 1.51 +- 0.04 GeV
M_b = 4.3 +- 0.1 GeV

5

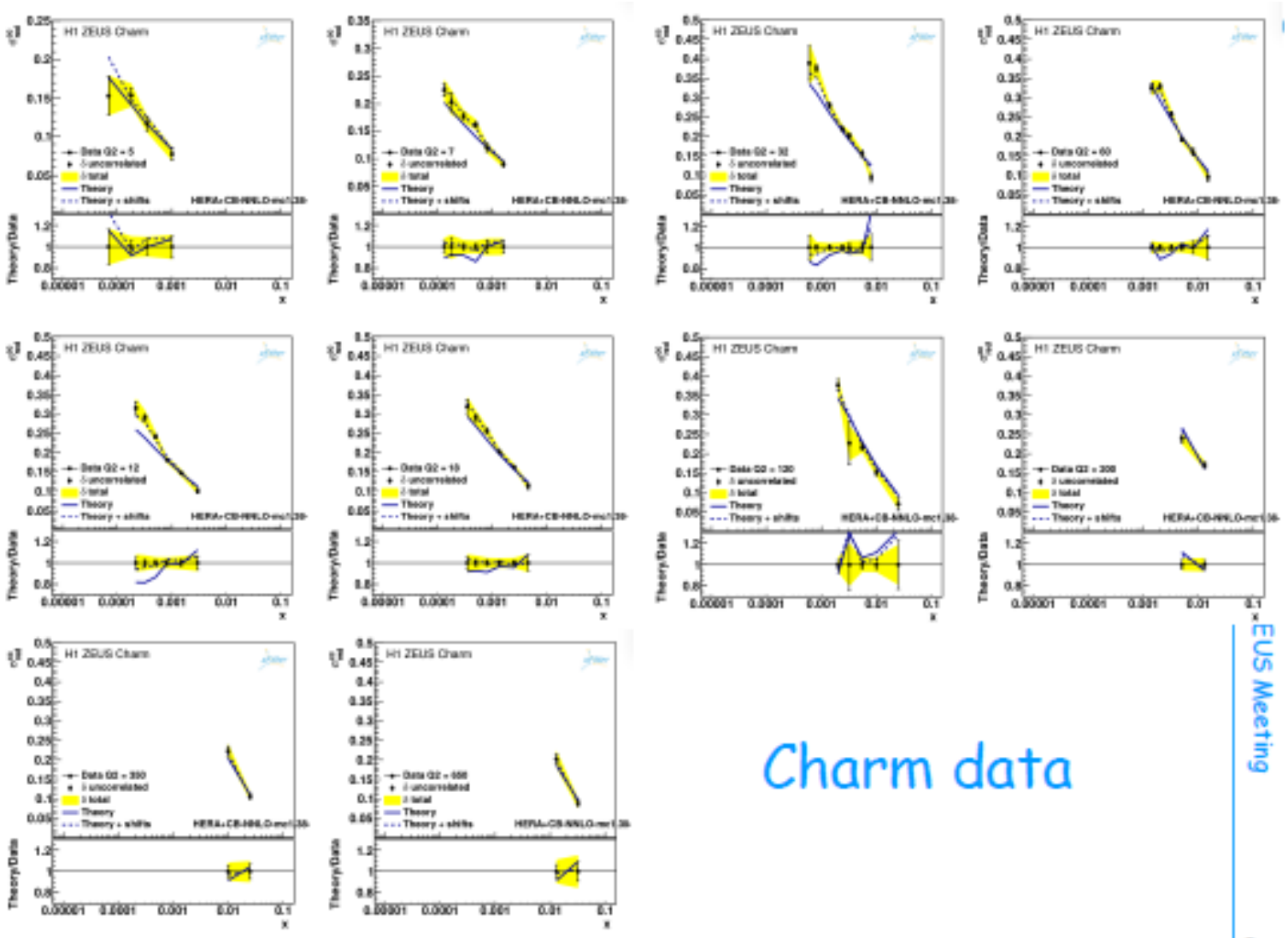
NLO

Compare fits with new and old settings but no charm/beauty data

Compare fits old settings and no charm/beauty data to new settings plus charm beauty data

NNLO



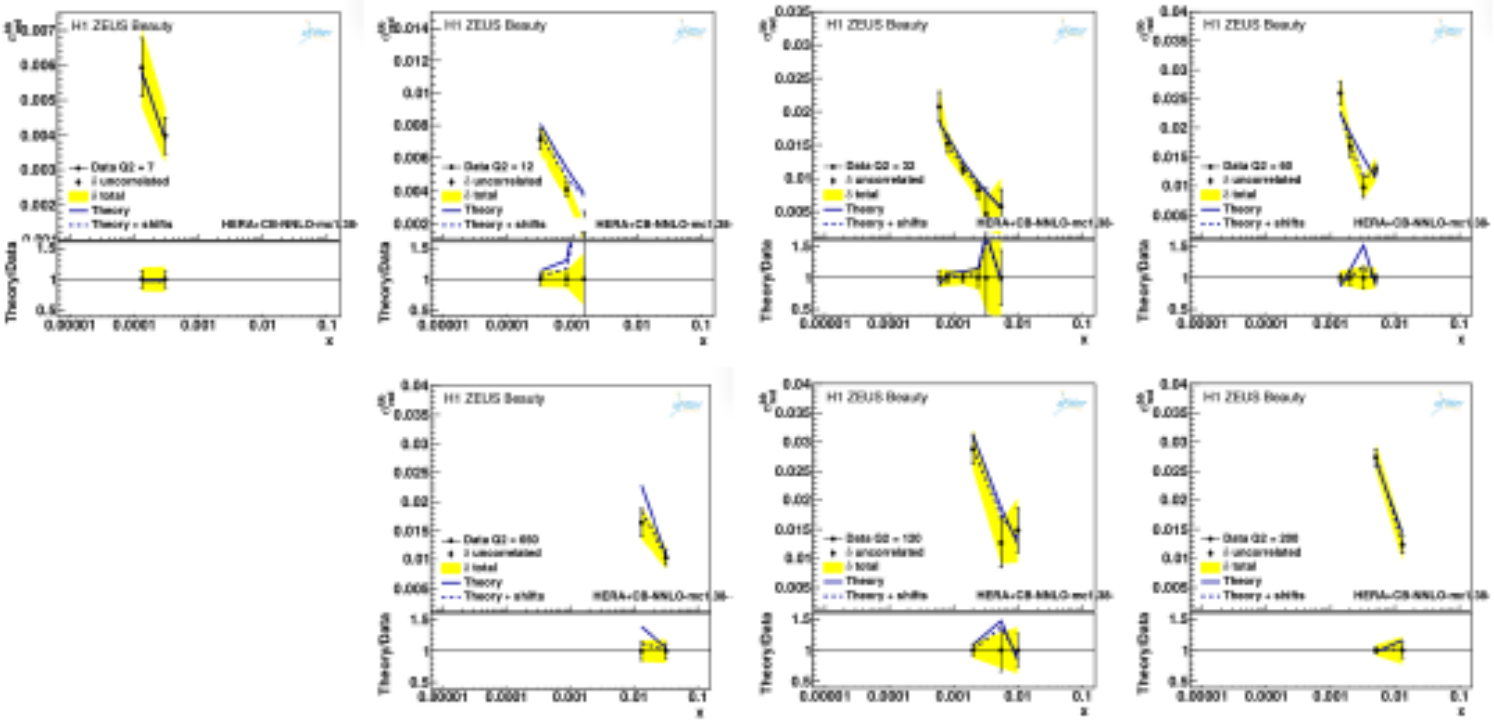
Charm data

EUS Meeting

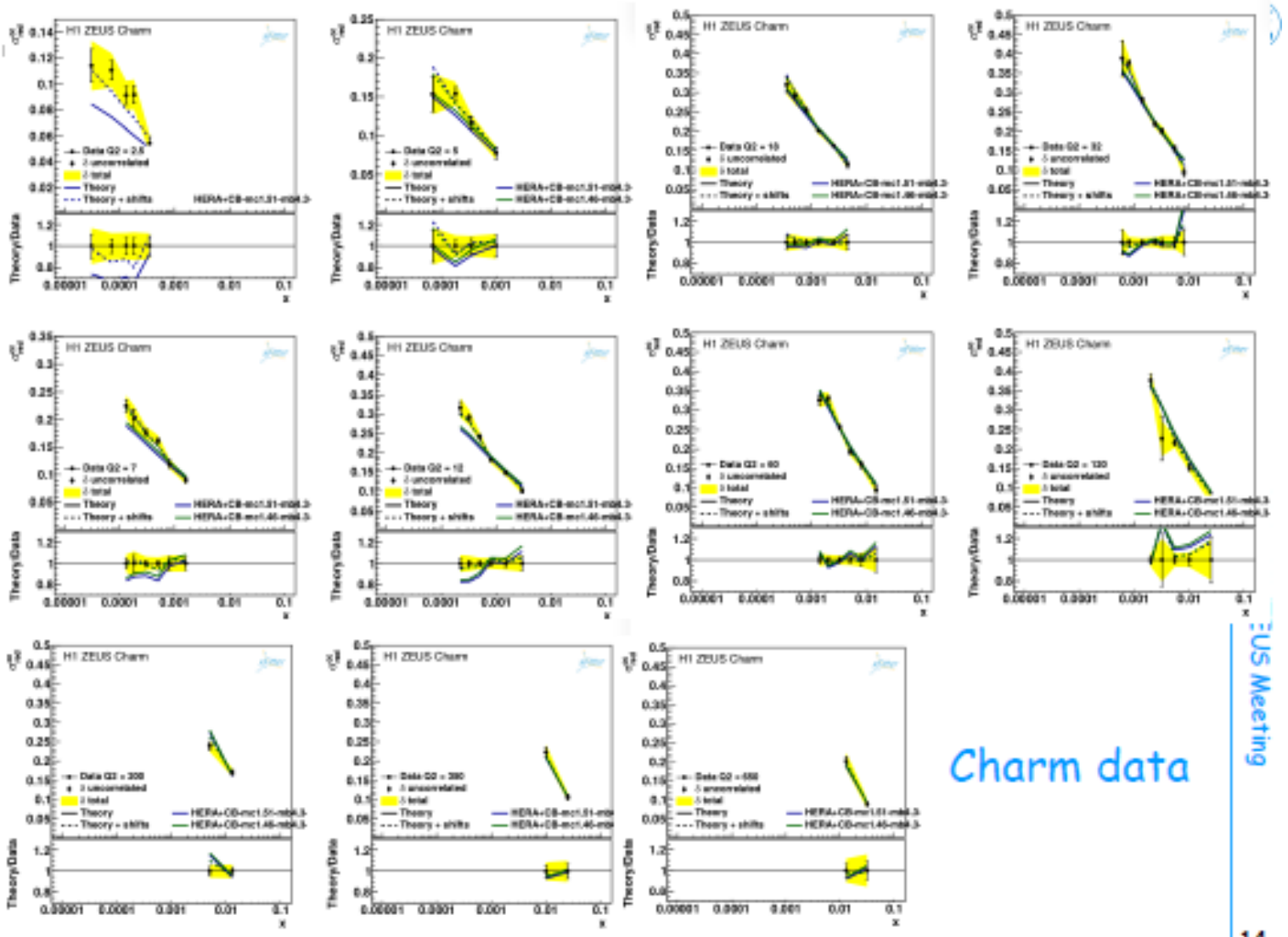
9

NNLO

Beauty data



NLO



Charm data

US Meeting

14

Beauty data