Combination of HERA c and b data

Paper draft v2 presentation

Editors: Karin Daum, Oleksandr Zeniaev
Referees: Mandy Cooper-Sarkar, Katja Krüger
Other EB members: I.Abt, A.Geiser, S.Levonian,
S.Schmitt (chair), K.Wichmann, M.Wing

Outline

- Time-line towards publication

- Paper content summary

- Comments summary

- Editorial board summary

- Revised paper structure

- Figure and table changes

Timeline

- Paper draft (v1) presentation on 23.11.2017

- Circulation for two weeks: 23.11.-8.12.2017

- 19 sets of comments received

- Editorial board meeting on 13.12.2017

- Second draft released on 2.2.2018

- This talk: draft v2 presentation

- Next steps
  - Paper reading on 2.3.2018
  - Circulate post-reading draft for another week
  - Submit to journal

- For spring conferences:
  - Additional (extended) preliminary with new material → presentation by Sasha

Paper content recap

- Paper consists of three major parts

  – Combination of HERA charm and beauty cross sections (supercedes previous charm combination)

  – Comparison to predictions

  – QCD analysis focussing on the determination of charm and beauty quark masses

- Observation: data and QCD predictions have a 3σ tension in the x-slope

- Dedicated studies are included to shed more light on this

- The quark masses are found to be

$$m_c(m_c) = 1.290^{+0.046}_{-0.041}(\text{exp/fit})^{+0.062}_{-0.014}(\text{model})^{+0.003}_{-0.031}(\text{parametrisation}) \text{ GeV}$$

$$m_b(m_b) = 4.094^{+0.104}_{-0.109}(\text{exp/fit})^{+0.090}_{-0.032}(\text{model})^{+0.001}_{-0.031}(\text{parametrisation}) \text{ GeV}$$

PDG: $m_c(m_c) = 1.28 \pm 0.03$ GeV $\quad m_b(m_b) = 4.18^{+0.04}_{-0.03}$ GeV

Summary of comments received

19 sets of comments were received.
```
 1  20171124−180604 Mandy Cooper−Sarkar
 2  20171124−192632 Achim Geiser
 3  20171127−104013 Iris Abt
 4  20171127−133650 Sergey Levonian
 5  20171130−184207 Joerg Gayler
 6  20171201−133658 Misha Lisovyi (plus attachment)
 7  20171202−170022 Brian Foster
 8  20171203−174808 Dietrich Wegener
 9  20171204−135338 Stefan Schmitt
10  20171205−121157 Ewald Paul
11  20171207−214529 Boris Levchenko.txt
12  20171208−004918 Katja Krueger
13  20171208−055147 Dieter Haidt (plus attachment)
14  20171208−173515 Jan Olsson and Nelly Gogitidze
15  20171208−184645 Achim Geiser: answer to Jan and Nelly
16  20171210−115907 Max Klein
17  20171211−000318 Boris Kuprash
18  20171211−131140 Peter Truoel (plus attachment)
19  20171211−141058 Daniel Britzger
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- **All comments supported publication of the data**

  … I appreciate very much that this final combinations wqas possible leading to improved HERA results…

- **Some criticism about arrangement and length of sections**

  … the introduction is far too long and detailed…

- **Various (contradicting) suggestions to include or exclude figures or studies around the ~3σ tension**

Editorial board meeting

- All major comments were discussed in the EB
  - Content
  - Text structure
  - Figures, tables

  Minutes are available
- The detailed text changes were delegated to Karin, Achim, Sasha
  - An answer file is available where each single comment is addressed
- We also decided on the journal
  - to be submitted to EPJC

Decisions on content change requests

- 3σ as "discrepancy" or "fair description"?

  → keep the word "tension"

- Remove (parts of) section 6.2? Remove study with $x>0.01$?

  → keep it but improve text structure

- Quantify impact on LHC?

  → beyond the scope of this paper

- Interpret 3σ tension in charm in comparison to the agreement in beauty?

  → not possible (different x range)

Changes to the paper structure

- **Shorter introduction, heavy flavour tagging techniques now in sect. 3**

- **New table with quark mass uncertainty breakdown**

- **Section 6.3 (study of the x_{BJ} dependence...) split into two parts**

- **Technicalities are collected in an appendix: systematic uncertainty details (Table 4), PDF fit settings and central results**

Draft v1: 22 text pages, 5 tables, 24 figures
Draft v2: 23 text pages, 8 tables, 22 figures

Draft V1:
1. Introduction
2. Open heavy flavour production in DIS
2.1 Theory of hea
3. Combination of
3.1 Data samples
3.2 Extrapolation
3.3 Combination
4. Combined cros
5. Comparison wit
5.1 FFNS predicti
5.2 VFNS predicti
5.3 Summary of th
6. QCD analsyis
6.1 Theoretical for
6.2 QCD fit and d
6.3 Study of the x
7. Conclusions

Draft V2:
1. Introduction
2. Heavy flavour production in DIS
2.1 Theory of heavy flavour production
3. Combination of H1 and ZEUS measurements
3.1 Data samples
3.2 Extrapolation of visible cross sections to σ_{red}
3.3 Combination method
4. Combined cross sections
5. Comparison with theory predictions
5.1 FFNS predictions
5.2 VFNS predictions
5.3 Summary of theory comparisons
6. QCD analsyis
6.1 Theoretical formalism and settings
6.2 QCD fit and determination of the running heavy quark masses
6.3 $\sigma_{red}(c)$ and $\sigma_{red}(b)$ as a function of the partonic x
6.4 increasing the impact of charm data on the gluon density
7. Summary
Appendix

- Figure 2,3 removed

- PDF figures 15, 22 color code unified with other figures

- PDF fits have names (figures 15-19 and 22-24)

- Figure 20 was improved in many aspects

- Figure 24 now has a reduced number of Q^2 bins

- Table 4 moved to appendix

- New table with quark mass error breakdown

- New tables with fit settings and PDF parameters

Full table of correlations and cross sections will be published as extra material (online)

- Figure 2,3 removed

  - These showed only the combined cross sections

  - The same cross sections are visible on many other figures, either in comparisons with the data before combination or with various predictions
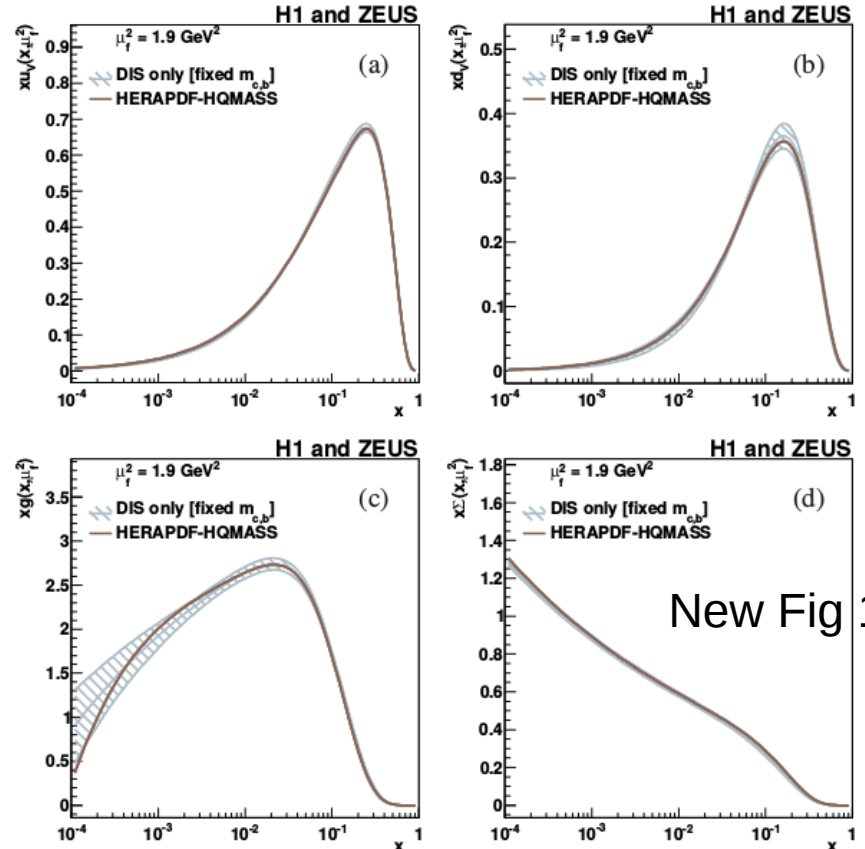

Former fig 2

REMOVED

Former fig 3
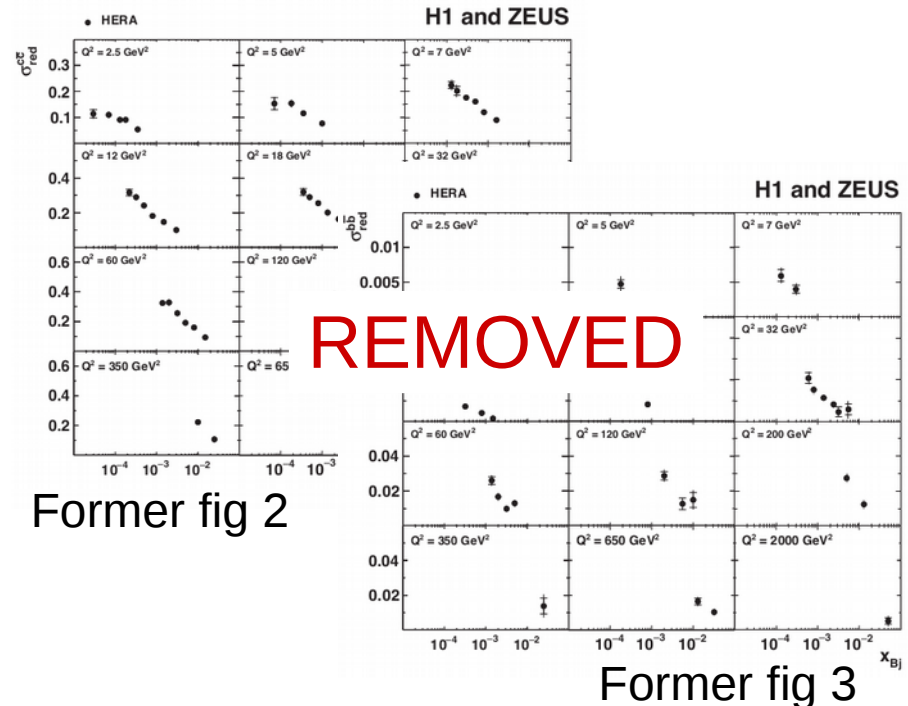
- ## Color code now matches other figures. Hatch style improved

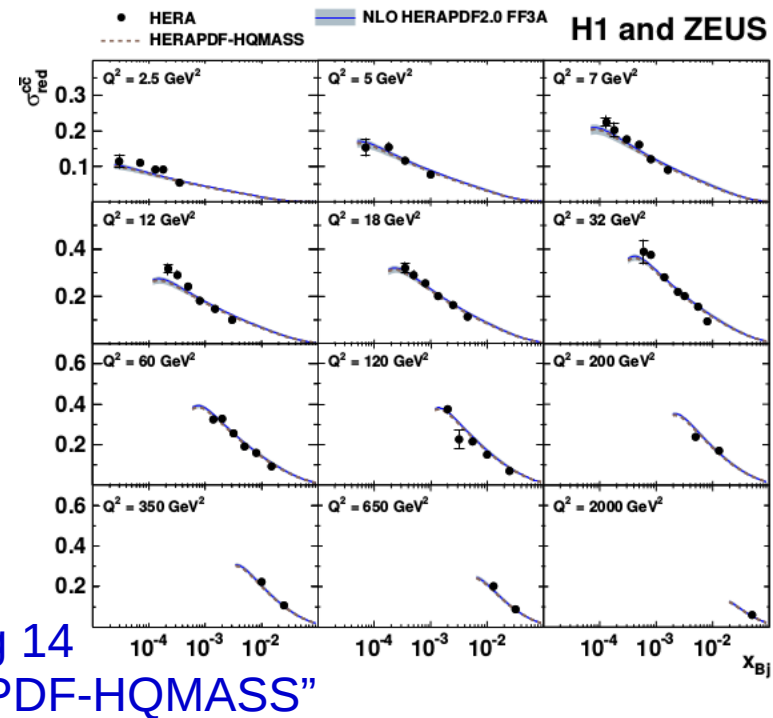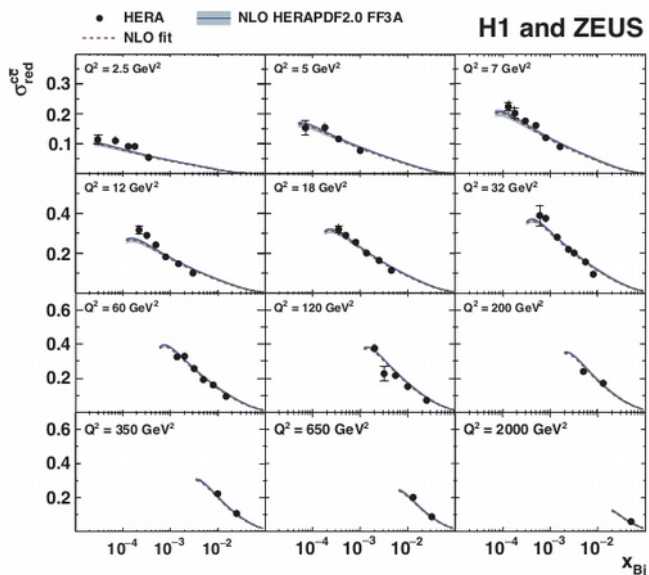Figure showing the PDFs corresponding to the quark mass extraction
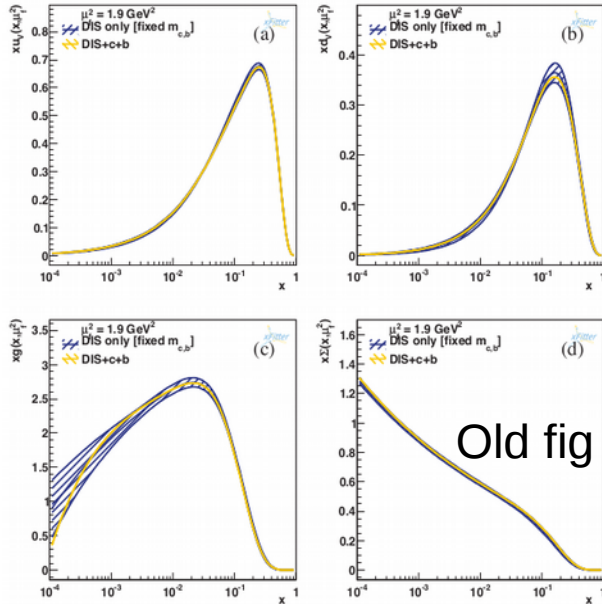
Old fig 15

New Fig 13
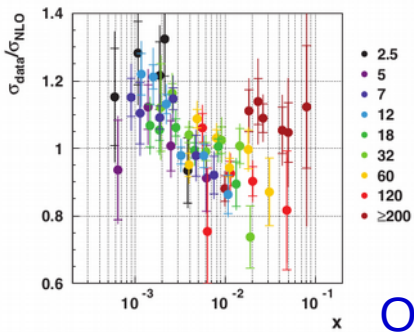
- ## All fits have a name tag

Old fig 16
"NLO fit"

Figures show
comparisons of our
fit to the charm and
beauty data

New Fig 14
"HERAPDF-HQMASS"
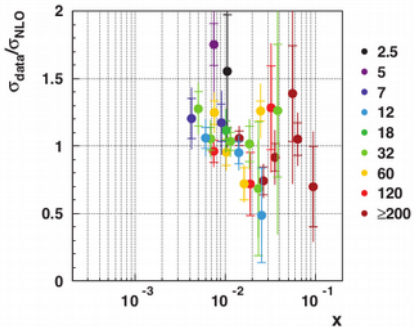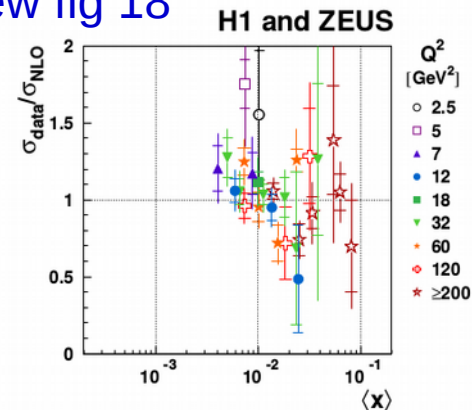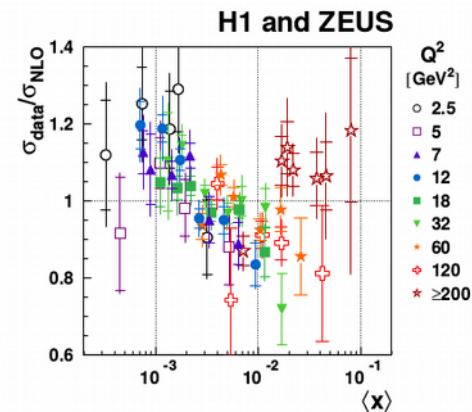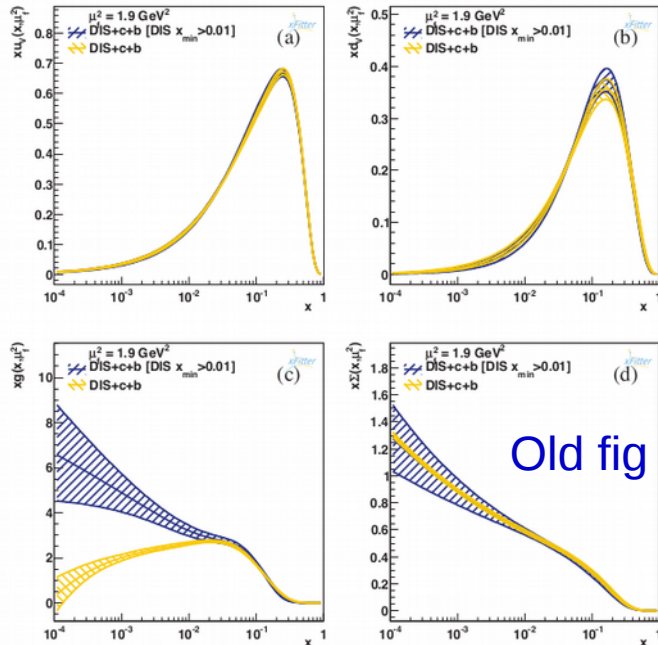
- ## Several improvements

Old fig 20

Figure shows the integration variable <x> probed in the PDF fit by the charm and beauty data
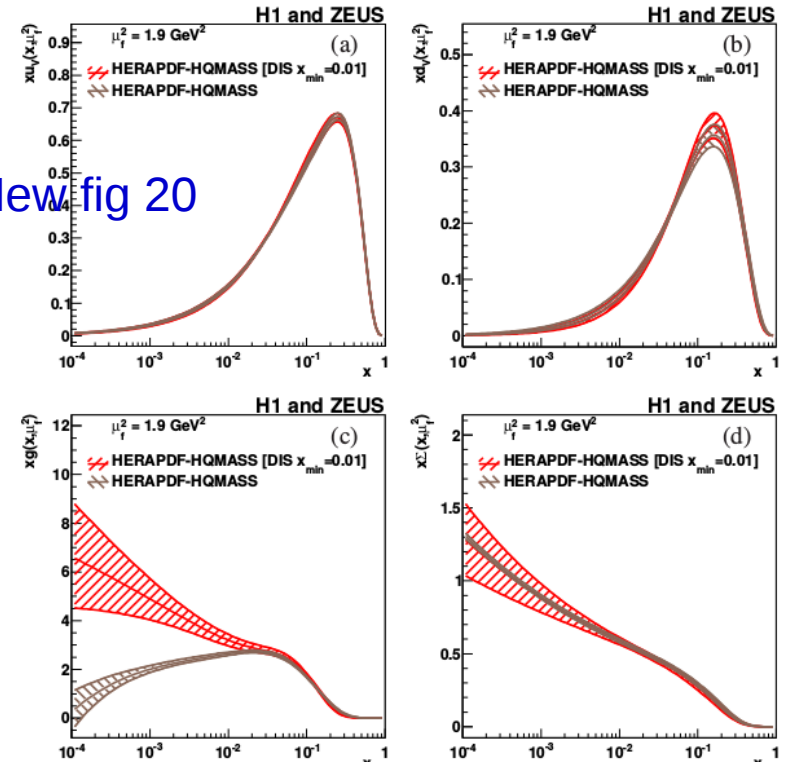
New fig 18
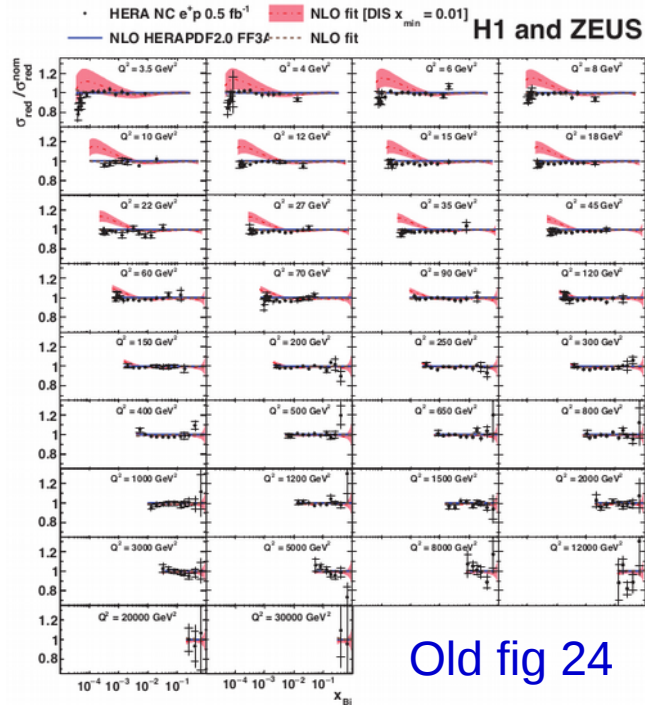
- Updated color coding, add H1 and ZEUS on top

New fig 20

Figure shows comparisons of default PDFs and those from a fit with a cut $x_{BJ} > 0.01$ for inclusive data
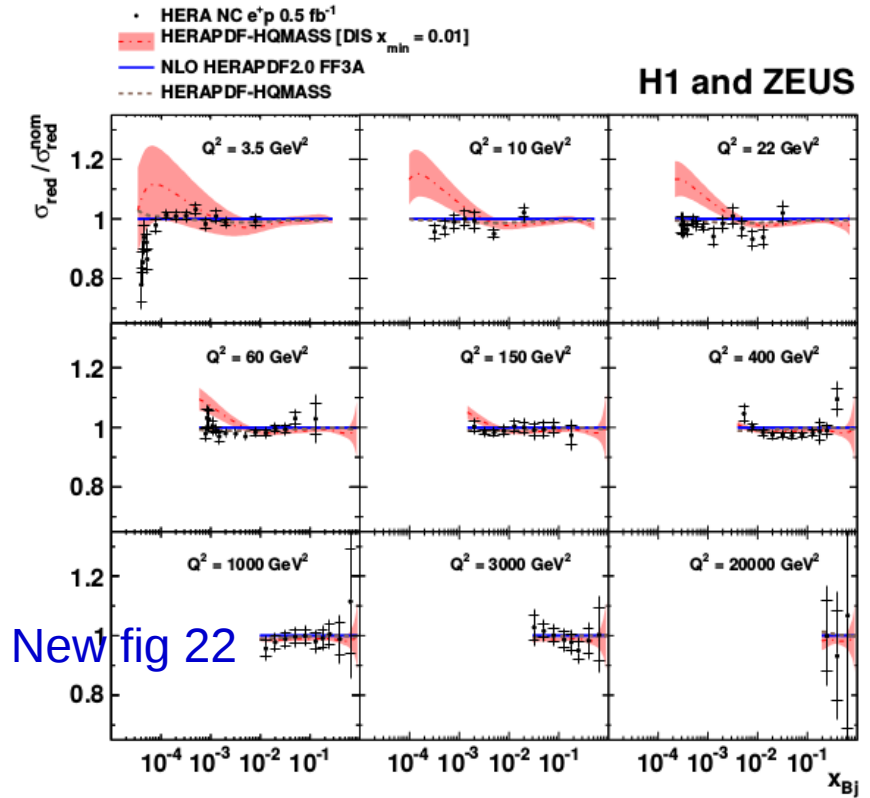
Old fig 22

- **Show only selected Q² bins**

Figure shows comparisons of our fits to inclusive HERA data

Old fig 24

New fig 22

- **New table 5 shows a detailed breakdown of the quark mass uncertainties**

Parameter	Variation	$m_c(m_c)$ uncertainty (GeV)	$m_b(m_b)$ uncertainty (GeV)
Experimental / Fit uncertainty			
Total	$\Delta\chi^2 = 1$	$+0.046$ -0.041	$+0.104$ -0.109
Model uncertainty			
f_s	$0.4^{+0.1}_{-0.1}$	-0.003 $+0.004$	-0.001 $+0.001$
Q^2_{min}	$3.5^{+1.5}_{-1.0}$ GeV^2	-0.001 $+0.007$	-0.005 $+0.007$
$\mu_{r,f}$	$\mu_{r,f} {}^{\times 2.0}_{\times 0.5}$	$+0.030$ $+0.060$	-0.032 $+0.090$
$\alpha_s^{n_f=3}(M_Z)$	$0.106^{+0.0015}_{-0.0015}$	-0.014 $+0.011$	$+0.002$ -0.005
Total		$+0.062$ -0.014	$+0.090$ -0.032
PDF parameterisation uncertainty			
$\mu^2_{f,0}$	1.9 ± 0.3 GeV^2	$+0.003$ -0.001	-0.001 $+0.001$
E_{u_v}	set to 0	-0.031	-0.031
Total		$+0.003$ -0.031	$+0.001$ -0.031

Table 5: List of uncertainties for the charm and beauty quark mass determination. The rest of PDF parameterisation uncertainties have no effect on $m_c(m_c)$ and $m_b(m_b)$.

- New tables in the appendix give fit settings and PDF parameters

	A	B	C	D	E	A'	B'
xg	2.81	−0.198	8.14			1.39	−0.273
xu_v	3.66	0.678	4.87		14.7		
xd_v	3.38	0.820	4.27				
$x\overline{U}$	0.102	−0.172	8.27	13.9			
$x\overline{D}$	0.170	−0.172	5.83				
$m_c(m_c)$ [GeV]	1.29						
$m_b(m_b)$ [GeV]	4.05						

Table A.3: Central values of the fitted parameters of HERAPDF-HQMASS.

Variation	Standard Value	Lower Limit	Upper Limit
$Q^2_{\min}$ [GeV^2]	3.5	2.5	5.0
f_s	0.4	0.3	0.5
$\alpha_s^{n_f=3}(M_Z)$	0.106	0.1045	0.1075
$\mu^2_{r,f}$	$Q^2+4m_Q^2$	$0.25\cdot(Q^2+4m_Q^2)$	$4\cdot(Q^2+4m_Q^2)$
$\mu^2_{f,0}$ [GeV^2]	1.9	1.6	2.2

Table A.2: Input parameters for the HERAPDF-HQMASS fit and the variations considered to evaluate model and parametrisation ($\mu^2_{f,0}$) uncertainties.

Summary

- Many comments were received to the paper on H1/ZEUS charm and beauty data and lead to significant improvement to draft v1

- The draft v2 is available since February 2^{nd}, 2018

- The reading (based on draft v2) is scheduled for: March 2nd, 2018

- Comments should be shared with the EB: h1zeus-eb17bc@desy.de

  (Comments to v2 are expected to address mainly the differences between v1 and v2)