

1 DESY-21-xxx
2 following H1prelim-19-041, ZEUS-prel-19-001
3

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Impact of jet-production data on the next-to-next-to-leading-order 5 determination of HERAPDF2.0 parton distributions

6 **Extra Internal Material – November 17, 2021**

7 Abstract provided for information

8 **Abstract**

9 The HERAPDF2.0 ensemble of parton distribution functions (PDFs) was introduced in
10 2015. The final stage is presented, a next-to-next-to-leading-order (NNLO) analysis of the
11 HERA data on inclusive deep inelastic ep scattering together with jet data as published by
12 the H1 and ZEUS collaborations. A perturbative QCD fit, simultaneously of $\alpha_s(M_Z^2)$ and
13 and the PDFs, was performed with the result $\alpha_s(M_Z^2) = 0.1156 \pm 0.0011$ (exp) $^{+0.0001}_{-0.0002}$ (model
14 +parameterisation) ± 0.0029 (scale). The PDF sets of HERAPDF2.0Jets NNLO were de-
15 termined with separate fits using two fixed values of $\alpha_s(M_Z^2)$, $\alpha_s(M_Z^2) = 0.1155$ and 0.118 ,
16 since the latter value was already chosen for the published HERAPDF2.0 NNLO analysis
17 based on HERA inclusive DIS data only. The different sets of PDFs are presented, eval-
18 uated and compared. The consistency of the PDFs determined with and without the jet data
19 demonstrates the consistency of HERA inclusive and jet-production cross-section data.

20 **1 Comparison of results on $\alpha_s(M_Z^2)$ determined at NLO and**
21 **NNLO:**

22 A more detailed comparison between the NLO and NNLO results must account for the following
23 differences:

- 24 • the choice of scale was different;
25 • the NLO result did not include the recently published H1 low- Q^2 inclusive and dijet data [?];
26 • the NLO result did not include the newly published low p_T points from the H1 high- Q^2
27 inclusive data;
28 • the NNLO result does not include trijet data;
29 • the NNLO result does not include the low p_T points from the ZEUS dijet data;
30 • the NNLO analysis imposes a stronger kinematic cut $\mu > 10.0$ GeV;
31 • the treatment of hadronisation uncertainty differs.

33 All these changes with respect to the NLO analysis had to be made to create a consistent envi-
34 ronment for a fit at NNLO. At the same time, an NLO fit cannot be done under exactly the same
35 conditions as the NNLO fit, since the H1 low Q^2 data cannot be well fitted at NLO. However, an
36 NLO and an NNLO fit can be done under the common conditions:

- 37 • choice of scale, $\mu_f^2 = \mu_r^2 = Q^2 + p_T^2$;
38 • exclusion of the H1 low- Q^2 inclusive and dijet data;
39 • exclusion of the low- p_T points from the H1 high- Q^2 inclusive jet data;
40 • exclusion of trijet data;
41 • exclusion of low- p_T points from the ZEUS dijet data;
42 • exclusion of data with $\mu < 10.0$ GeV;
43 • hadronisation uncertainties treated as correlated systematic uncertainties as done in the
44 NNLO analysis.

45 In this case, the values obtained were $\alpha_s(M_Z^2) = 0.1186 \pm 0.0014(\text{exp})$ at NLO and $\alpha_s(M_Z^2) =$
46 $0.1144 \pm 0.0013(\text{exp})$ at NNLO. The new NLO value of $\alpha_s(M_Z^2)$ agrees with the published [?]
47 value of 0.1183. The change of the NNLO result from the preferred value of 0.1156 is mostly
48 due to the exclusion of the H1 low Q^2 data and the low- p_T points at high Q^2 .

49 2 Gluon uncertainties

50 Detailed information concerning the source of uncertainty on the gluon PDF is presented. HERA-
 51 PDF2.0Jets NNLO uses a new way of calculating this uncertainty, eliminating some double
 52 counting. The question was whether the reduction of the uncertainty on the gluon PDF was
 53 entirely due to the new way of calculating it. Figures 1 and 2 also present the uncertainties for
 54 HERAPDF2.0Jets NNLO for the old way of calculating the uncertainty. They show that the new
 55 way of calculating the uncertainty is only important at low x .

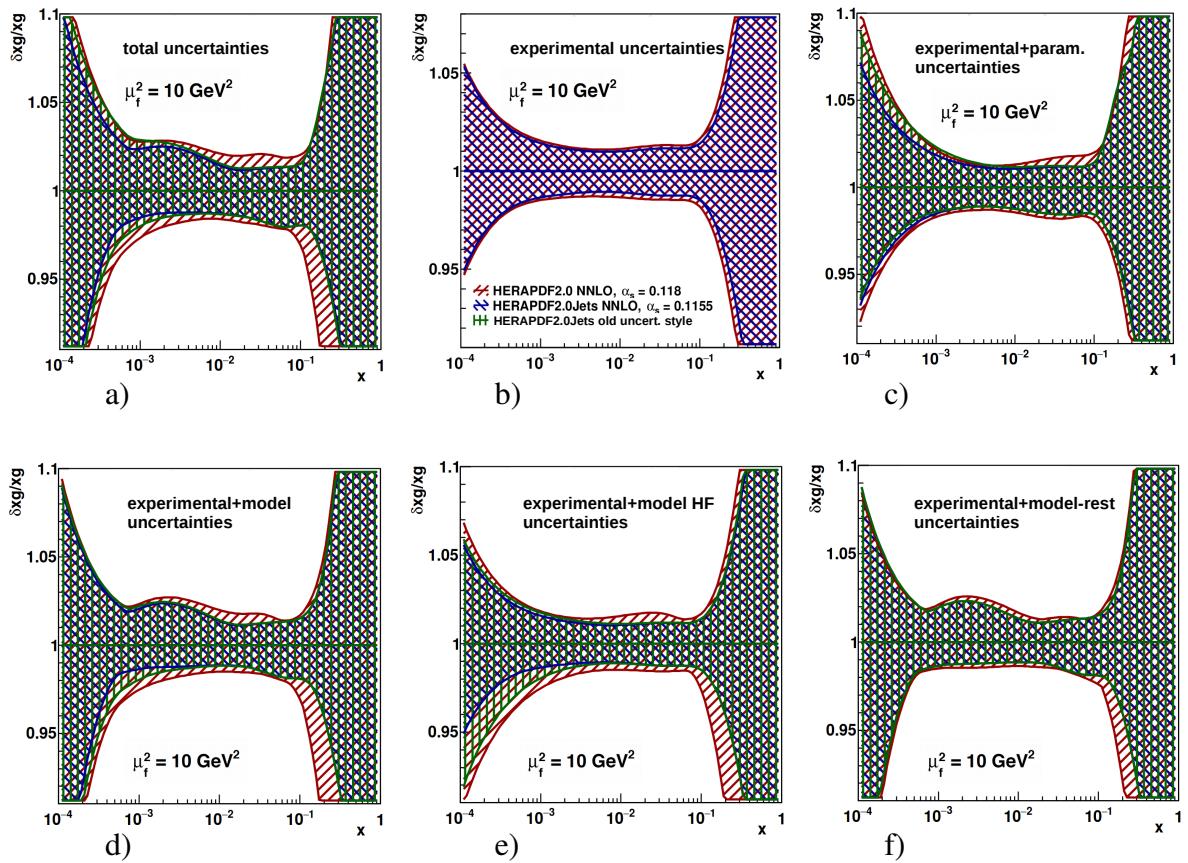


Figure 1: Comparison of the normalised uncertainties on the gluon PDFs of HERAPDF2.0Jets NNLO, HERAPDF2.0 NNLO and HERAPDF2.0Jets NNLO with the old procedure on uncertainties for a) total, b) experimental (fit), c) experimental plus parameterisation, d) experimental plus model, e) experimental plus model due to heavy-flavour uncertainties, f) experimental plus all model but heavy-flavour uncertainties, at the scale $\mu_f^2 = 10 \text{ GeV}^2$. The uncertainties on the three gluon distributions are shown as differently hatched bands. The green bands represent HERAPDF2.0Jets NNLO $\alpha_s(M_Z^2)=0.1155$ as obtained for the old procedure, i.e. with double counting.

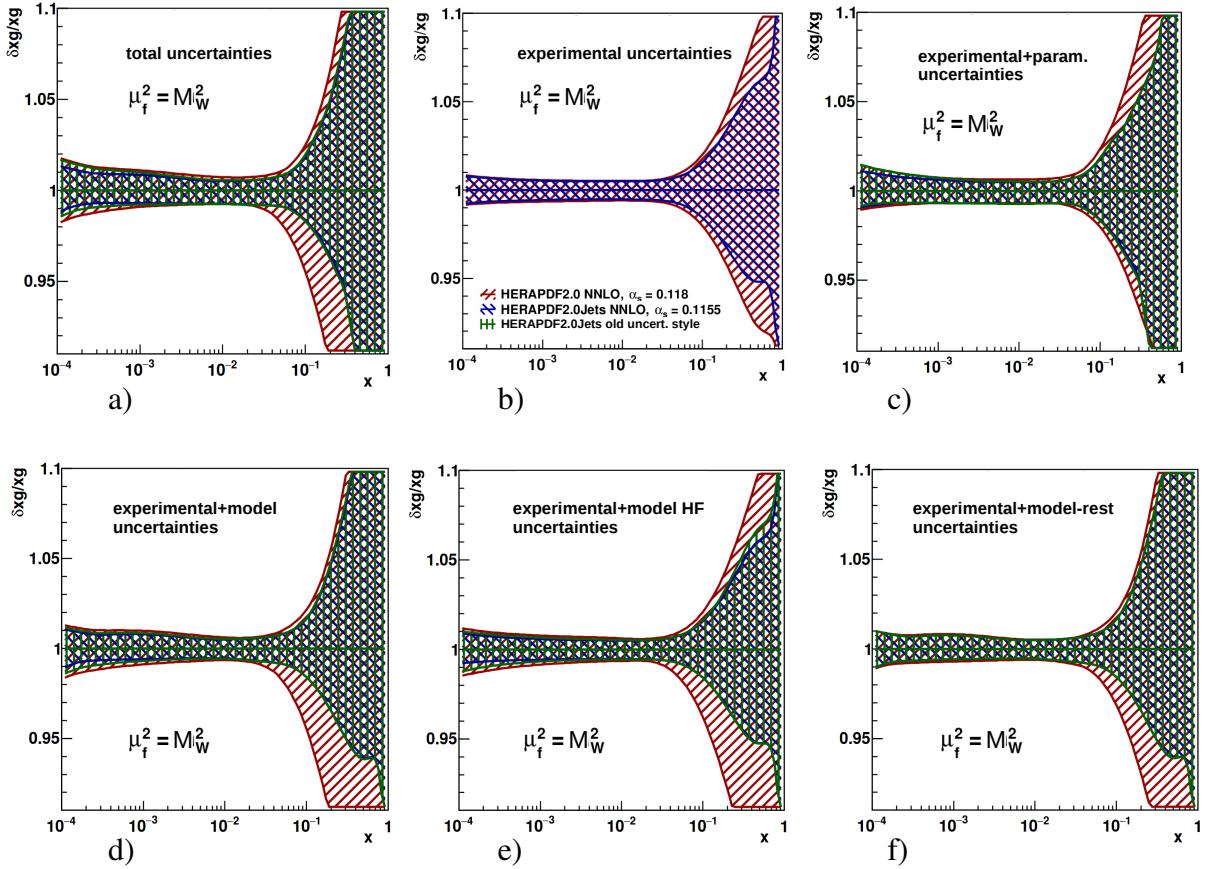


Figure 2: Comparison of the normalised uncertainties on the gluon PDFs of HERAPDF2.0Jets NNLO, HERAPDF2.0 NNLO and HERAPDF2.0Jets NNLO with the old procedure on uncertainties for a) total, b) experimental (fit), c) experimental plus parameterisation, d) experimental plus model, e) experimental plus model due to heavy-flavour uncertainties, f) experimental plus all model but heavy-flavour uncertainties, at the scale $\mu_f^2 = M_W^2$. The uncertainties on the three gluon distributions are shown as differently hatched bands. The green bands represent HERAPDF2.0Jets NNLO $\alpha_s(M_Z^2)=0.1155$ as obtained for the old procedure, i.e. with double counting.

56 3 Parameters and their correlations

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57
58 Parameters as determined by the fits and their correlations
59 =====
60
61 PARAMETERS WITH UNCERTAINTIES:
62 =====
63 as free
64 =====
65
66    2  'Bg'      -0.084608   0.071758
67    3  'Cg'       6.145485   0.553362
68    7  'Aprig'    0.148366   0.134036
69    8  'Bprig'    -0.408486   0.062832
70    9  'Cprig'    25.000000   0.000000 fixed
71   12  'Buv'      0.782478   0.027706
72   13  'Cuv'      4.878155   0.083909
73   15  'Euv'      10.390885   1.352200
74   22  'Bdv'      0.983110   0.083080
75   23  'Cdv'      4.795152   0.383854
76   33  'Cubar'    7.123114   1.699099
77   34  'Dubar'    1.995344   2.431042
78   41  'Adbar'    0.262598   0.010781
79   42  'Bdbar'    -0.128810   0.004899
80   43  'Cdbar'    9.094971   1.741850
81  101  'alphas'   0.115638   0.001142
82
83 as = 0.1155
84 =====
85
86    2  'Bg'      -0.085574   0.039648
87    3  'Cg'       6.171545   0.496131
88    7  'Aprig'    0.147903   0.040820
89    8  'Bprig'    -0.409380   0.028287
90    9  'Cprig'    25.000000   0.000000 fixed
91   12  'Buv'      0.781078   0.025867
92   13  'Cuv'      4.880050   0.080411
93   15  'Euv'      10.401539   1.289019
94   22  'Bdv'      0.983055   0.084572
95   23  'Cdv'      4.804735   0.380423
96   33  'Cubar'    7.125150   1.645404
97   34  'Dubar'    2.031948   2.222251
98   41  'Adbar'    0.262191   0.010036
99   42  'Bdbar'    -0.128934   0.004725
100  43  'Cdbar'    9.161993   1.693978
101
102 as = 0.118
103 =====
104
105    2  'Bg'      -0.070319   0.043016
106    3  'Cg'       5.670899   0.482567
107    7  'Aprig'    0.161572   0.043068
108    8  'Bprig'    -0.391610   0.027755
109    9  'Cprig'    25.000000   0.000000 fixed
110   12  'Buv'      0.806334   0.028281
111   13  'Cuv'      4.844608   0.081284
112   15  'Euv'      10.242348   1.441602
113   22  'Bdv'      0.981522   0.092135
114   23  'Cdv'      4.622768   0.397334
115   33  'Cubar'    7.137838   1.347568
116   34  'Dubar'    1.458837   1.614989
117   41  'Adbar'    0.269978   0.010673
118   42  'Bdbar'    -0.126504   0.004831
119   43  'Cdbar'    8.036277   1.509073
120
121
122
123
124 PARAMETER CORRELATION COEFFICIENTS
125 =====
126 as free
127 =====
128
129 NO. GLOBAL  2   3   7   8   12  13  15  22  23  33  34  41  42  43  101
130 2  0.99909  1.000 0.544-0.880-0.627 0.112-0.024-0.040 0.030-0.015 0.024 0.019-0.090-0.166-0.066 0.135
131 3  0.99544  0.544 1.000-0.294-0.077-0.034 0.078-0.036-0.095-0.060 0.141 0.242-0.452-0.503-0.226-0.386
132 7  0.99942  -0.880-0.294 1.000 0.914 0.101-0.067-0.115 0.033 0.028 0.010-0.001 0.025 0.028-0.026 0.092
133 8  0.99710  -0.627-0.077 0.914 1.000 0.251-0.130-0.230 0.094 0.057 0.010-0.028 0.038-0.009-0.062 0.093
134 12  0.99580  0.112-0.034 0.101 0.251 1.000-0.208-0.711 0.254 0.050 0.326 0.036 0.524 0.400 0.021 0.418
135 13  0.98055  -0.024 0.078-0.067-0.130-0.208 1.000 0.708-0.193-0.212 0.374 0.410-0.168-0.124-0.089-0.183
136 15  0.99428  -0.040-0.036-0.115-0.230-0.711 0.708 1.000-0.226-0.165 0.133 0.338-0.369-0.299-0.137-0.056
137 22  0.99034  0.030-0.095 0.033 0.094 0.254-0.193-0.226 1.000 0.892 0.370 0.287 0.266 0.228 0.591 0.020
138 23  0.98232  -0.015-0.060 0.028 0.057 0.050-0.212-0.165 0.892 1.000 0.151 0.114 0.154 0.147 0.553-0.197
139 33  0.99829  0.024 0.141 0.010 0.010 0.326 0.374 0.133 0.370 0.151 1.000 0.923-0.006-0.020 0.160 0.092
140 34  0.99812  0.019 0.242-0.001-0.028 0.036 0.410 0.338 0.287 0.114 0.923 1.000-0.253-0.252 0.228-0.108
141 41  0.97212  -0.090-0.452 0.025 0.038 0.524-0.168-0.369 0.266 0.154-0.006-0.253 1.000 0.950 0.168 0.330
142 42  0.97595  -0.166-0.503 0.028-0.009 0.409-0.124-0.299 0.228 0.147-0.020-0.252 0.950 1.000 0.188 0.220
143 43  0.98859  -0.066-0.226-0.026-0.062 0.021-0.089-0.137 0.591 0.553 0.160 0.228 0.168 0.188 1.000-0.291 1.000
144 101 0.99603  0.135-0.386 0.002 0.093 0.418-0.183-0.056 0.020-0.197 0.002-0.108 0.330 0.220-0.291 1.000
145
146 as = 0.1155
147 =====
148
149 NO. GLOBAL  2   3   7   8   12  13  15  22  23  33  34  41  42  43

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150   2  0.99909  1.000  0.653-0.891-0.656  0.060  0.002-0.031  0.027  0.012  0.023  0.033-0.145-0.204-0.027
151   3  0.99467  0.653  1.000-0.325-0.056  0.160  0.023-0.053-0.078-0.144  0.171  0.230-0.374-0.465-0.372
152   7  0.99943 -0.891-0.325  1.000  0.920  0.109-0.063-0.112  0.034  0.029  0.014  0.004  0.028  0.032-0.025
153   8  0.99712 -0.656-0.056  0.920  1.000  0.231-0.111-0.221  0.092  0.076  0.012-0.013  0.010-0.027-0.035
154  12  0.99499  0.060  0.160  0.109  0.231  1.000-0.117-0.734  0.285  0.154  0.379  0.134  0.442  0.340  0.171
155  13  0.98052  0.002  0.023-0.063-0.111-0.117  1.000  0.713-0.154-0.239  0.418  0.433-0.118-0.092-0.132
156  15  0.99429 -0.031-0.053-0.112-0.221-0.734  0.713  1.000-0.203-0.171  0.161  0.344-0.373-0.296-0.148
157  22  0.99053  0.027-0.078  0.034  0.092  0.285-0.154-0.203  1.000  0.910  0.404  0.331  0.265  0.220  0.625
158  23  0.98154  0.012-0.144  0.029  0.076  0.154-0.239-0.171  0.910  1.000  0.169  0.115  0.233  0.196  0.530
159  33  0.99858  0.023  0.171  0.014  0.012  0.379  0.418  0.161  0.404  0.169  1.000  0.940  0.000-0.223-0.228
160  34  0.99841  0.033  0.230  0.004-0.013  0.134  0.433  0.344  0.331  0.115  0.940  1.000-0.223-0.228  0.228
161  41  0.96869 -0.145-0.374  0.028  0.010  0.442-0.118-0.373  0.265  0.233-0.017-0.223  1.000  0.953  0.287
162  42  0.97473 -0.204-0.465  0.032-0.027  0.340-0.092-0.296  0.220  0.196-0.033-0.229  0.953  1.000  0.264
163  43  0.98749 -0.027-0.372-0.025-0.035  0.171-0.132-0.148  0.625  0.530  0.192  0.228  0.287  0.264  1.000
164
165 as = 0.118
166 ======
167
168 NO. GLOBAL    2     3     7     8    12    13    15    22    23    33    34    41    42    43
169  2  0.99830  1.000  0.584-0.794-0.507  0.052-0.002-0.029-0.005-0.017  0.025  0.045-0.188-0.238-0.067
170  3  0.99467  0.584  1.000-0.086  0.184  0.146-0.004-0.071-0.148-0.192  0.160  0.233-0.432-0.517-0.453
171  7  0.99906 -0.794-0.086  1.000  0.917  0.190-0.095-0.183  0.071  0.059  0.029  0.015-0.019-0.048-0.030
172  8  0.99645 -0.507  0.184  0.917  1.000  0.308-0.142-0.288  0.115  0.094  0.033  0.008-0.065-0.131-0.053
173 12  0.99521  0.052  0.146  0.190  0.308  1.000-0.176-0.777  0.302  0.184  0.381  0.166  0.429  0.321  0.216
174 13  0.98045 -0.002-0.004-0.095-0.142-0.176  1.000  0.712-0.219-0.278  0.360  0.389-0.112-0.079-0.150
175 15  0.99461 -0.029-0.071-0.183-0.288-0.777  0.712  1.000-0.258-0.208  0.089  0.264-0.354-0.270-0.188
176 22  0.99185 -0.005-0.148  0.071  0.115  0.302-0.219-0.258  1.000  0.920  0.351  0.291  0.287  0.238  0.666
177 23  0.98399 -0.017-0.192  0.059  0.094  0.184-0.278-0.208  0.920  1.000  0.159  0.107  0.248  0.208  0.556
178 33  0.99867  0.025  0.160  0.029  0.033  0.381  0.360  0.089  0.351  0.159  1.000  0.948  0.010-0.006  0.135
179 34  0.99849  0.045  0.233  0.015  0.008  0.166  0.389  0.264  0.291  0.107  0.948  1.000-0.178-0.186  0.157
180 41  0.96829 -0.188-0.432-0.019-0.065  0.429-0.112-0.354  0.287  0.248  0.010-0.178  1.000  0.953  0.337
181 42  0.97500 -0.238-0.517-0.048-0.131  0.321-0.079-0.270  0.238  0.208-0.006-0.186  0.953  1.000  0.312
182 43  0.99021 -0.067-0.453-0.030-0.053  0.216-0.150-0.188  0.666  0.556  0.135  0.157  0.337  0.312  1.000
183
184

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