The NNLO parton distributions in the 3-, 4-, and 5-flavour schemes

(S.Alekhin, IHEP, Protvino)

sa-Blümlein-Klein-Moch [arXiv:0908.2766 [hep-ph]]

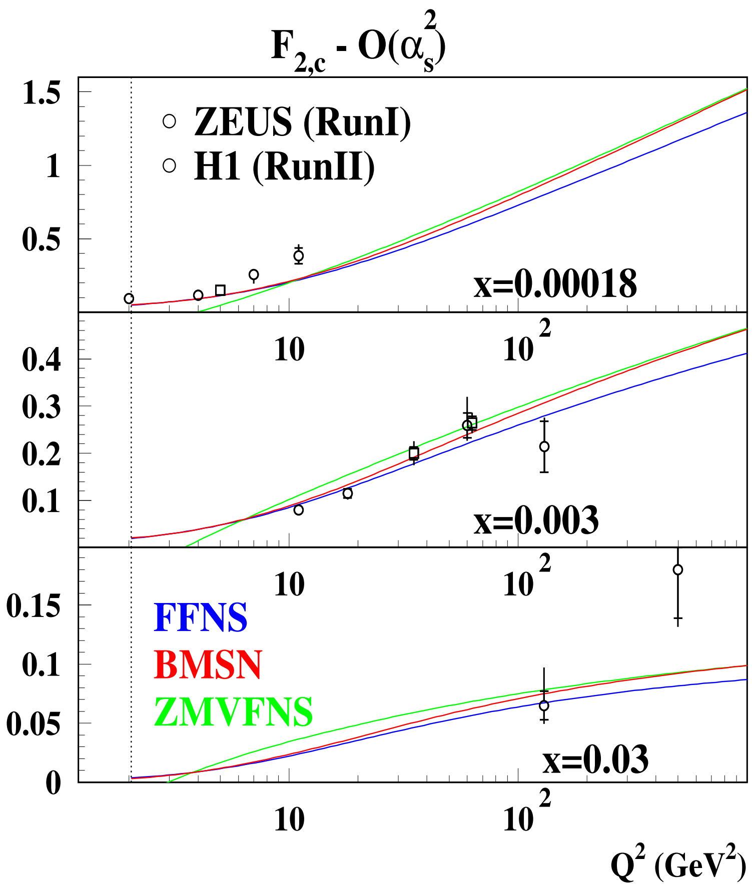
Update of the NNLO A06 fit

The 3-flavour PDFs are extracted from the fit with the NNLO PDFs evolution and the NNLO approximation for the light-parton coefficient functions.

- the inclusive DIS data with the transferred momentum $Q^2 > 2.5$ GeV^2 (SLAC-BCDMS-NMC-H1-ZEUS).
- the fixed target Drell-Yan data by FNAL-E-605 (p Cu) and FNAL-E-866 (pp/pD).
- data on dimuon production in the νN interactions by the CCFR and NuTeV collaborations

The heavy quark contribution to the charged-lepton DIS is calculated in the $O(\alpha_s^2)$ and Two variants of the fit, in the FFN and in the VFN schemes are considered. The 3-, 4-, and 5- flavour PDFs are generated using the $O(\alpha_s^2)$ Buza-Matiounine-Smith-van Neerven (BMSN) matching conditions.

$$F_{2,c}^{\mathrm{BMSN}} = F_{2,c}^{\mathrm{FFNS}}(N_f = 3) + F_{2,c}^{\mathrm{ZMVFNS}}(N_f = 4) - F_{2,c}^{\mathrm{ASYMP}}(N_f = 3)$$

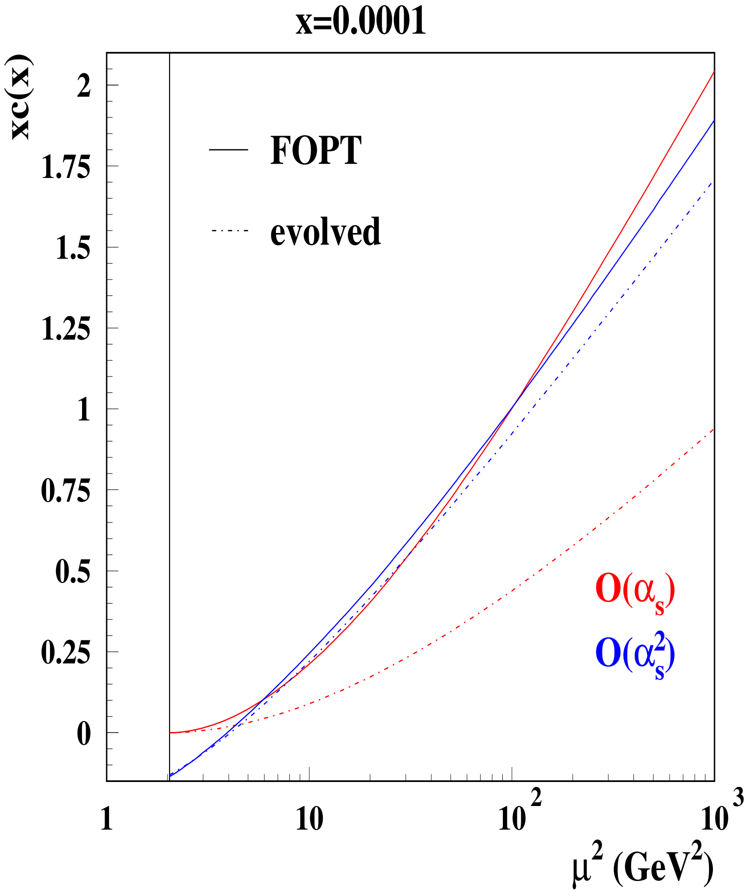


- The BMSN prescription for VFNS provides a smooth transition between the FFNS and ZMVFNS, it is not too far from the FFNS for the realistic HERA kinematics.
- The remaining discrepancies with the data at small Q can be rather cured by the NNLO corrections than by the VFNS.

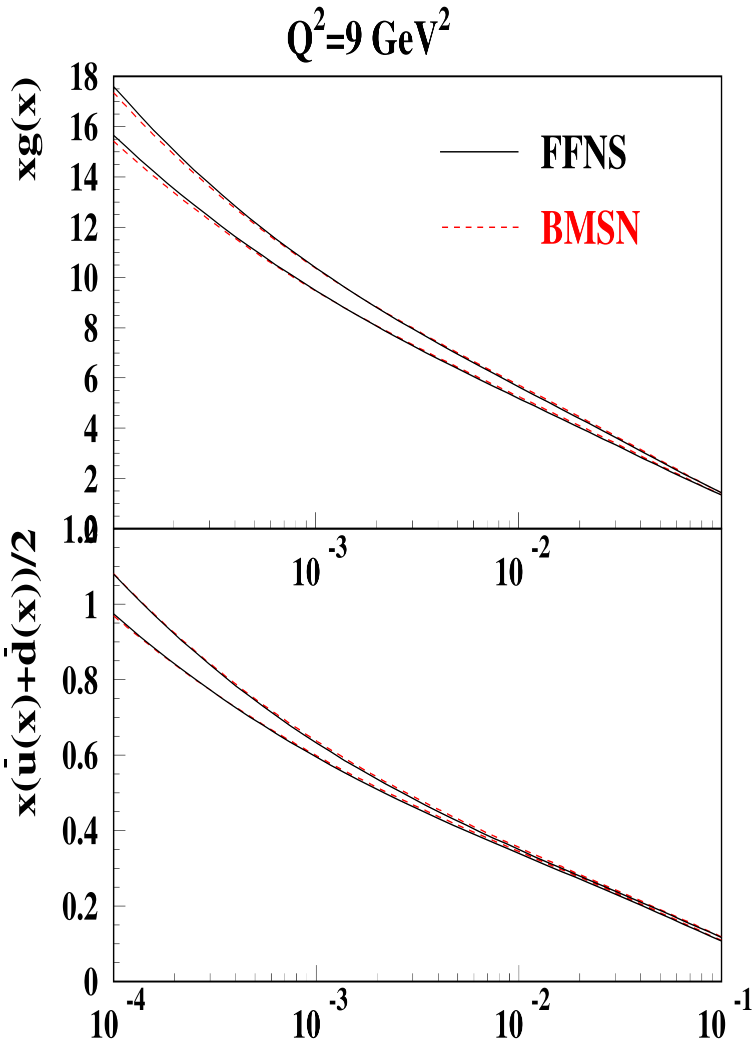
(sa-Moch 08)

$$A_{H,i}^{(1)} = a_{H,i}^{(1,1)} \ln(\mu^2/m_H^2) \qquad O(\alpha_s)$$

$$A_{H,i}^{(2)} = a_{H,i}^{(2,0)} + a_{H,i}^{(2,1)} \ln(\mu^2/m_H^2) + a_{H,i}^{(2,2)} \ln^2(\mu^2/m_H^2) \qquad O(\alpha_s^2)$$



The operator-matrix elements (OMEs), which provide the matching between (N_f)- and (N_f+1)- flavour schemes are calculated in the fixed-order of QCD. In the $O(\alpha_\mathrm{s})$ the difference between the evolved and the FOPT PDFs is sizable and rise with μ, however in the $O(\alpha_\mathrm{s}^2)$ it is greatly reduced due to the large-log terms appearing as a result of the PDF evolution are partially taken into account in the OMEs.

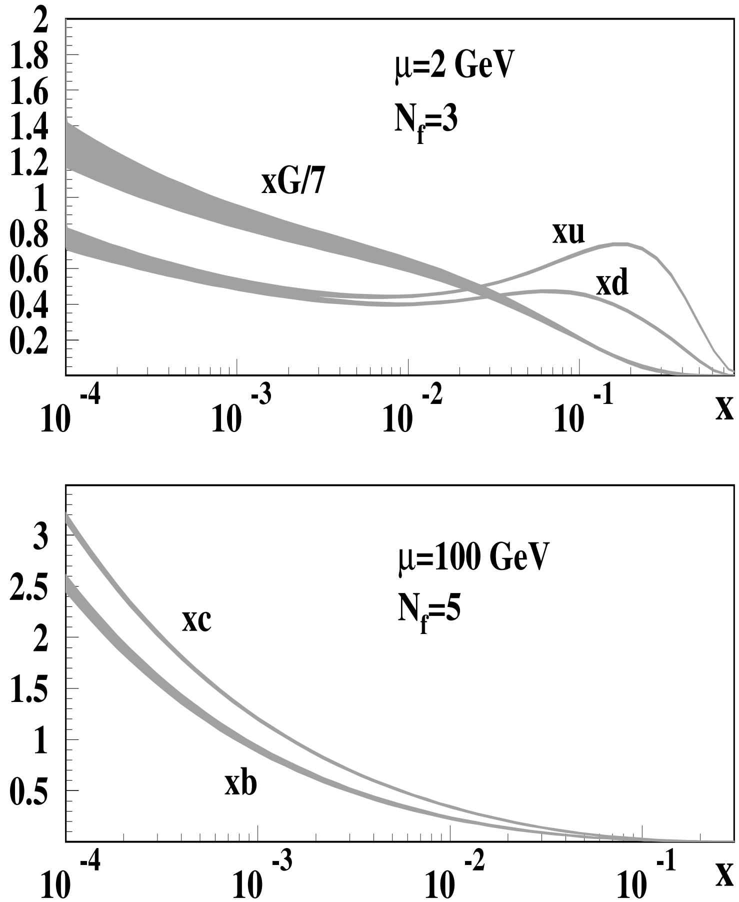


- Impact of the scheme choice on the PDFs is marginal, if only the GMVFN scheme provides smooth matching with the FFN one. For the sea and gluon distribution at small x effect is well within 1σ; other PDFs are practically the same.

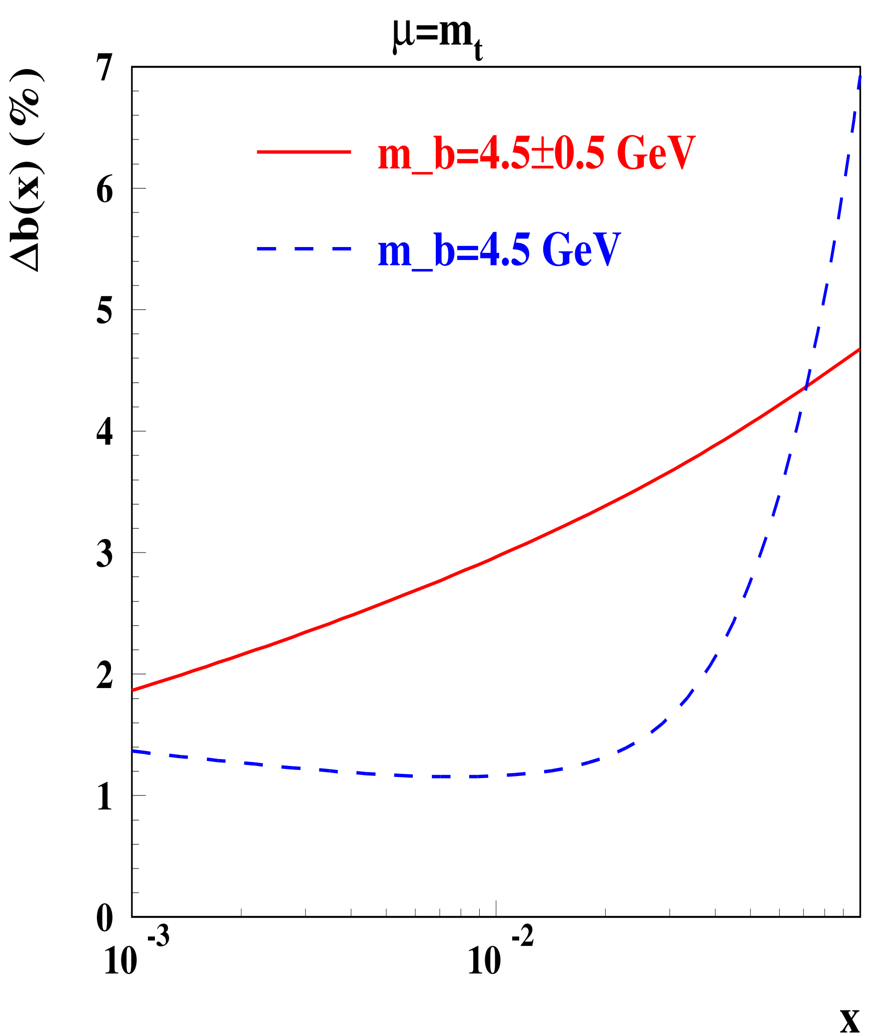
(Cooper-Sarkar 07)

- *The VFNS is useless for the analysis of available DIS data with account of the corrections up to $O(\alpha_s^2)$ due to limited kinematics.*

(Glück-Reya-Stratmann 94)



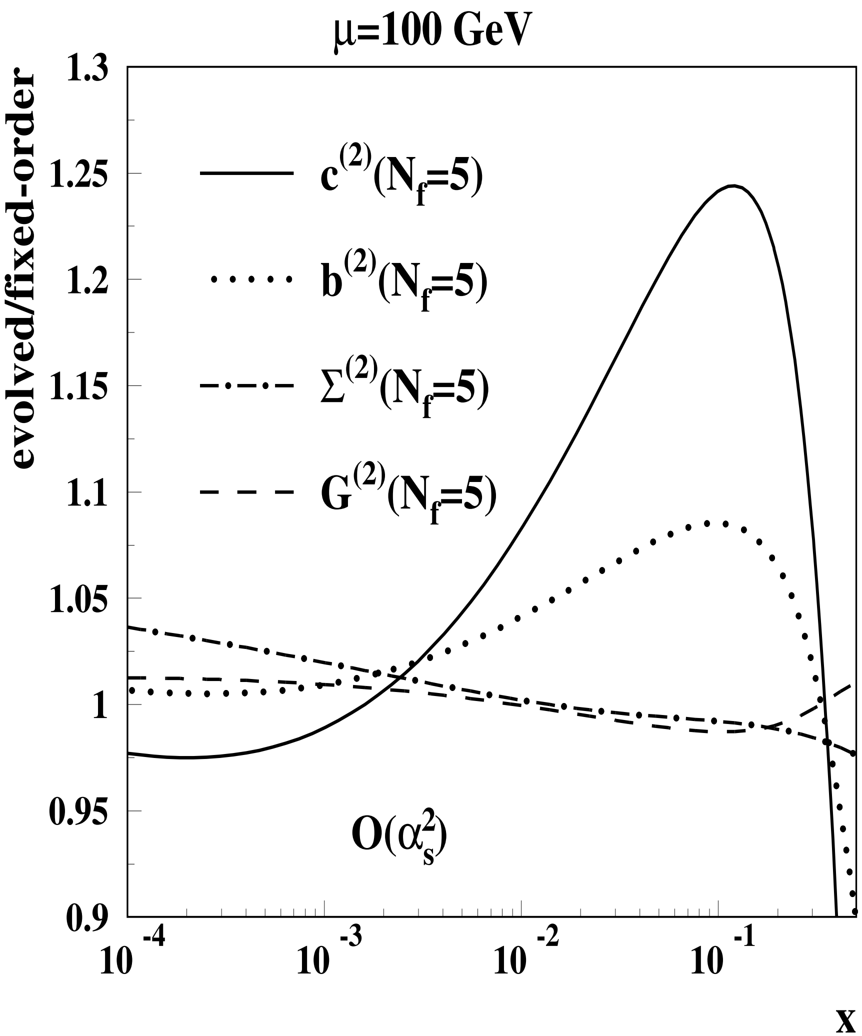
- The 4-flavour NNLO PDFs are matched with the 3-flavour ones at $\mu = m_c$ and evolved above this scale. This allows to take into account the large-logs missed in the FOPT OMEs.
- the 5-flavour PDFs are similarly matched with the 4-flavour ones at $\mu = m_b$ and evolved above $\mu = m_b$.



- For the typical kinematics of the single-top production uncertainty in $b(x)$ due to the experimental data is $1.5 \div 7\%$ $(\Delta\chi^2 = 1)$.
- The uncertainty due to the b-quark mass variation

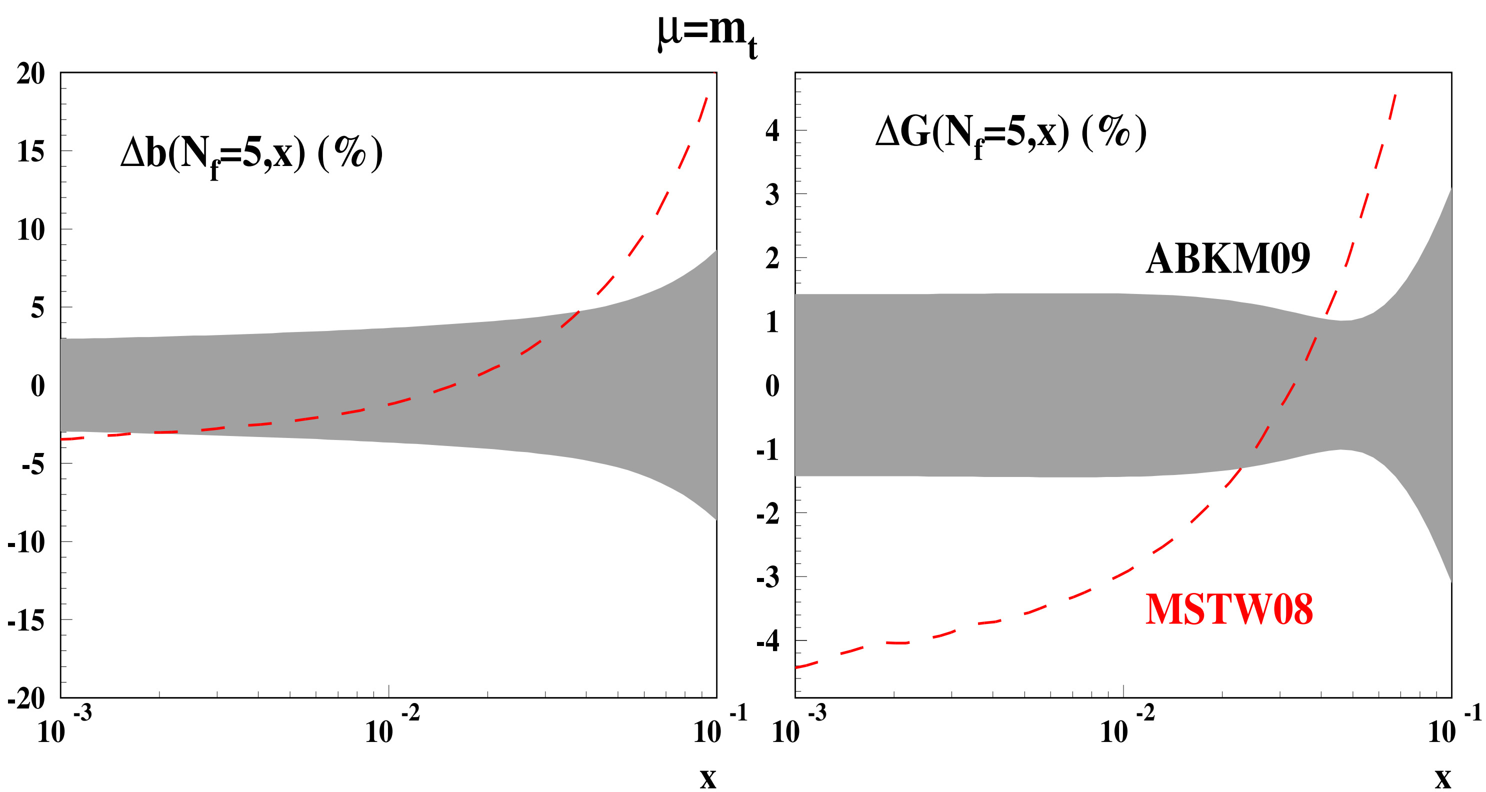
$$(\Delta b/b)_M \sim \frac{\Delta m_b/m_b}{\ln(\mu/m_b)}$$

is $2 \div 5\%$ at $\mu = m_t$ and dominates over the experimental one at $x \lesssim 0.05$ (LHC kinematics).

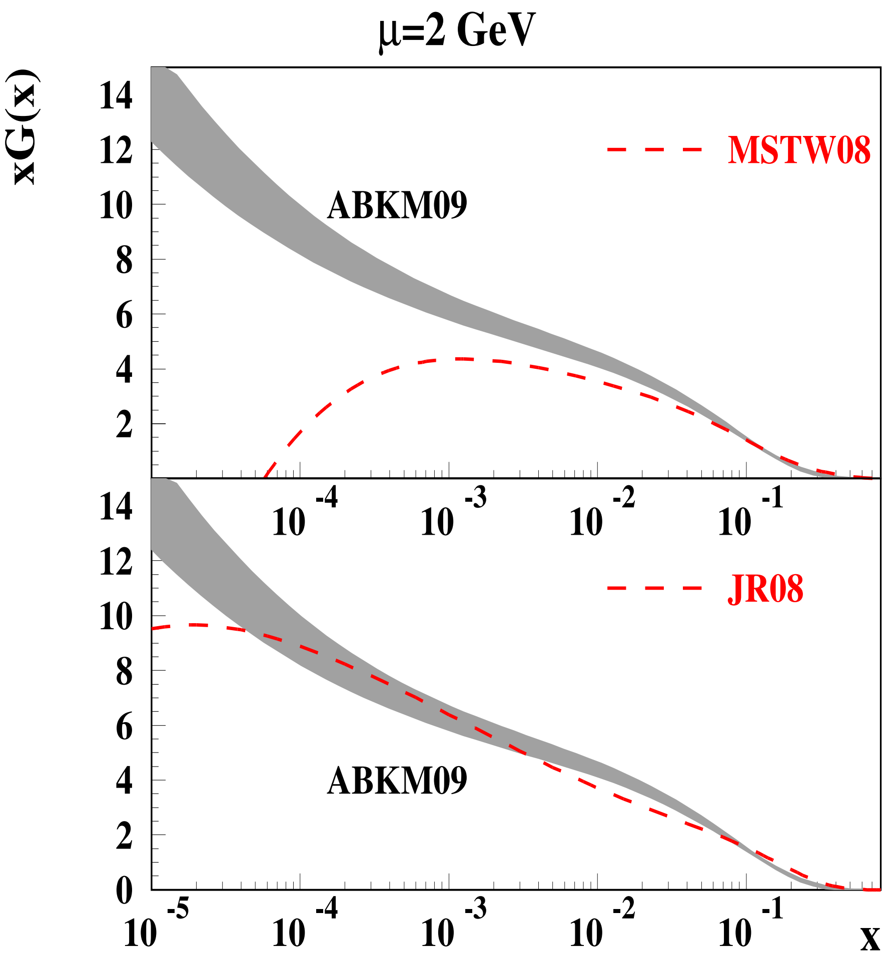


- The ratio of the evolved and fixed-order PDFs gives estimate of the uncertainty due to the high-order corrections. In the $O(\alpha_s^2)$ it is O(1%) at small x. At large x it is bigger, up to 25% and 8% for the c- and b-quark distributions, respectively.
- With the $O(\alpha_s^3)$ correction to the OME's taken into account the uncertainty should be reduced.

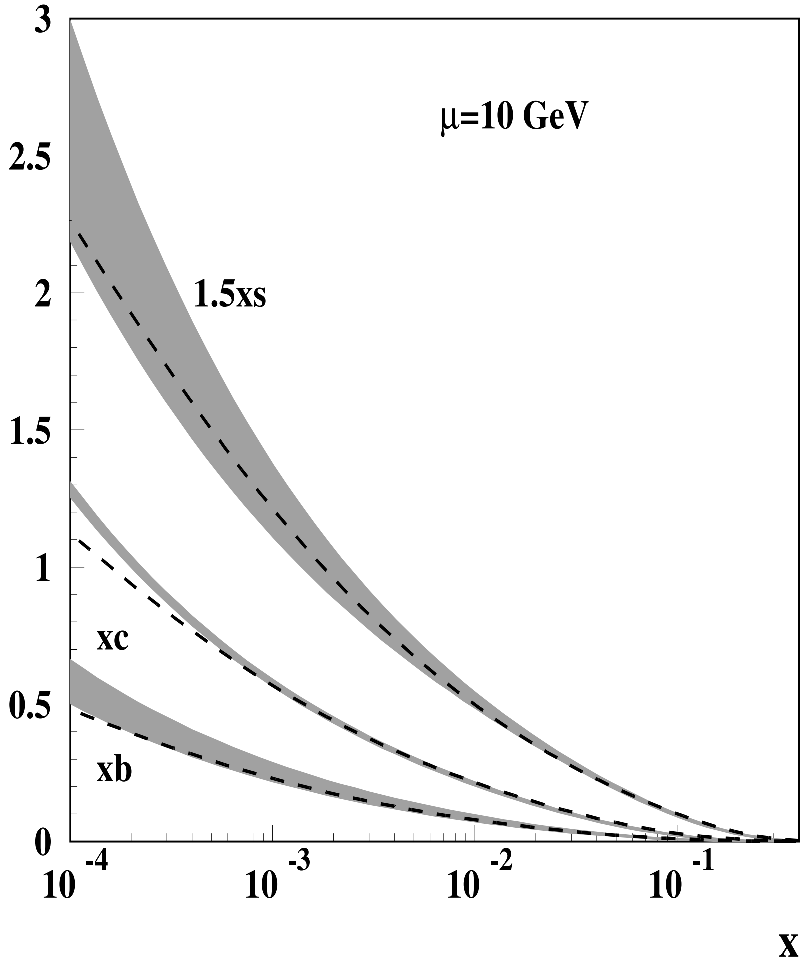
(Bierenbaum-Blümlein-Klein 09)



At small x the NNLO MSTW08 b-quark distribution is somewhat smaller than the ABKM09 one due to the difference in the gluons of these two sets.



- At small μ the MSTW08 gluons are much lower than the ABKM09 ones and gets negative at $x \lesssim 10^{-4}$.
- Agreement between the JR08 and ABKM09 gluons is much better. These two analyzes employ the FFN scheme, while the MSTW08 is based on the VFN scheme (note the negative gluons are disfavored by the RunII H1 measurements of F_L at small x/Q and the Fermilab collider data do not affect the recent MSTW fit).



- A strange sea suppression factor $\kappa(20\ \text{GeV}^2) = 0.62 \pm 0.04(\text{exp.}) \pm 0.03(\text{QCD})$, somewhat bigger than earlier determination by CCFR. The strange/anti-strange asymmetry is comparable to zero.

(sa-Kulagin-Petti 08)

- The strange sea distribution is most uncertain between the PDFs due to the lack of dimuon data at $x \lesssim 0.01$ (we release the low-x exponent in our fit).

Summary

We have update of the NNLO fit with the 3-, 4-, or 5- flavour PDFs available at

`https://mail.ihep.ru/~alekhin/pdfs.html`

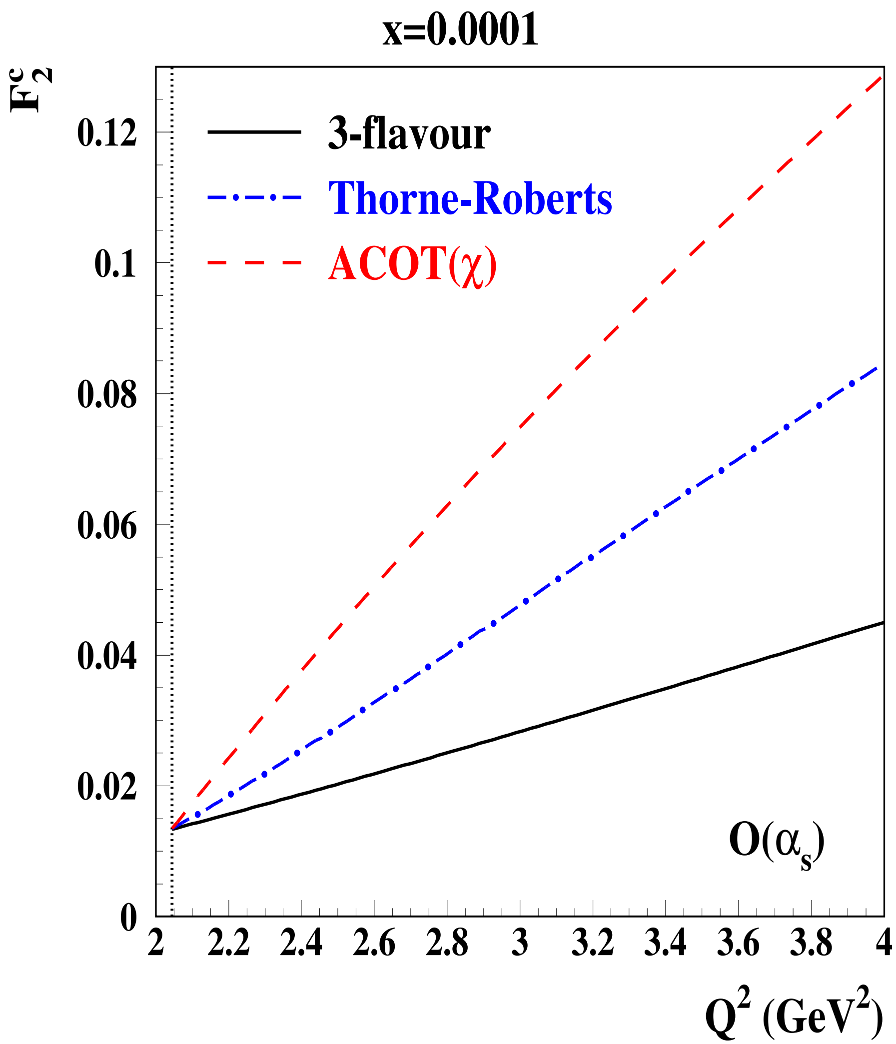
Depending on the convenience and the Wilson coefficient availability a particular set or a mixture of them can used (for our fit we take the 3-flavour PDF for the DIS data and the 5-flavour PDFs for the Drell-Yan c.s.).

BACKUP

The gluon distribution at small x is constrained by the HERA data mainly. At the HERA kinematics up to 30% of the inclusive cross section is given by the heavy-quark production contributions. At large $Q^2 \gg m_c$ the structure function $F_{2,c}$ can be described within the ZMVFN scheme, however at $Q^2 \sim m_c^2$ it is clearly irrelevant since the power corrections in $F_{2,c}^{\rm FFNS}$ spoil the collinear factorization.

A complete definition of the general-mass VFNS should include a matching between $F_{2,c}^{\rm FFNS}$ at small Q^2 and $F_{2,c}^{\rm ZMVFNS}$ at large Q^2. This matching cannot be derived from the first principles and must be modeled, with a natural requirement of the smooth transition between the large- and small-Q^2 regions.

Number of GMVFNS prescriptions were used in the global PDF fits (Thorne-Roberts, Thorne, ACOT(χ),...).



Different variants of the GM-VFNS used in the global PDFs fits demonstrate a kink in the matching region. It cannot be attributed to the large-log effects and just reflects uncertainty in the ingredients of these models. On a practical side this leads to overestimation of the heavy-quark contribution and corresponding suppression of the other PDFs.