The b-quark distribution in nucleon

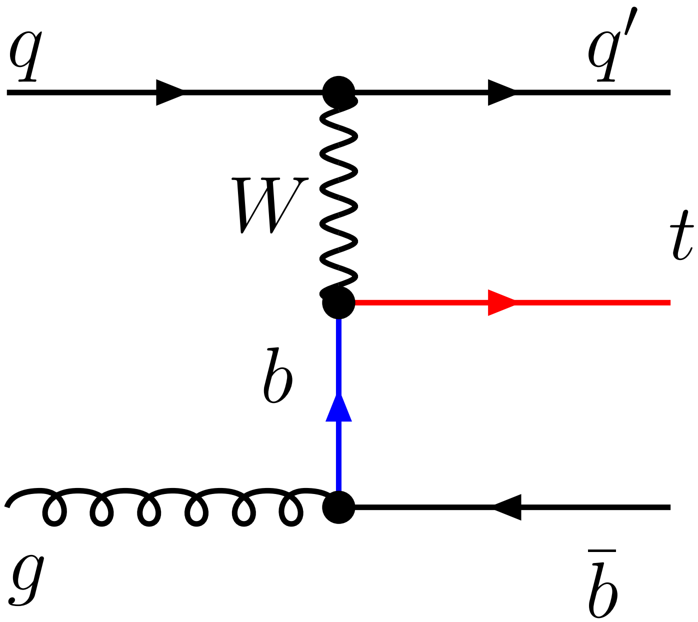
(S.Alekhin, IHEP, Protvino)

- the Variable-Flavour-Number scheme formalism
- general properties of the heavy-quark distributions
- uncertainties in the b-quark distributions
- comparison of different PDF sets

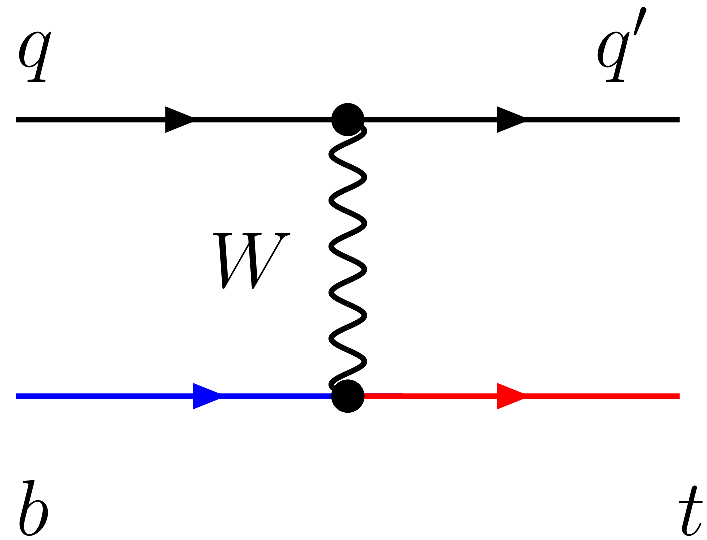
sa-Blümlein-Klein-Moch [arXiv:0908.2766 [hep-ph]]

sa-Moch [arXiv:0811.1412 [hep-ph]]

FFNS



ZMVFNS



$$\sigma \sim C^{\mathrm{FFNS}} \otimes q \otimes G$$

$$\sigma \sim C^{\mathrm{light}} \otimes b \otimes q$$

$$C^{\mathrm{FFNS}} \approx C^{\mathrm{light}} \otimes A_{b,G}$$

$$b = A_{b,G} \otimes G$$

$$(\mu_F \sim m_t \gg m_b)$$

The OMEs $A_{h,i}$ are process independent and its convolution with the N_f-flavour PDFs $p_i(N_f)$ is considered as a heavy-quark PDF.

$$h = A_{h,i} \otimes p_i(N_f).$$

The light-partons are modified accordingly with the corresponding OMEs employed

$$p_j(N_f + 1) = A_{j,i} \otimes p_i(N_f)$$

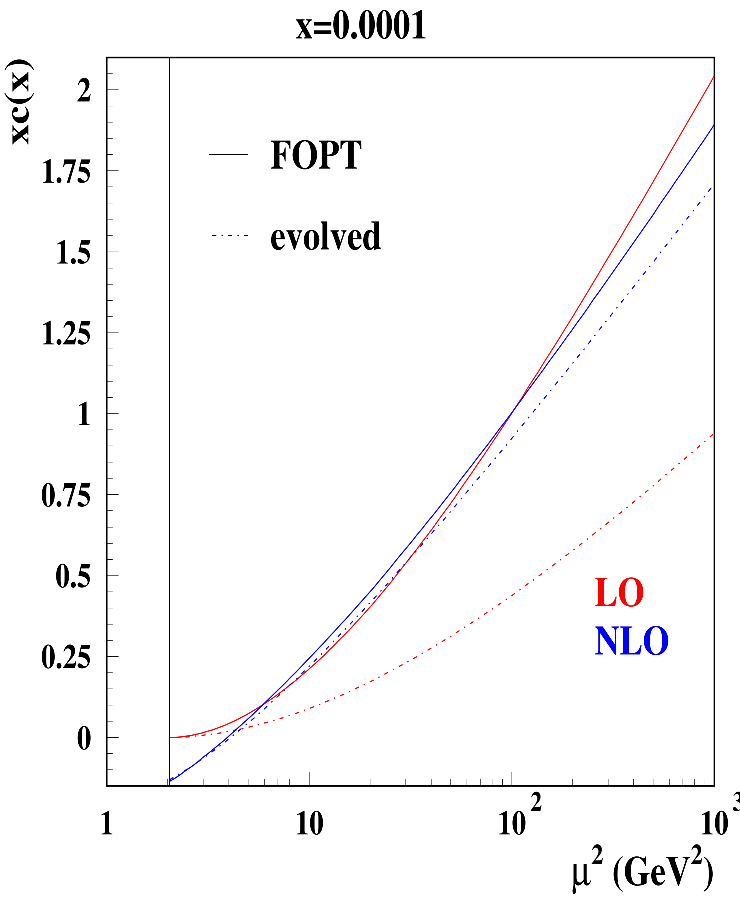
that gives the light $(N_f + 1)$-flavour PDFs. The total momentum is conserved

$$\int_0^1 dx[2h(x) + \sum_{i=1}^{N_f} p_i^h(N_f + 1, x)] = 1.$$

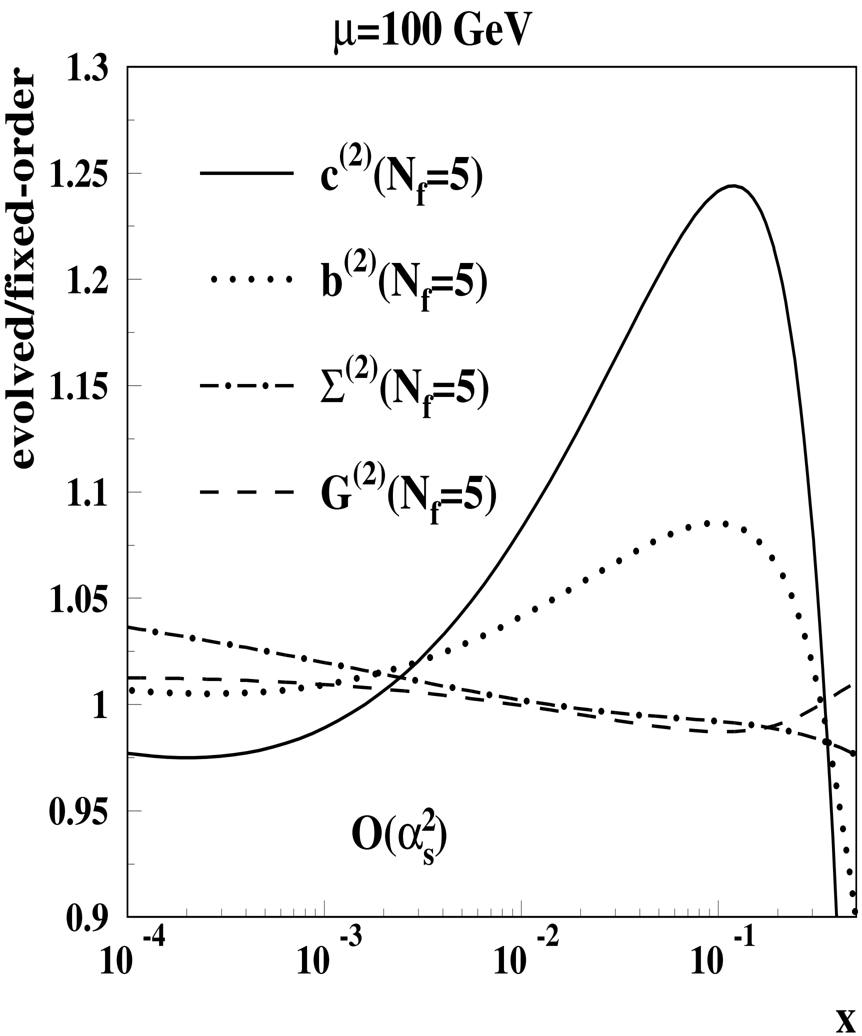
(Buza-Matiounine-Smith-van Neerven)

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

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



The OMEs are calculated in the fixed-order of QCD. In the $O(\alpha_s)$ the difference between the evolved and the FOPT PDFs is sizable and rise with μ, however in the $O(\alpha_s^2)$ 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.



- 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 8% for the b-quark distribution.
- With the $O(\alpha_s^3)$ correction to the OME's taken into account the uncertainty should be reduced.

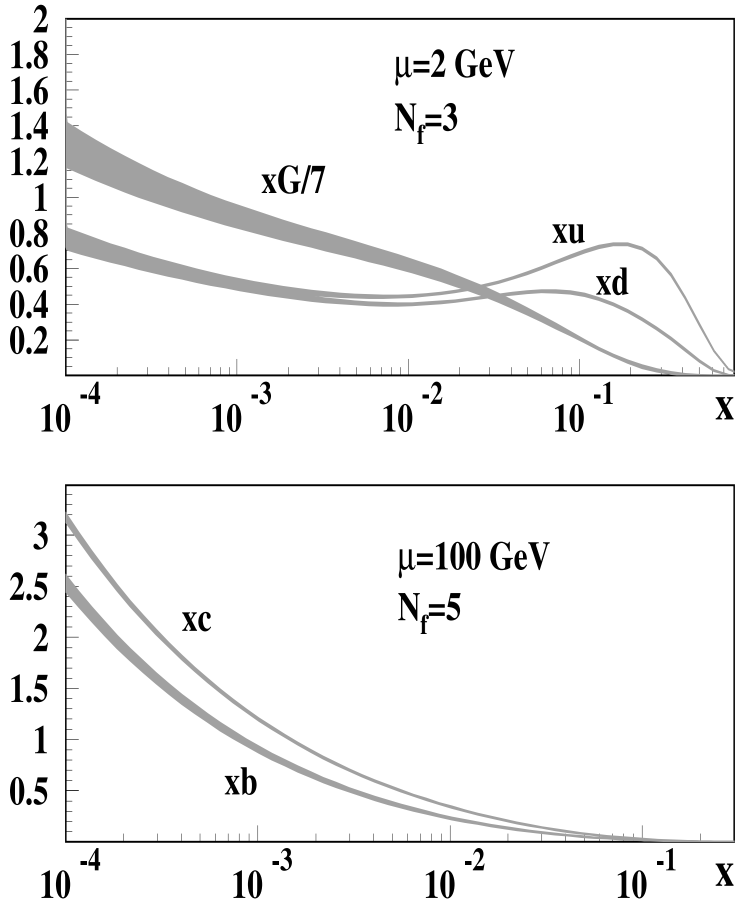
(Bierenbaum-Blümlein-Klein 09)

The 3-flavour PDFs are extracted from the fit to

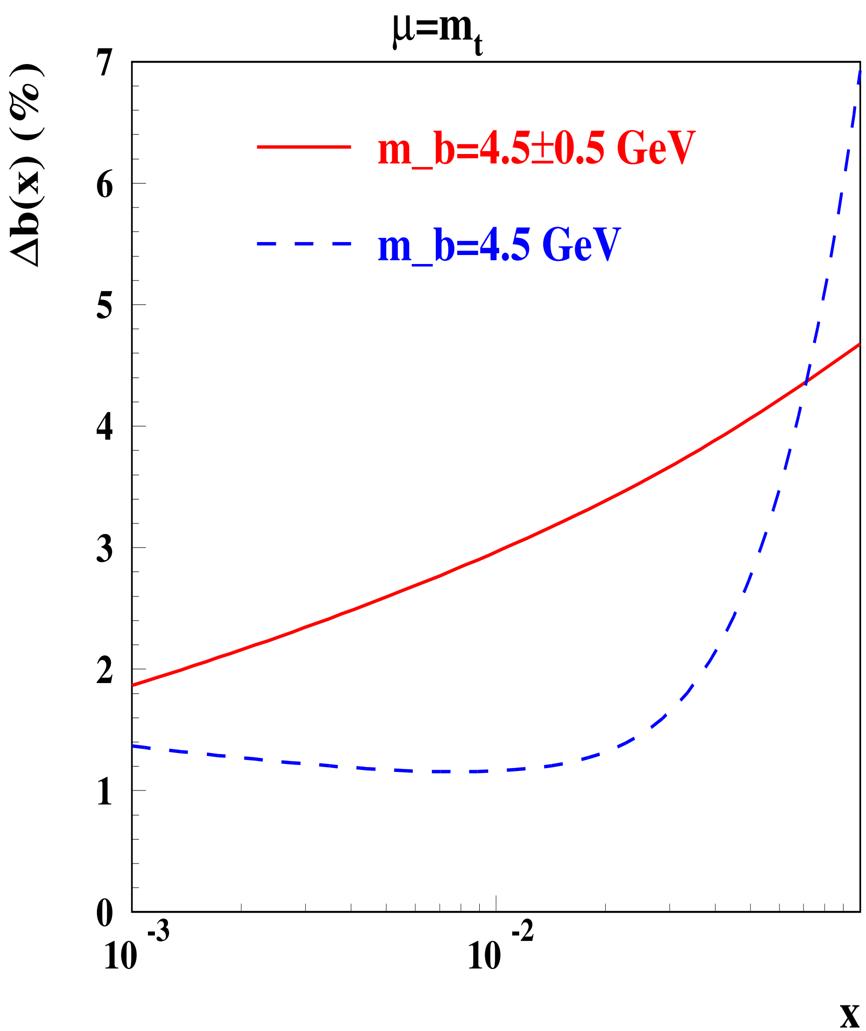
- the inclusive DIS data with the transferred momentum $Q^2 > 2.5$ GeV^2 (SLAC-BCDMS-NMC-H1-ZEUS).
- the fixed target Drell-Yan data by FNAL-E-605 (p Cu) and FNAL-E-866 (pp/pD).
- data on dimuon production in the νN interactions by the CCFR and NuTeV collaborations

in the NNLO approximation for the PDFs evolution and the light-parton coefficient functions. The heavy quark contribution to the charged-lepton DIS is calculated in the $O(\alpha_{\rm s}^2)$ in the 3-flavour scheme.

(sa-Blümlein-Klein-Moch 09)



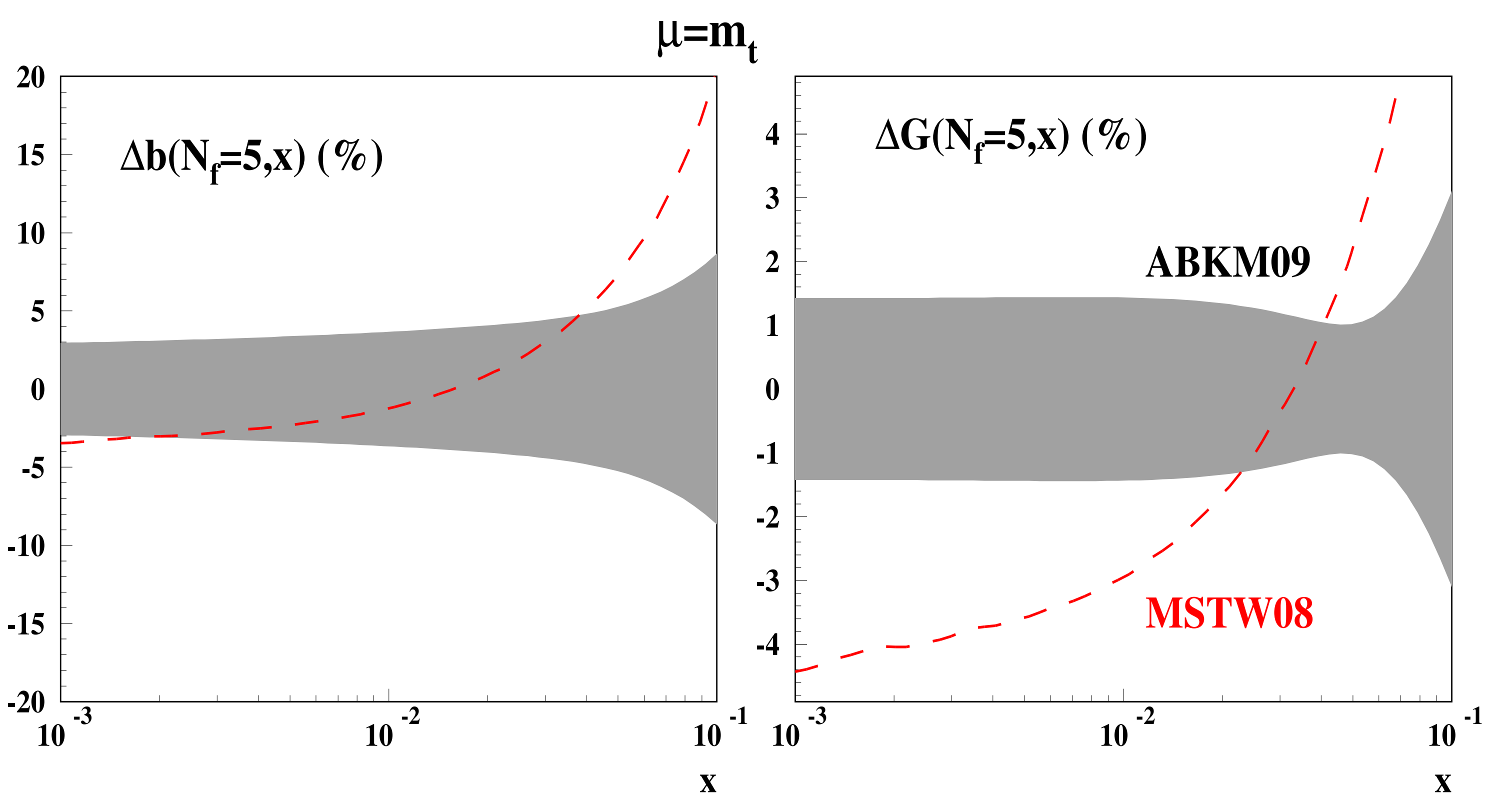
- The 4-flavour NNLO PDFs are matched with the 3-flavour ones at $\mu = m_c$ and evolved above this scale. This allows to take into account the large-logs missed in the FOPT OMEs.
- the 5-flavour PDFs are similarly matched with the 4-flavour ones at $\mu = m_b$ and evolved above $\mu = m_b$.
- The value of $m_b \sim m_c$ therefore decoupling of the c- and b-quark contributions is incomplete. This is a source of theoretical uncertainty in the 5-flavour PDFs.



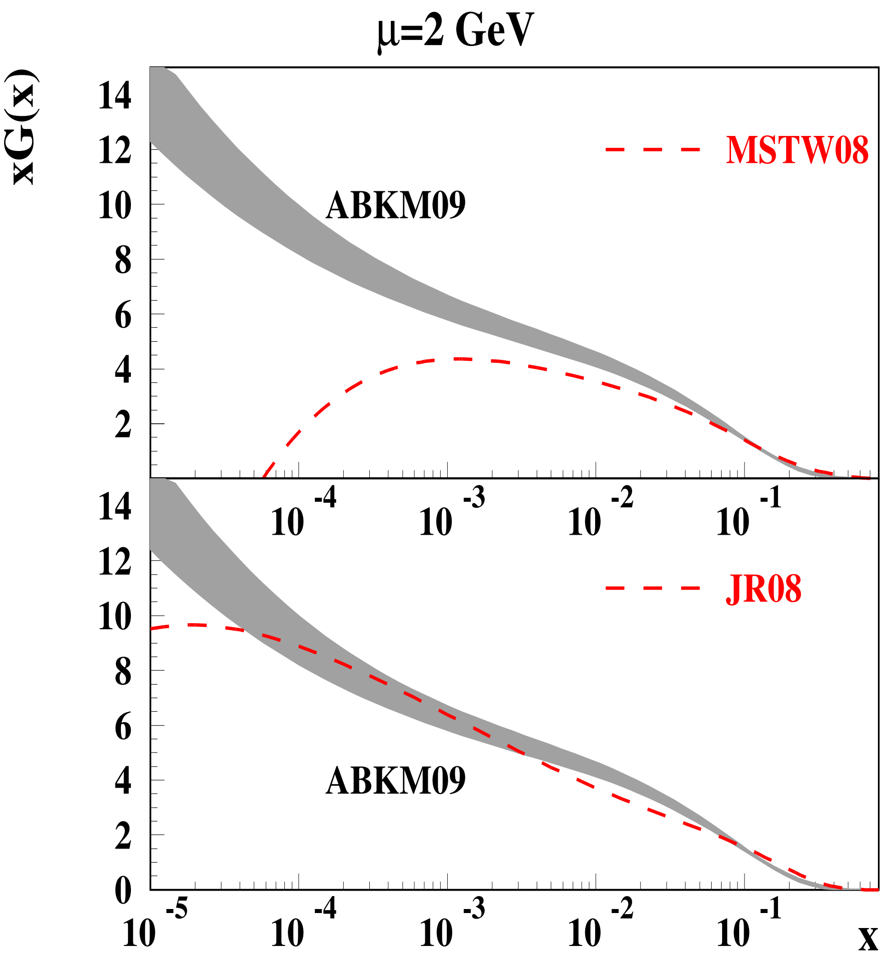
- For the typical kinematics of the single-top production uncertainty in $b(x)$ due to the experimental data is $1.5 \div 7\%$ ($\Delta\chi^2 = 1$).
- The uncertainty due to the b-quark mass variation

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

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



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. For the CTEQ case comparison with ABKM09 is inconclusive since the NNLO CTEQ PDFs are unavailable.

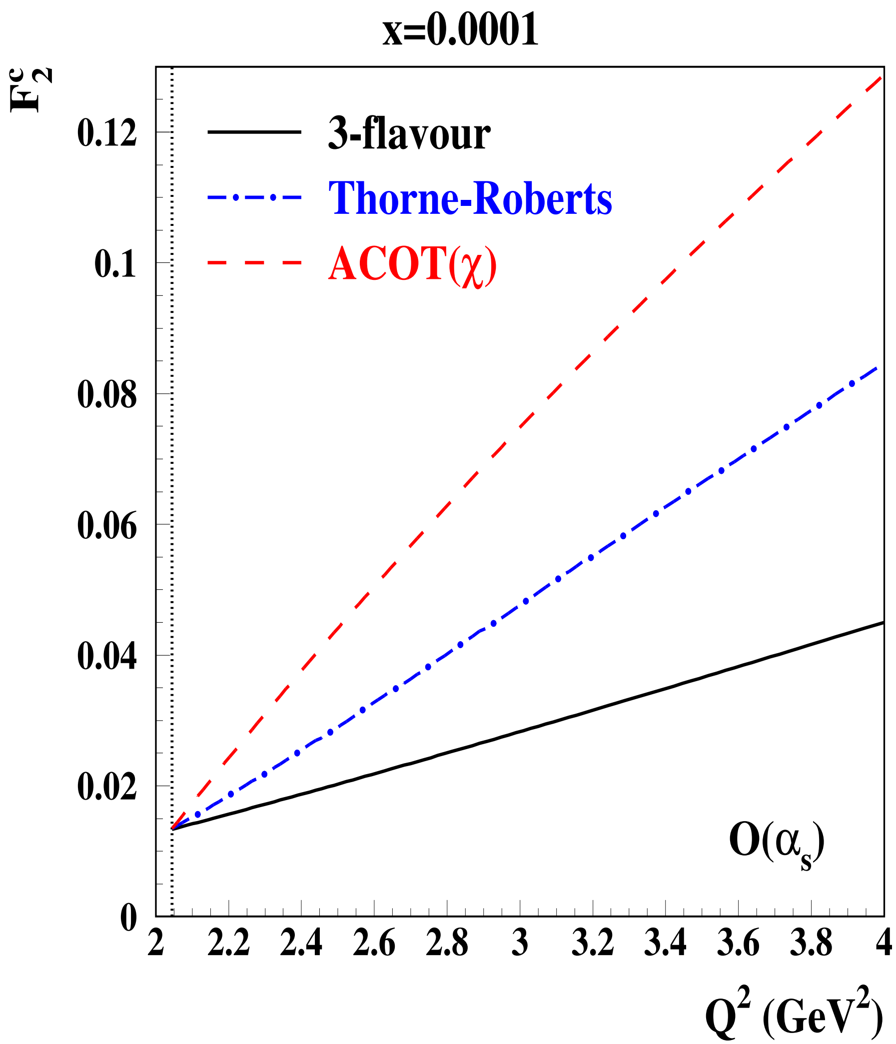


- At small μ the MSTW08 gluons are much lower than the ABKM09 ones and gets negative at $x \lesssim 10^{-4}$.
- Agreement between the JR08 and ABKM09 gluons is much better. These two analyzes employ the FFN scheme, while the MSTW08 is based on the VFN scheme (note the negative gluons are disfavored by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

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.

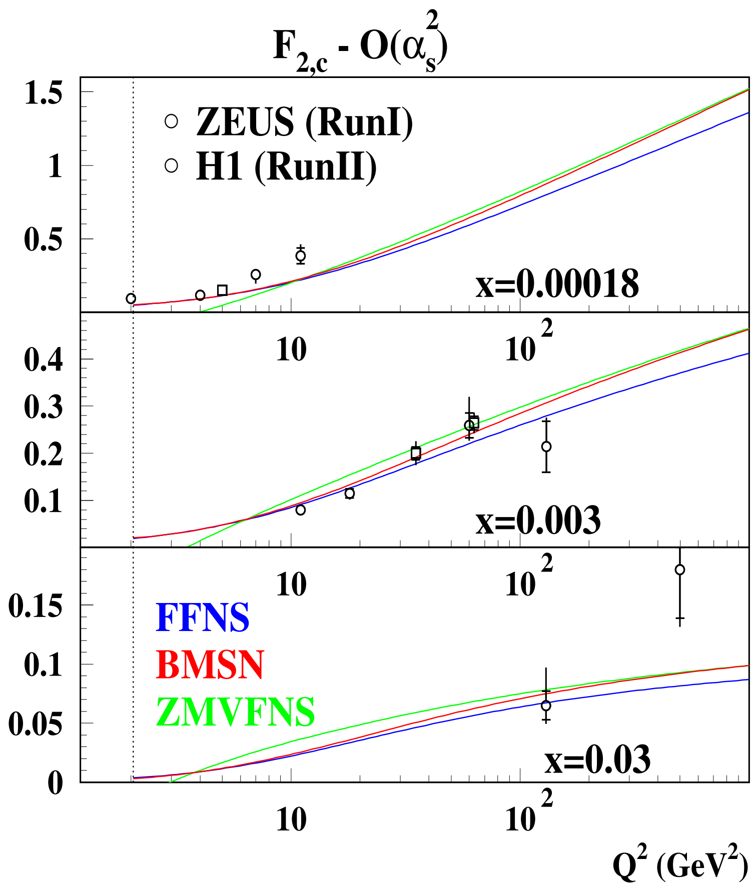
A complete definition of the general-mass VFNS should include a matching between $F_{2,c}^{\rm FFNS}$ at small Q^2 and $F_{2,c}^{\rm ZMVFNS}$ at large Q^2. This matching cannot be derived from the first principles and must be modeled, with a natural requirement of the smooth transition between the large-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

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



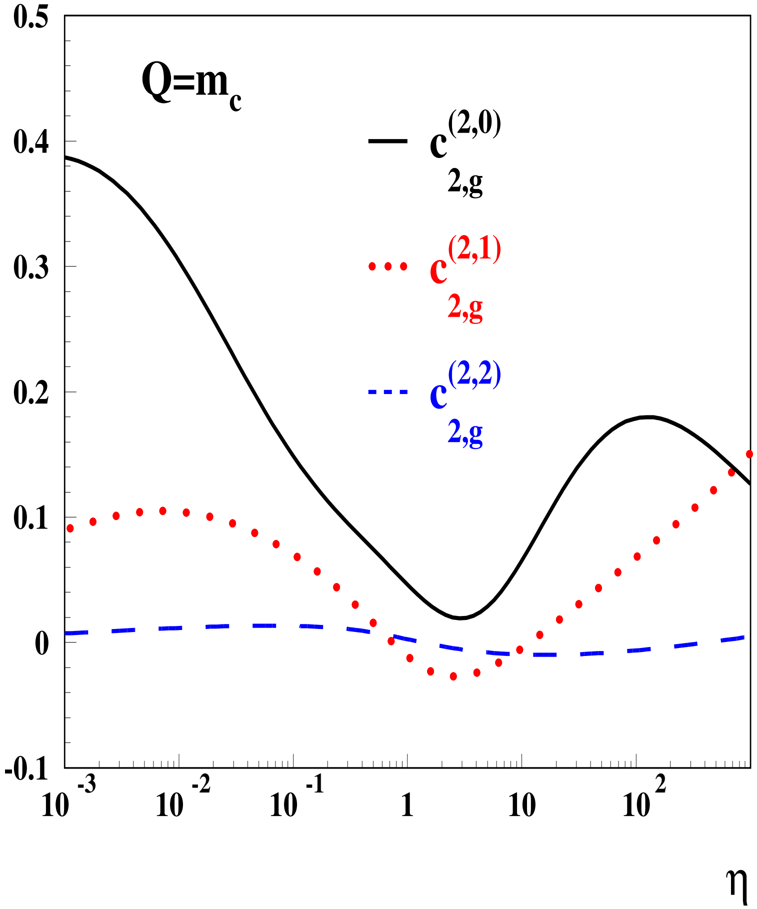
Different variants of the GM-VFNS used in the global PDFs fits demonstrate a kink in the matching region. It cannot be attributed to the large-log effects and just reflects uncertainty in the ingredients of these models. On a practical side this leads to overestimation of the heavy-quark contribution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

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



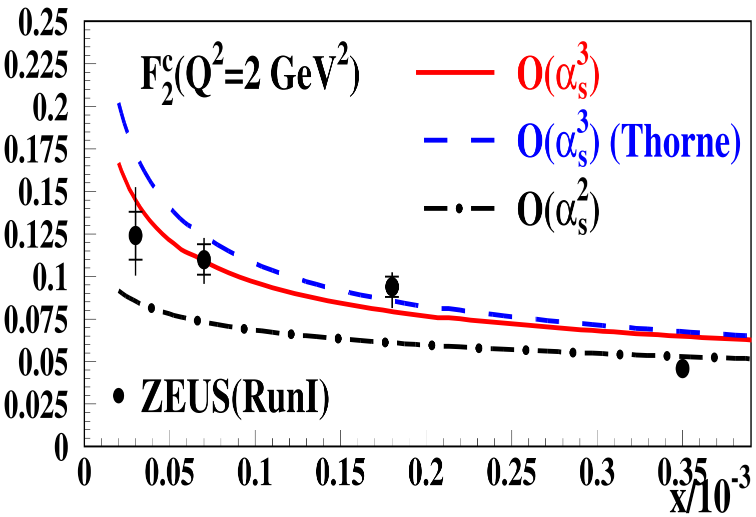
- The BMSN prescription for GMVFNS provides a smooth transition between the FFNS and ZMVFNS, it is not too far from the FFNS for the realistic HERA kinematics.
- The remaining discrepancies with the data can be rather cured by the NNLO corrections than by the VFNS.

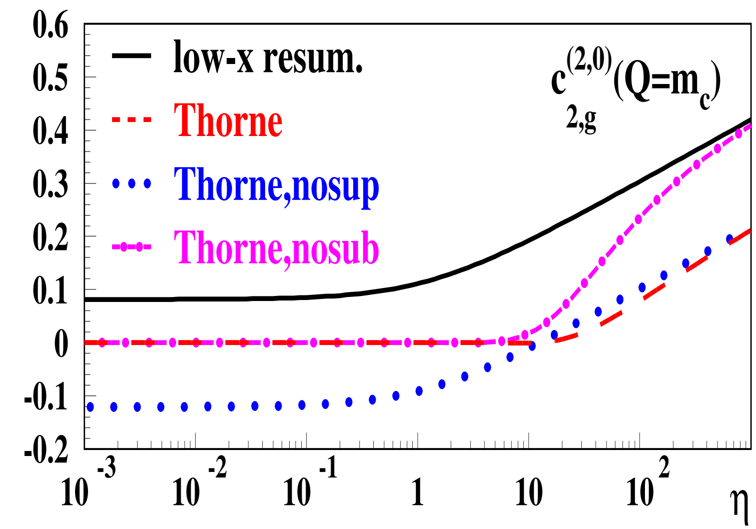
$$C_{2,g}^{\mathrm{NNLO}} = c_{2,g}^{(2,0)} + c_{2,g}^{(2,1)} \ln(\mu^2/m_c^2) + c_{2,g}^{(2,2)} \ln^2(\mu^2/m_c^2)$$



- The NNLO coefficients $c_{2,g}^{(2,1)}$ and $c_{2,g}^{(2,2)}$ are known exactly.
- The coefficient $c_{2,g}^{(2,0)}$ can be estimated from the soft-gluon threshold resummation (Laenen-Moch 99). At $\eta = \hat{s}/4m_c^2 - 1 > 1$ this approximation is out of control, however at small Q^2 impact of the high-η tail of $c_{2,g}^{(2,0)}$ is suppressed

(Vogt 96)

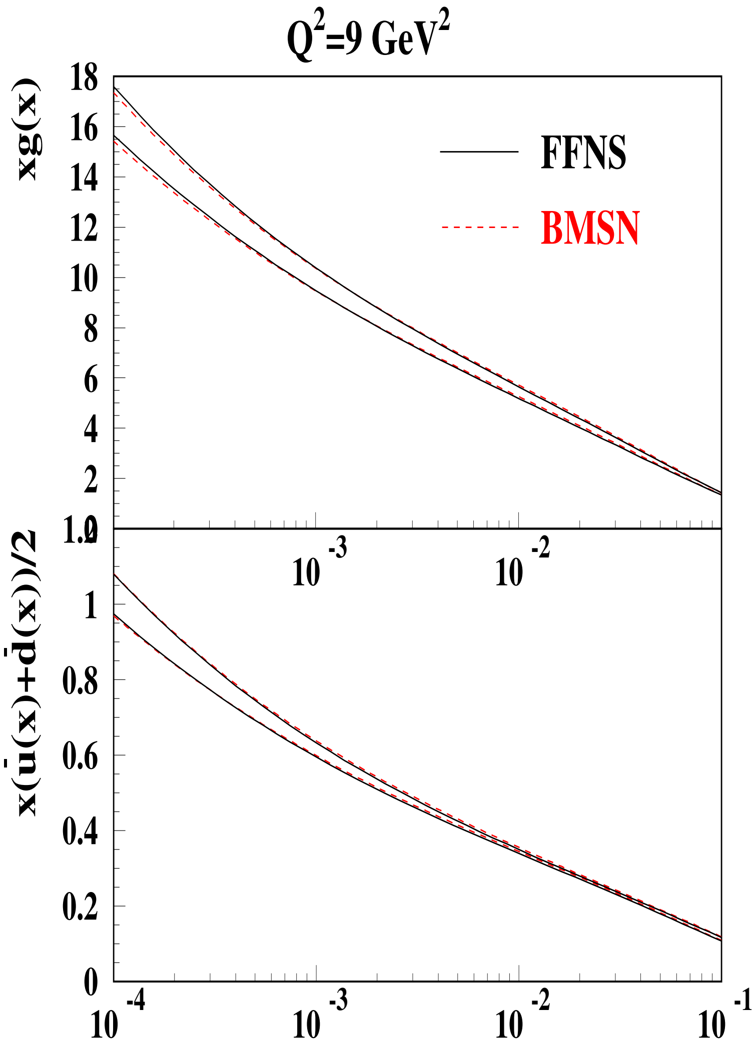




- With the partial NNLO corrections taken into account the FFNS is in agreement with the data at small Q^2.

  (sa-Moch 08)

- The coefficient $c_{2,g}^{(2,0)}$ at large η was modeled by Thorne using the Catani-Hautmann small-x resummation results, however uncertainty in the model is quite big.



- 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.
- *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)

Summary

The uncertainty in the NNLO b-quark distribution for the single-top production kinematics is estimated as $3 \div 7\%$.

- The dominating source at the LHC is variation of the b-quark mass by ± 0.5 GeV.
- The dominant source at the Fermilab collider is due to the errors in the data. It may be improved after new HERA and Fermilab data are included into the PDF fit.
- The uncertainty due to the high-order corrections is within $\sim 1 \div 8\%$, will be improved with the NNLO corrections to OMEs taken into account.

The difference between the NNLO b-quark distributions of the ABKM09 and MSTW08 sets is $\sim 1 \div 2\sigma$. It might be related to the scheme choice made in these fits and more careful study of the issue is needed.