Update of TR′ scheme in HERAFitter

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HERAFitter Users' Meeting, CERN, 18th April 2012

- Old HERAFitter: **4** copies of robert_thorne.f for NLO/NNLO and standard/optimal. Needed to recompile when switching between different versions ⇒ inconvenient.

Availability of public code for NC structure functions

http://projects.hepforge.org/mstwpdf/code/code.html

"Corresponding Fortran code for calculating proton (and neutron) structure functions in neutral-current deep-inelastic scattering (only photon exchange), i.e. F_2 and F_L including their heavy quark (c,b) components, is available on request. Note that the previous MRST structure function code, available from HEPDATA, should not be used with the MSTW PDFs due to the different implementation of the general-mass variable flavour number scheme (GM-VFNS).
Update (26th January 2012):
mstw2008structurefunctions.f and example_sf.f now public."

- CALL MSTWNC(x,q,ipn,f2,f2c,f2b,fl,flc,flb)
- Calculates F_2, F_2^c, F_2^b, F_L, F_L^c, F_L^b at LO, NLO, NNLO.
- Corresponds to exact TR′ code used in **MSTW 2008** fits.
- h1fitter-0.1.0/RT/src/robert_thorne.f (provided privately by R. S. Thorne) should agree with NLO public code.
- "Standard" NNLO and "optimal" NLO/NNLO also provided privately by R. S. Thorne for a future HERAFitter release.

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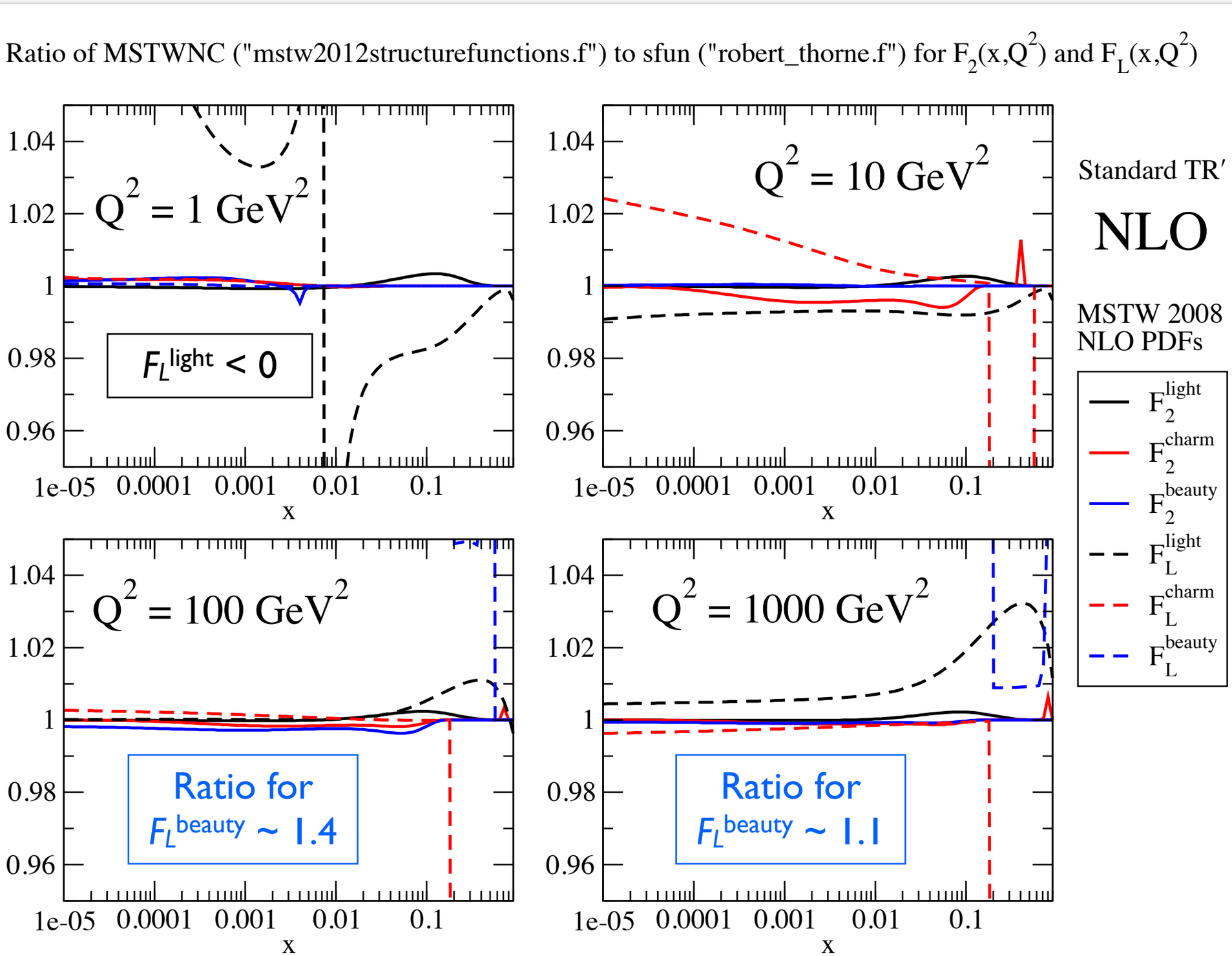
G.W., HERAFitter Meeting, CPP Marseille, 13th February 2012:
http://indico.cern.ch/contributionDisplay.py?contribId=6&confId=168468

- Voica implemented into HERAFitter mstw2008structurefunctions.f.
- But some problems with code:
  1. More PDF calls than necessary ⇒ slower than robert_thorne.f.
  2. Only standard, **not** optimal TR′.
  3. robert_thorne.f "*should* agree" but not checked explicitly. Some minor corrections needed in both robert_thorne.f and mstw2008structurefunctions.f (mostly affecting F_L not F_2).
- New version solving these problems (implemented into HERAFitter by Voica): http://mstwpdf.hepforge.org/code/mstw2012structurefunctions.f

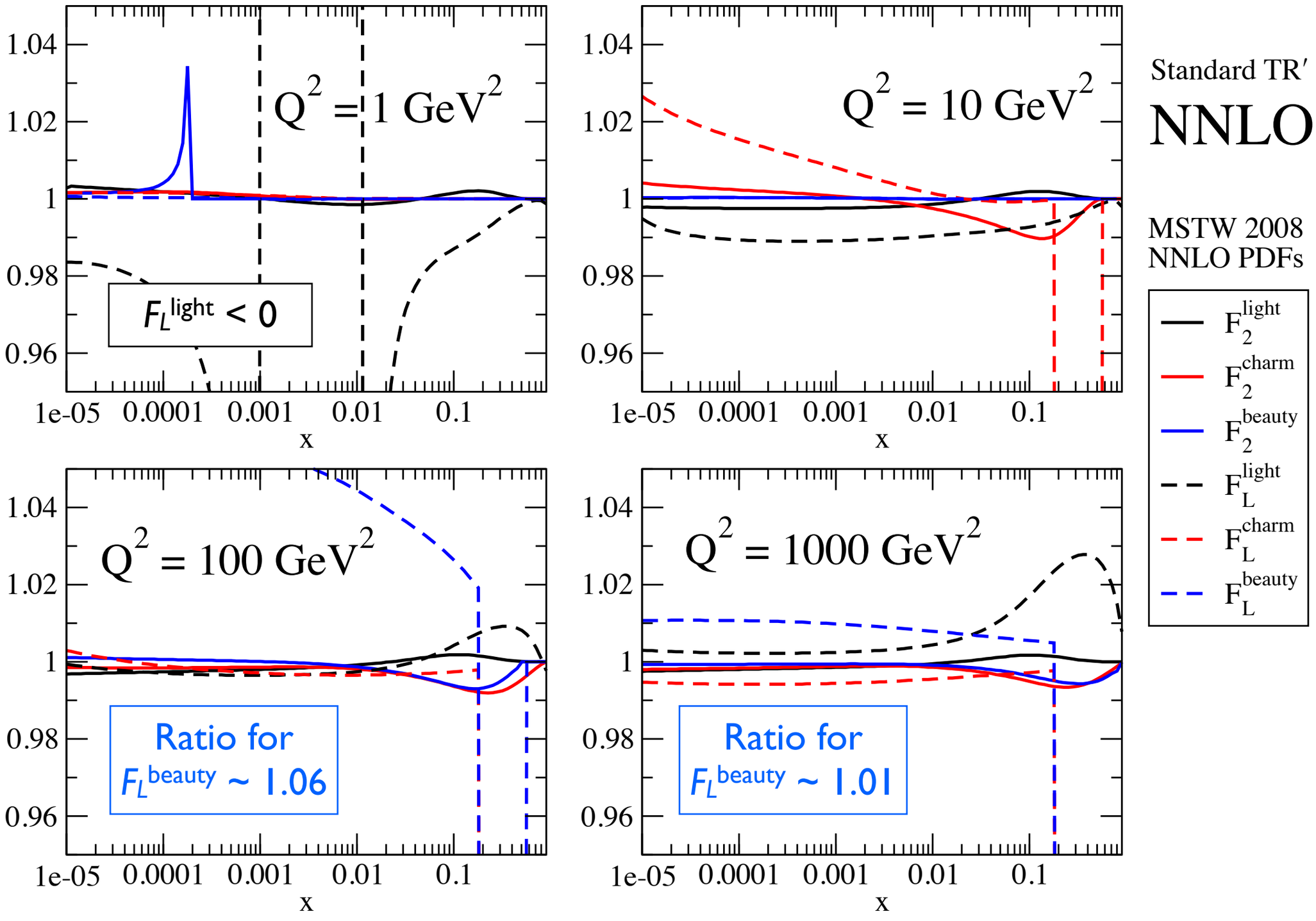
Validation: Standard TR′ at NLO



- |Ratio-1| < 1% for F_2. Some terms missing in `robert_thorne.f` for F_L^{beauty}.

Validation: Standard TR′ at NNLO

Ratio of MSTWNC ("mstw2012structurefunctions.f") to sfun ("robert_thorne.f") for $F_2(x,Q^2)$ and $F_L(x,Q^2)$

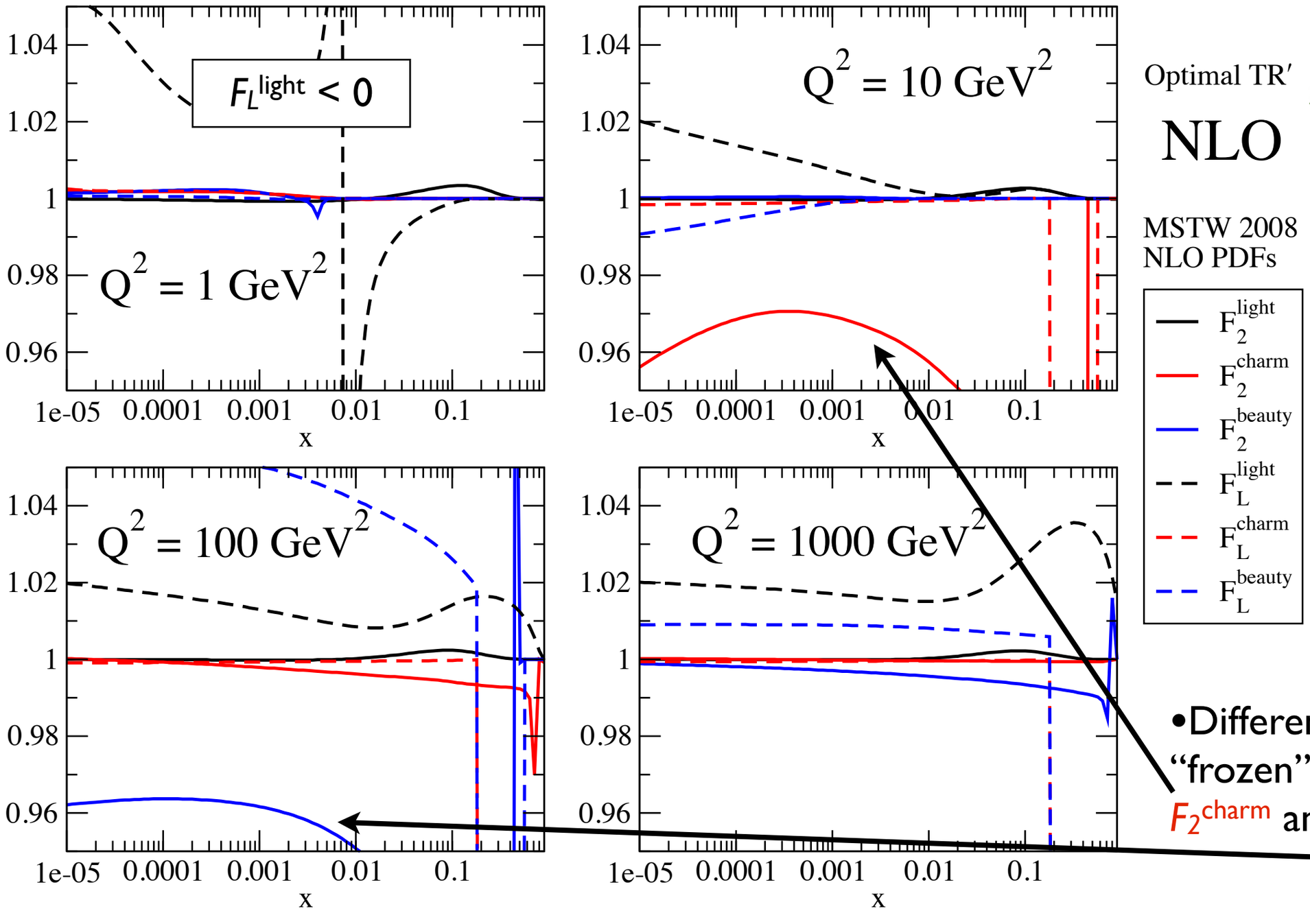


Validation: Optimal TR′ at NLO

$(m_h^2/Q^2)^a \alpha_S^n(m_h^2) \sum C_{2,i}^{FF}(m_h^2) \otimes f_i(m_h^2)$ or $(m_h^2/Q^2)^a \alpha_S^n(Q^2) \sum C_{2,i}^{FF}(Q^2) \otimes f_i(Q^2)$.

Ratio of MSTWNC ("mstw2012structurefunctions.f") to sfun ("robert_thorne.f") for $F_2(x,Q^2)$ and $F_L(x,Q^2)$

(a = 1)



Optimal TR′

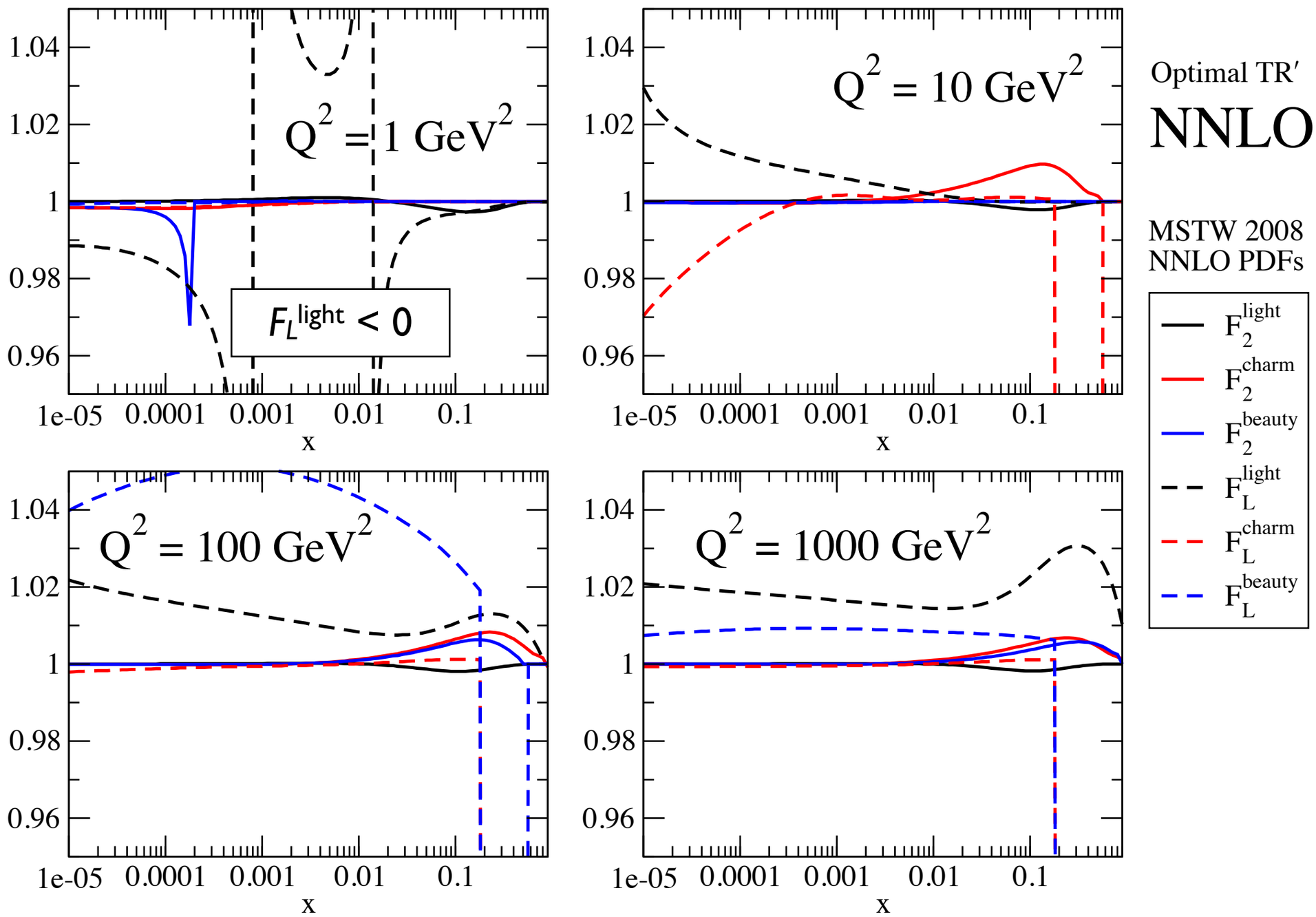
NLO

MSTW 2008 NLO PDFs

[R. S. Thorne, arXiv:1201.6180v1]

- Different scales in "frozen" term affects F_2^{charm} and F_2^{beauty}.

Validation: Optimal TR′ at NNLO



- |Ratio-1| < 1% for F_2. More recent version of `robert_thorne.f` ⇒ same scales in "frozen" term.

Parameter values of TR′ variations

Variants of the TR′ GM-VFNS [R. S. Thorne, arXiv:1201.6180]

TR′ standard (MSTW08)

- Frozen term ($Q^2 = m_H^2$):

$$\left(\frac{\alpha_S}{4\pi}\right)^m \sum_j C_{2,Hj}^{\mathrm{FF},n_f,(m)}(1) \otimes f_j^{n_f}(m_H^2)$$

- Coefficient function:

$$C_{2,HH}^{\mathrm{VF},n_f,(0)} \propto \delta(z - x_{\max})$$

- Threshold ($W^2 \geq 4m_H^2$):

$$x_{\max} = \left(1 + \frac{4m_H^2}{Q^2}\right)^{-1}$$

- Frozen term **persists** even at asymptotic Q^2.
- Necessary for original TR, but not for TR′.

TR′ variations (4 parameters)

- Allow power-suppression ("a"):

$$\left(\frac{m_H^2}{Q^2}\right)^a \left(\frac{\alpha_S}{4\pi}\right)^m \sum_j C_{2,Hj}^{\mathrm{FF},n_f,(m)}(1) \otimes f_j^{n_f}(m_H^2)$$

- Modify with extra factor ("b", "c"):

$$C_{2,HH}^{\mathrm{VF},n_f,(0)} \propto \left[1 + b\left(\frac{m_H^2}{Q^2}\right)^c\right] \delta(z - x_{\max})$$

- Modify argument of δ-function ("d"):

$$x_{\max} \to \left\{1 + \left[x\left(1 + \frac{4m_H^2}{Q^2}\right)\right]^d \frac{4m_H^2}{Q^2}\right\}^{-1}$$

cf. intermediate-mass (IM) scheme of Nadolsky–Tung [arXiv:0903.2667].

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G.W., HERAFitter Meeting, CPP Marseille, 13th February 2012:
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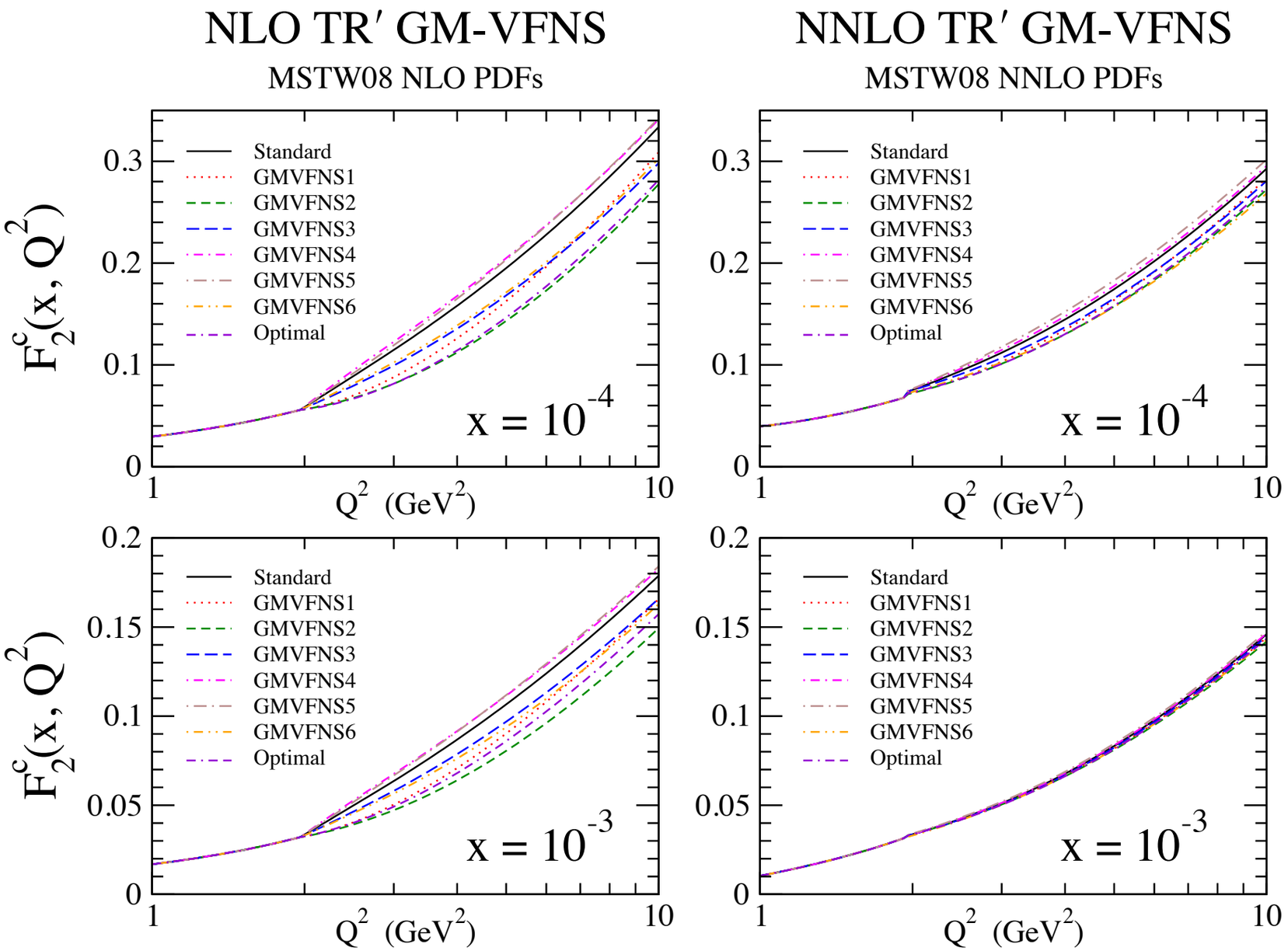
- Fixed scale choices $\mu_R^2 = \mu_F^2 = Q^2$ (and flavour matching / transition scale at $\mu^2 = m_H^2$). No possibility for scale variations.

TR′ variant	a	b	c	d
Standard	0	0	0	0
GM-VFNS1	0	-1	1	0
GM-VFNS2	0	-1	0.5	0
GM-VFNS3	1	0	0	0
GM-VFNS4	0	0.3	1	0
GM-VFNS5	0	0	0	0.1
GM-VFNS6	0	0	0	-0.2
Optimal	1	-2/3	1	0

- Pass parameters {a, b, c, d} = {var4, var3, var2, var1} via: COMMON/TRprimeCommon/
- Options in steering.txt:
  HF_SCHEME = 'RT'
  HF_SCHEME = 'RT OPT'
- **Other** parameter values could be used to study theory uncertainty due to the choice of TR′ GM-VFNS.
- Scale variation not straightforward. No implementation in near future.

Impact of TR′ variations on F_2^{charm}

Check "mstw2012structurefunctions.f" can reproduce Figure 1 of arXiv:1201.6180v1 [G. Watt, 12th April 2012]



Fixed PDFs (MSTW08) and m_c = 1.40 GeV.

Compare to:

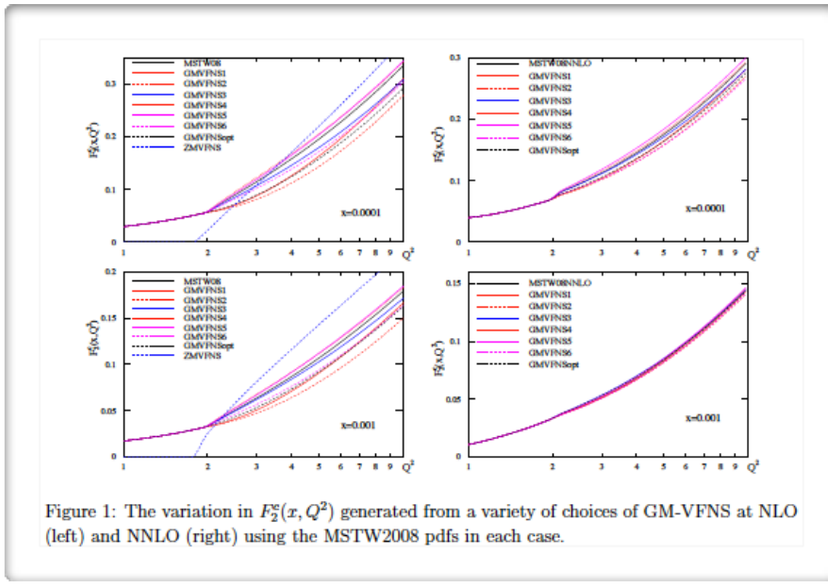


Figure 1: The variation in $F_2^c(x, Q^2)$ generated from a variety of choices of GM-VFNS at NLO (left) and NNLO (right) using the MSTW2008 pdfs in each case.

[R. S. Thorne, arXiv:1201.6180v1]

- Effect of GM-VFNS variations much reduced at NNLO.