

Recent Developments in **APFEL**

[V. Bertone, *et al.*, *Comput. Phys. Commun.* 185, 1647 (2014)]

Valerio Bertone

NIKHEF and VU Amsterdam



UNIVERSITY
AMSTERDAM

xFitter external meeting

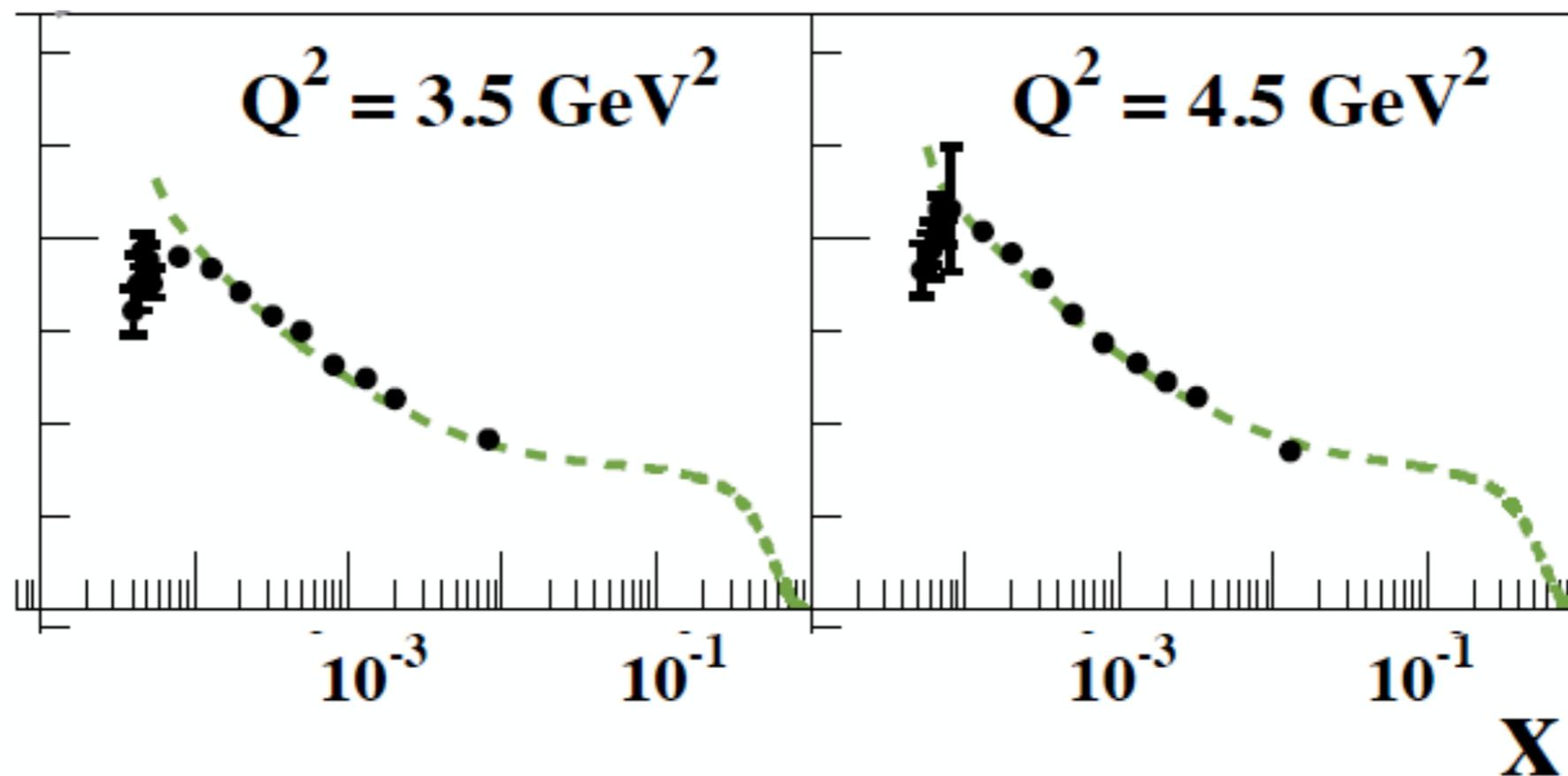
March 21, 2017, Oxford

APFEL in a Nutshell

- 🍏 APFEL is a **public** library for the computation of collinear PDF evolution and DIS structure functions:
 - 🍏 up to NNLO in QCD combined to QED corrections up to NLO.
 - 🍏 FFN and VFN schemes.
 - 🍏 Pole and $\overline{\text{MS}}$ heavy-quark masses.
 - 🍏 fast computation of DIS NC and CC observables in different mass schemes (ZM-VFNS, FFNS and FONLL).
 - 🍏 Interfaces to FORTRAN, C/C++ and Python.
 - 🍏 Web interface available on <http://apfel.mi.infn.it>.
 - 🍏 available from <http://apfel.hepforge.org/>.
- 🍏 Interfaced to **xFitter**.
- 🍏 Used for the next generation of the **NNPDF** fits (including FFs).

Small- x Resummation

- 🍏 **Tension** between fixed-order predictions and data in the small- x region reached by HERA:



From Eram Rizvi talk
at QCD@LHC14

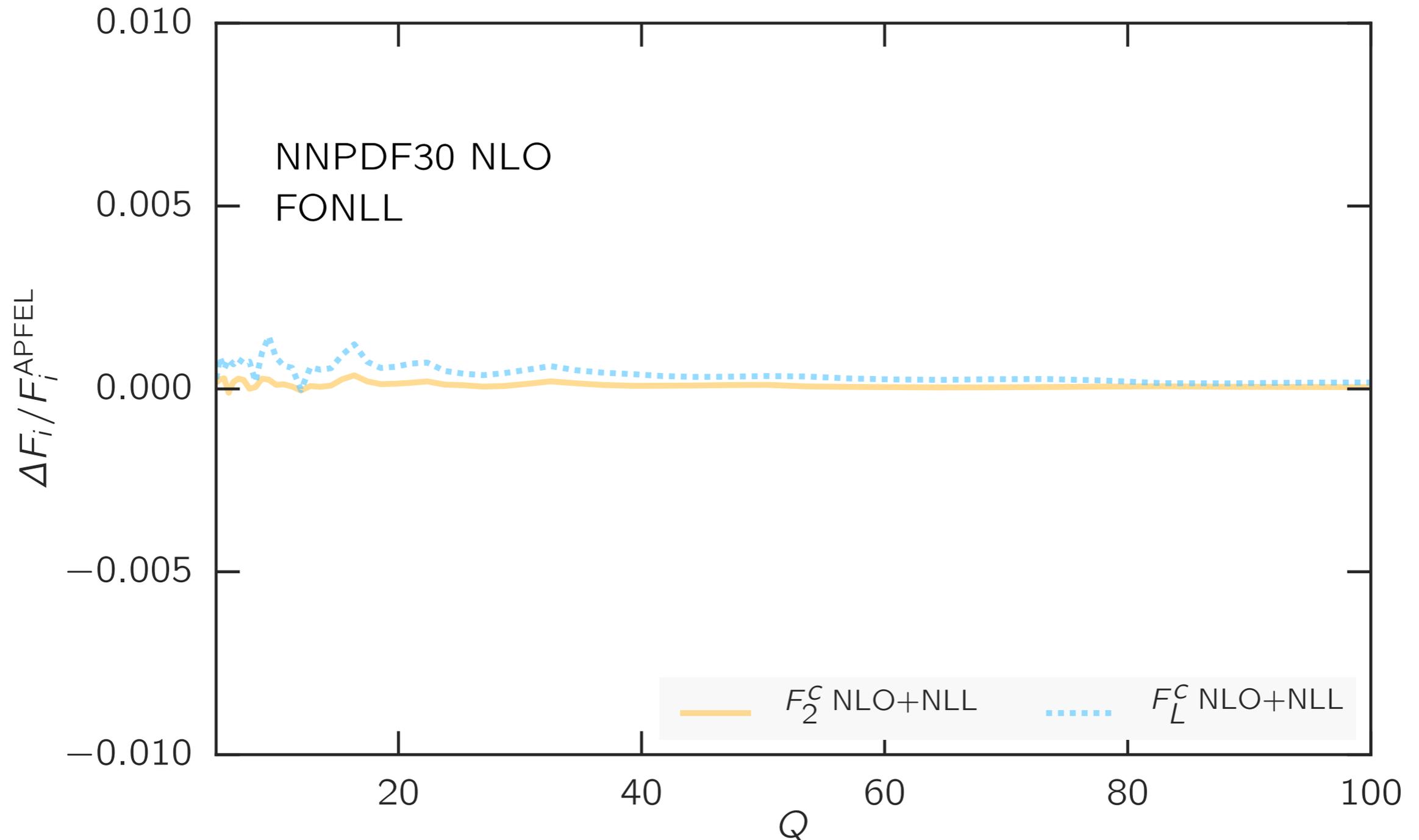
- 🍏 A similar effect was observed some time ago in the NNPDF framework by F. Caola *et al.* [[arXiv:1007.5405](https://arxiv.org/abs/1007.5405)].
- 🍏 Suggestion of the need for **small- x resummation**.

Small- x Resummation

- 🍏 The **HELL** code [[arXiv:1607.02153](#)] has been interfaced to APFEL:
 - 🍏 based on the ABF formalism (e.g. see [[hep-ph/9501231](#)]).
 - 🍏 Small- x **resummed splitting functions** up to **NLL** accuracy,
 - 🍏 Small- x **resummed DIS coefficient functions** up to **NLL**:
 - 🍏 massless,
 - 🍏 massive.
 - 🍏 **Resummed matching conditions.**
- 🍏 It is now possible to compute structure functions in the FONLL GM-VFNS scheme including small- x resummation up to NLL.
- 🍏 Forthcoming PDF fits in NNPDF.

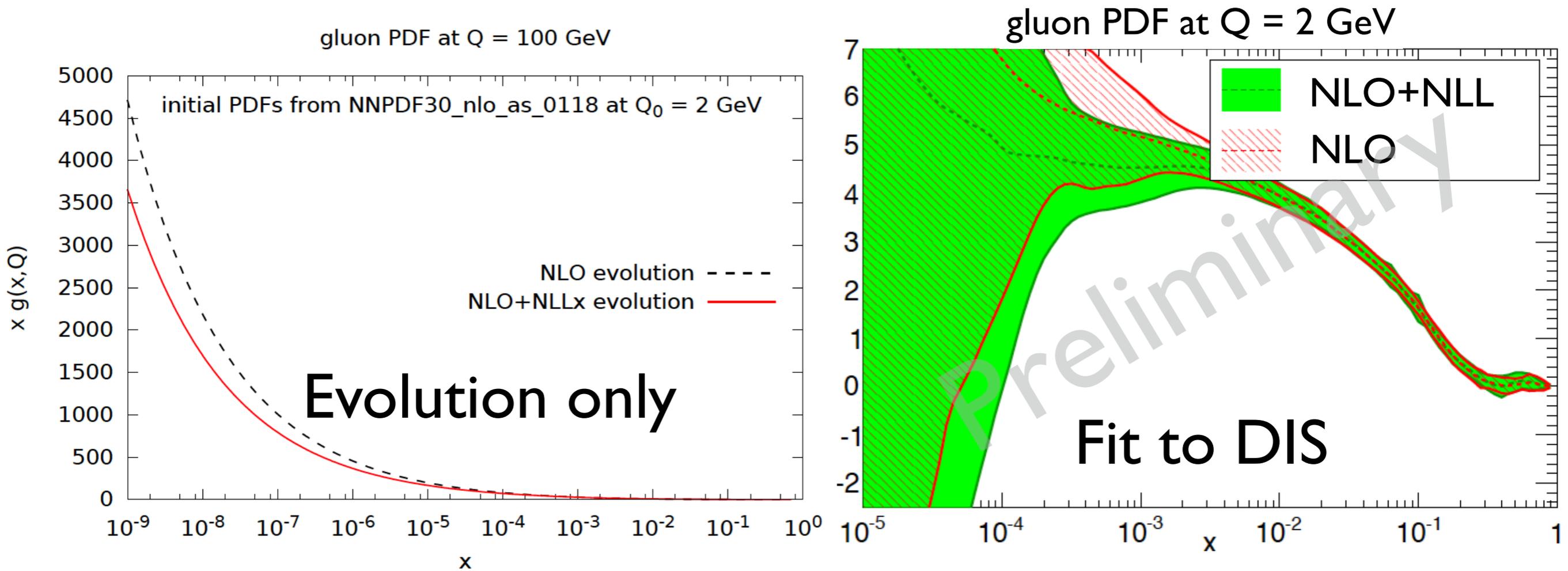
Small- x Resummation

F_i^c NC, $x = 0.00001$



🍏 Excellent agreement with MassiveDIS [Thanks to L. Rottoli]

Small- x Resummation



- 🍏 Resummed evolution leads to a **suppression** of the **gluon PDF** at small values of x as compared to fixed order.
- 🍏 **Compensation** when also resummed **coefficient functions** are introduced \Rightarrow effect on the small- x gluon PDF at the level of $1-\sigma$.
- 🍏 Other PDFs mostly unchanged.

NLO QCD+QED Corrections

Evolution

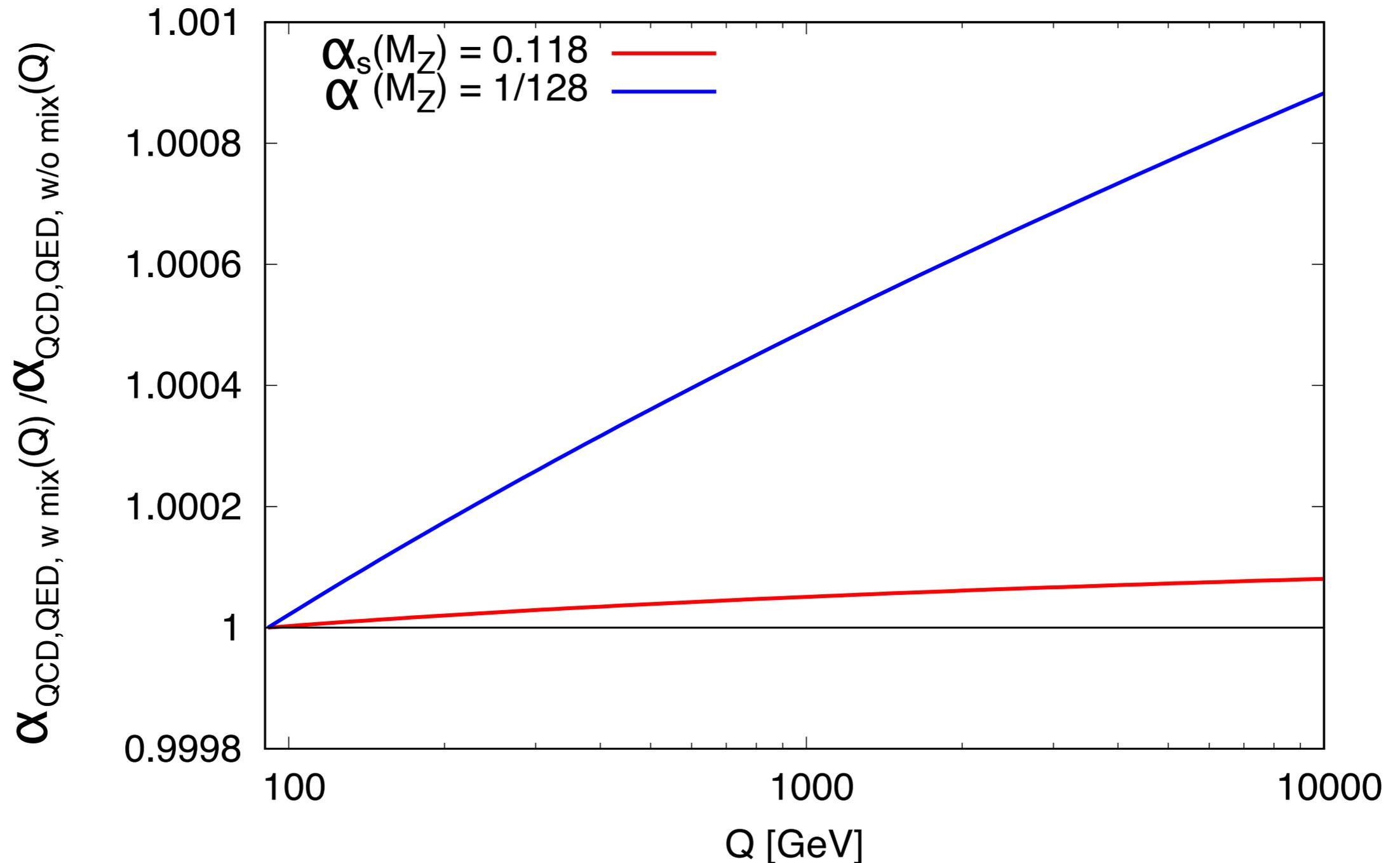
In order to implement the full NLO QCD+QED corrections in the DGLAP evolution two main steps are required:

1. Implementing the $O(\alpha_s^2\alpha)$, $O(\alpha^3)$, $O(\alpha^2\alpha_s)$ corrections to the **β -functions**:
 - running of α_s and α is coupled \Rightarrow solve of a coupled ODE,
 - Numerical tests have shown that such terms lead to differences of $O(10^{-4})$ for α_s and $O(10^{-3})$ for $\alpha \Rightarrow$ **unneeded complication.**

NLO QCD+QED Corrections

Coupling Evolution

running of the couplings, $N_F = 5$



🍏 Mixed terms in the β -functions lead to negligible effects.

NLO QCD+QED Corrections

Evolution

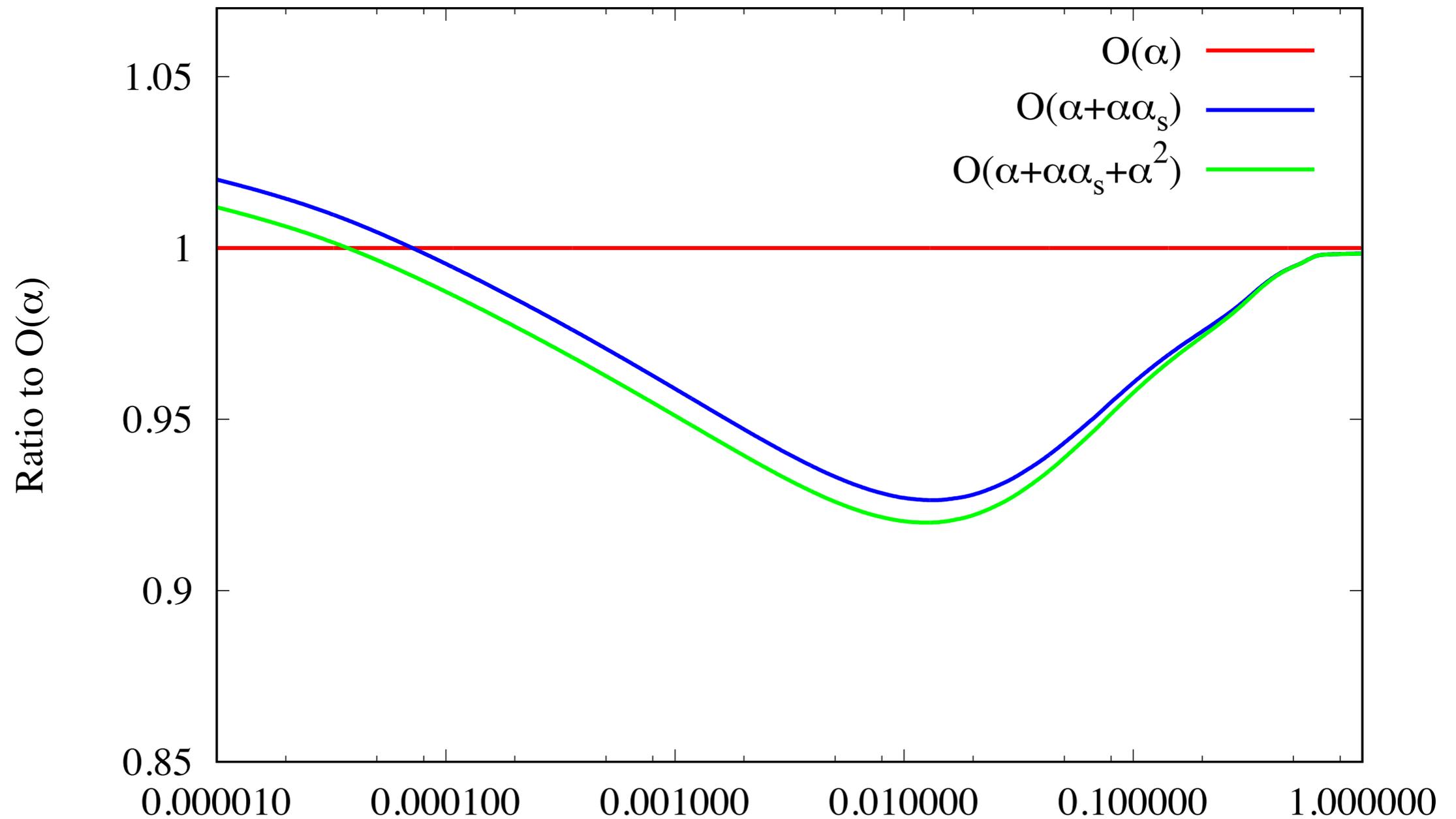
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 - running of α_s and α is coupled \Rightarrow solve of a coupled ODE,
 - Numerical tests have shown that such terms lead to differences of $O(10^{-4})$ for α_s and $O(10^{-3})$ for $\alpha \Rightarrow$ **unneeded complication**.
2. Implementing the $O(\alpha_s\alpha)$ and the $O(\alpha^2)$ corrections to the DGLAP **splitting functions** on top of the $O(\alpha)$ ones:
 - complication of the flavour structure due to the presence of terms proportional to e_q^2 and e_q^4 that break the isospin symmetry,
 - need for a more optimal evolution basis as compared to pure QCD.

NLO QCD+QED Corrections

DGLAP Evolution

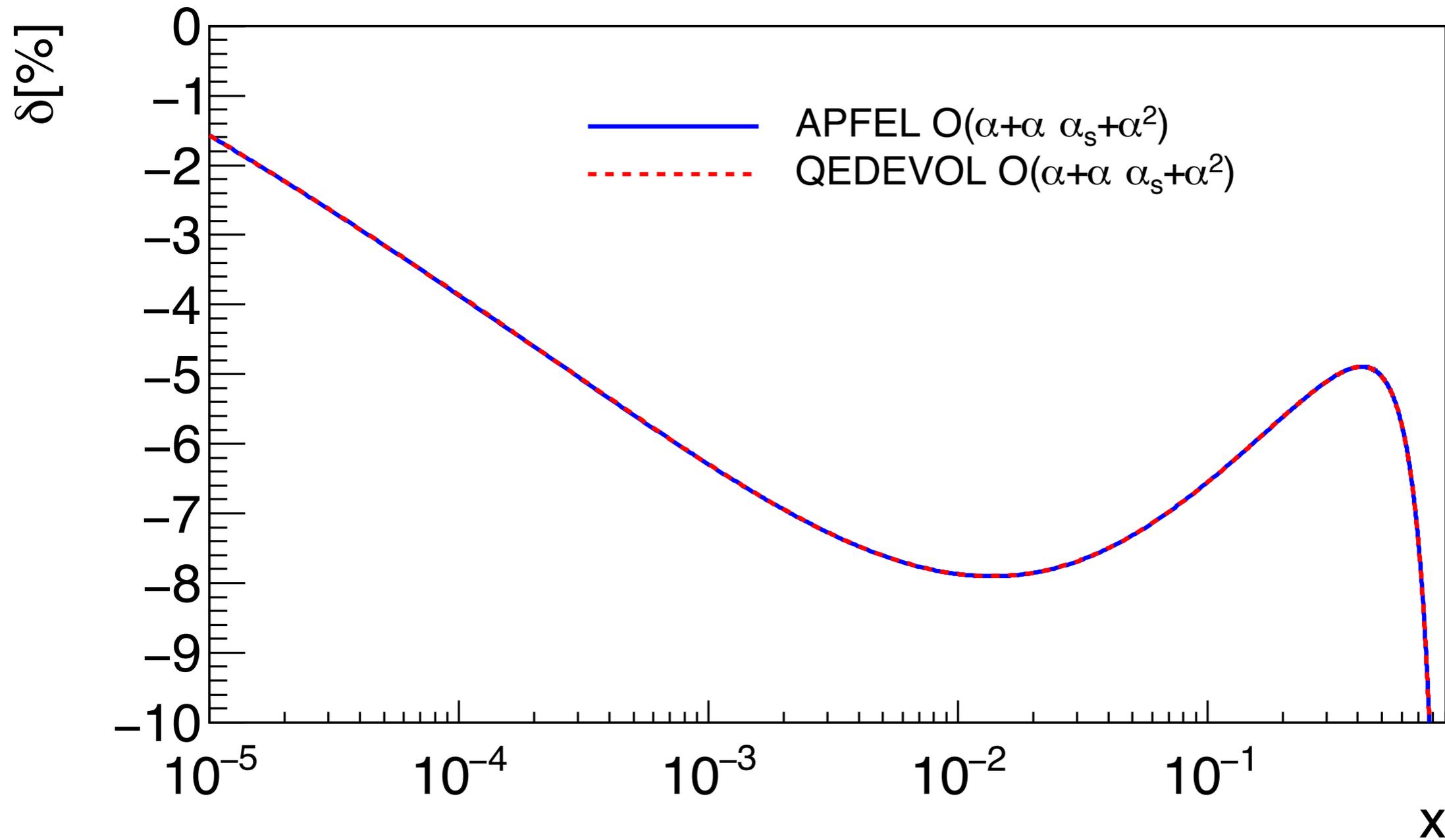
γ PDF at $Q = 100$ GeV



🍏 Effect on the photon PDF of the NLO^x corrns. at the level of 5%.

NLO QCD+QED Corrections

Benchmark against QEDDEVOL



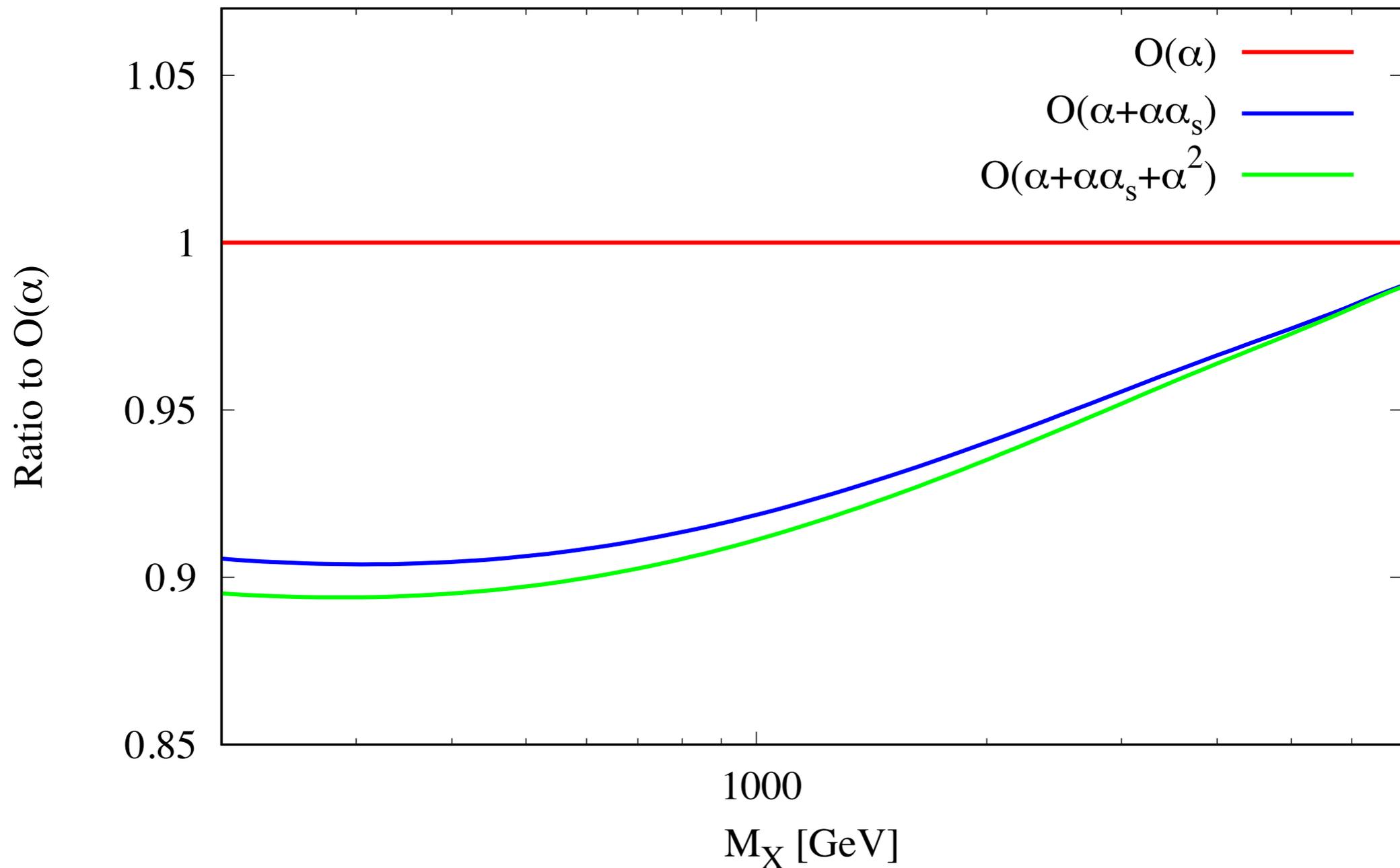
[Thanks to Renat Sadykov]

🍏 Perfect agreement between APFEL and QEDDEVOL.

NLO QCD+QED Corrections

Photon Luminosity

$\gamma\gamma$ Luminosity at $\sqrt{s} = 13$ TeV



🍏 More sizeable effect on the $\gamma\gamma$ luminosity.

NLO QCD+QED Corrections

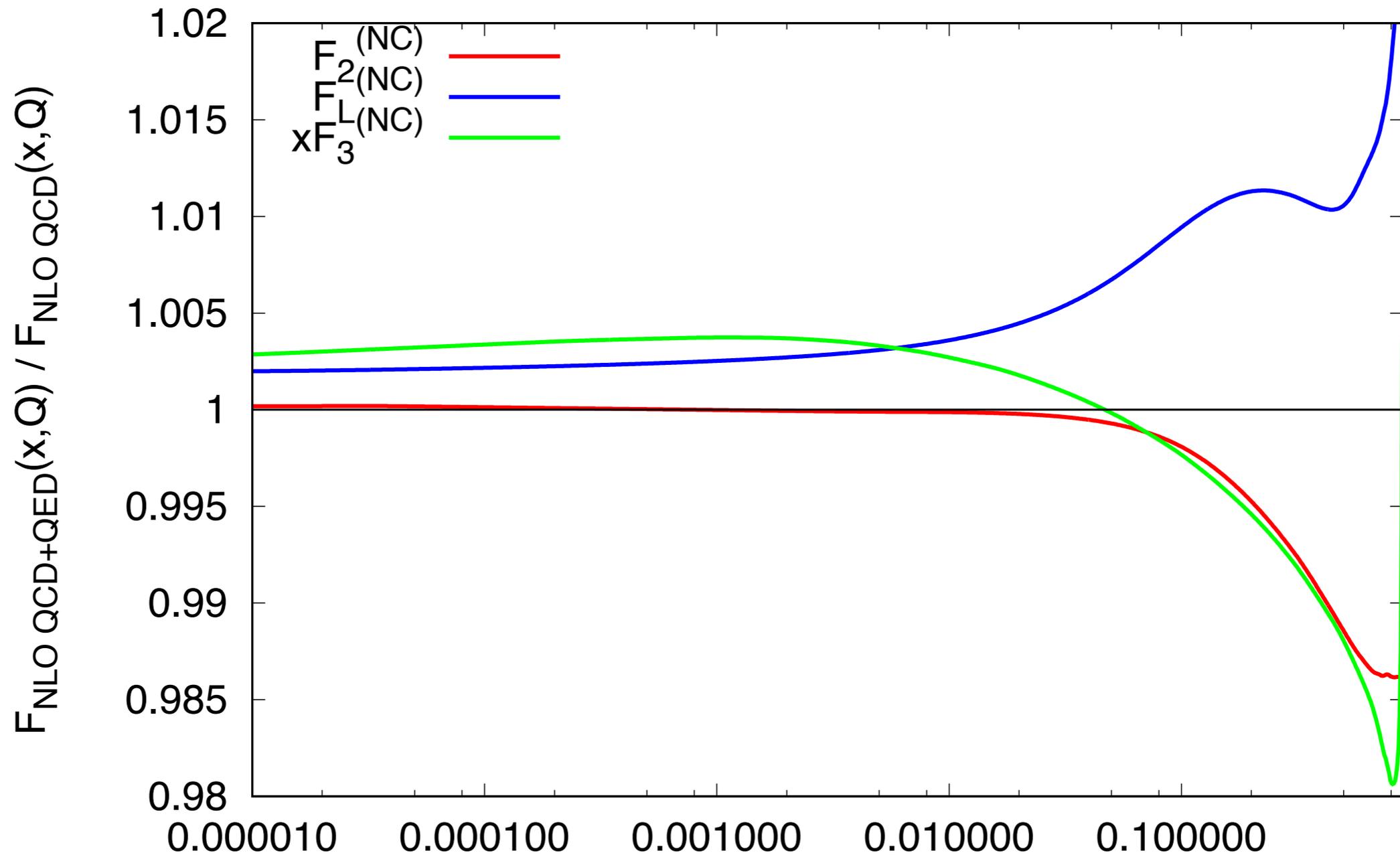
DIS Structure Functions

- While at LO in QED no corrections to the DIS structure functions are required ($\gamma^* q \rightarrow q$ itself is the LO), at NLO in QED $O(\alpha)$ corrections need to be taken into account:
 - **new diagrams:** $\gamma^* \gamma \rightarrow q\bar{q}$ and $\gamma^* q \rightarrow q\gamma$,
 - easily derivable from the corresponding QCD diagrams.
- The additional diagrams offer a **direct handle** on the photon PDF in DIS observables:
 - at LO in QED the photon PDF was entirely driven by the evolution.
- Small contribution proportional to $\alpha\gamma \sim O(\alpha^2)$ but can be relevant in some kinematic regions:
 - typically at large x and large Q^2 .

NLO QCD+QED Corrections

DIS Structure Functions (NC)

NC structure functions in the FONLL-B scheme

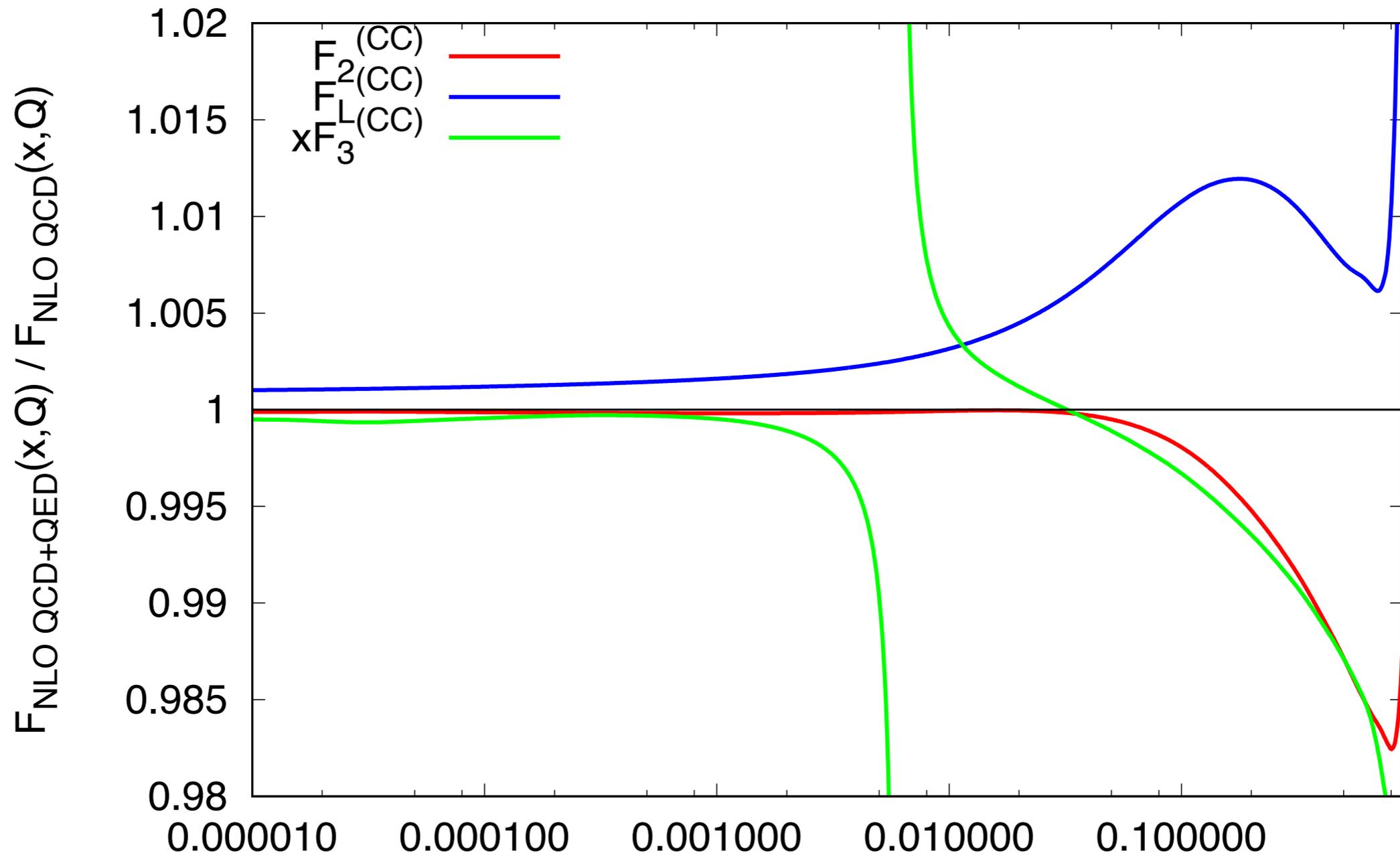


🍏 Generally small effect which becomes large at large x .

NLO QCD+QED Corrections

DIS Structure Functions (CC)

CC structure functions in the FONLL-B scheme



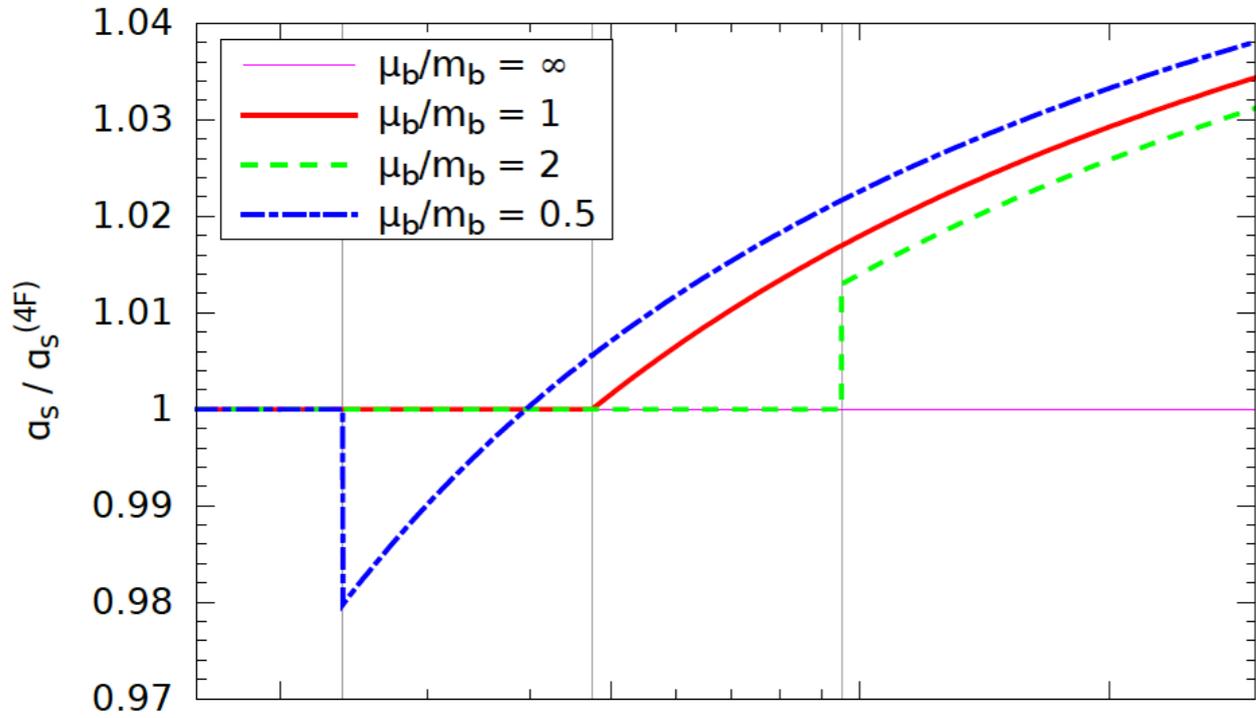
🍏 Generally small effect which becomes large at large x .

Displaced Heavy-Quark Thresholds

- 🍏 The implementation of the VFNS evolution both for PDFs and α_s requires **matching** factorisation schemes differing in the number of active flavours:
 - 🍏 the scale at which two consecutive factorisation schemes are matched are usually referred to as **heavy-quark thresholds**.
 - 🍏 Heavy-quark thresholds are usually (and for convenience) identified with the heavy quark masses by means of the so-called **matching conditions** presently known up to $O(\alpha_s^2)$ [[hep-ph/9612398](https://arxiv.org/abs/hep-ph/9612398)].
 - 🍏 However, heavy-quark thresholds are actually free parameters and can be chosen **arbitrarily**.
 - 🍏 If masses and thresholds are taken to be different, the matching conditions need to be “generalised” including **logarithmic terms**.
- 🍏 APFEL now implements the possibility to set masses and thresholds to different values in a consistent way both in the pole mass and in the $\overline{\text{MS}}$ renormalisation schemes.

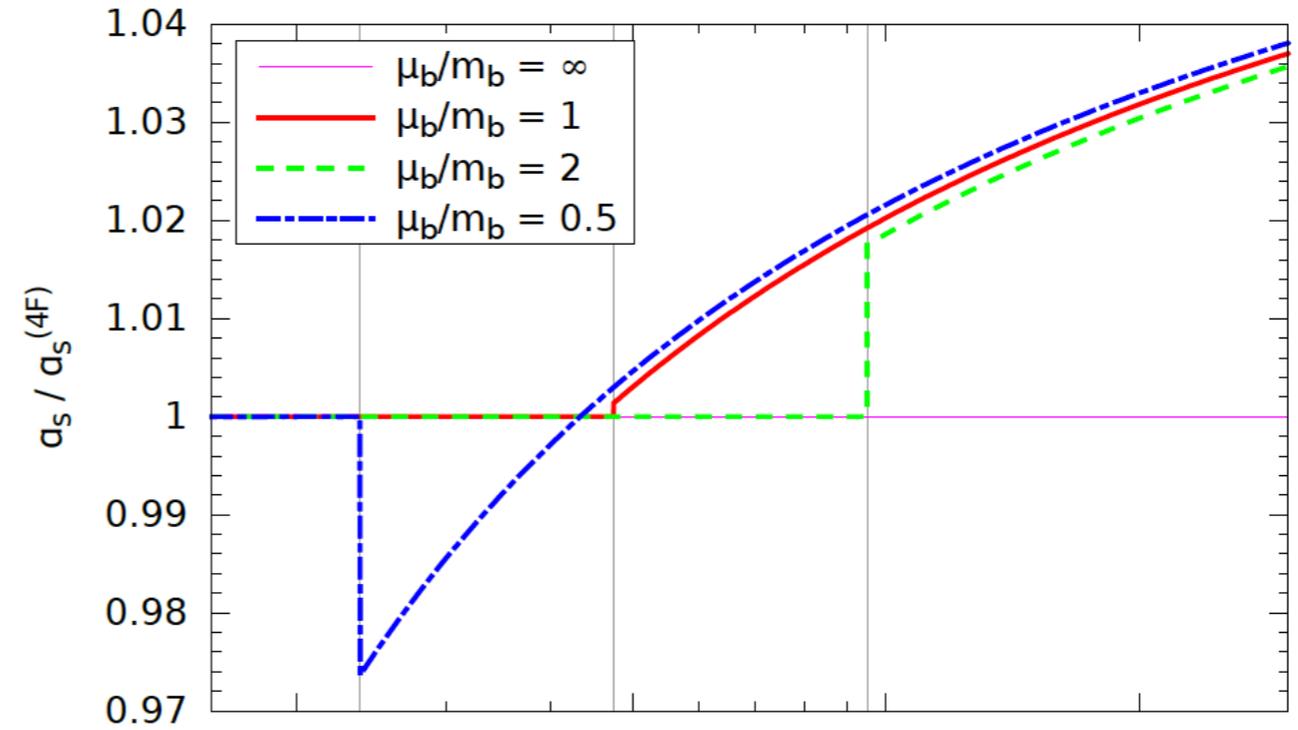
Displaced Heavy-Quark Thresholds

NLO

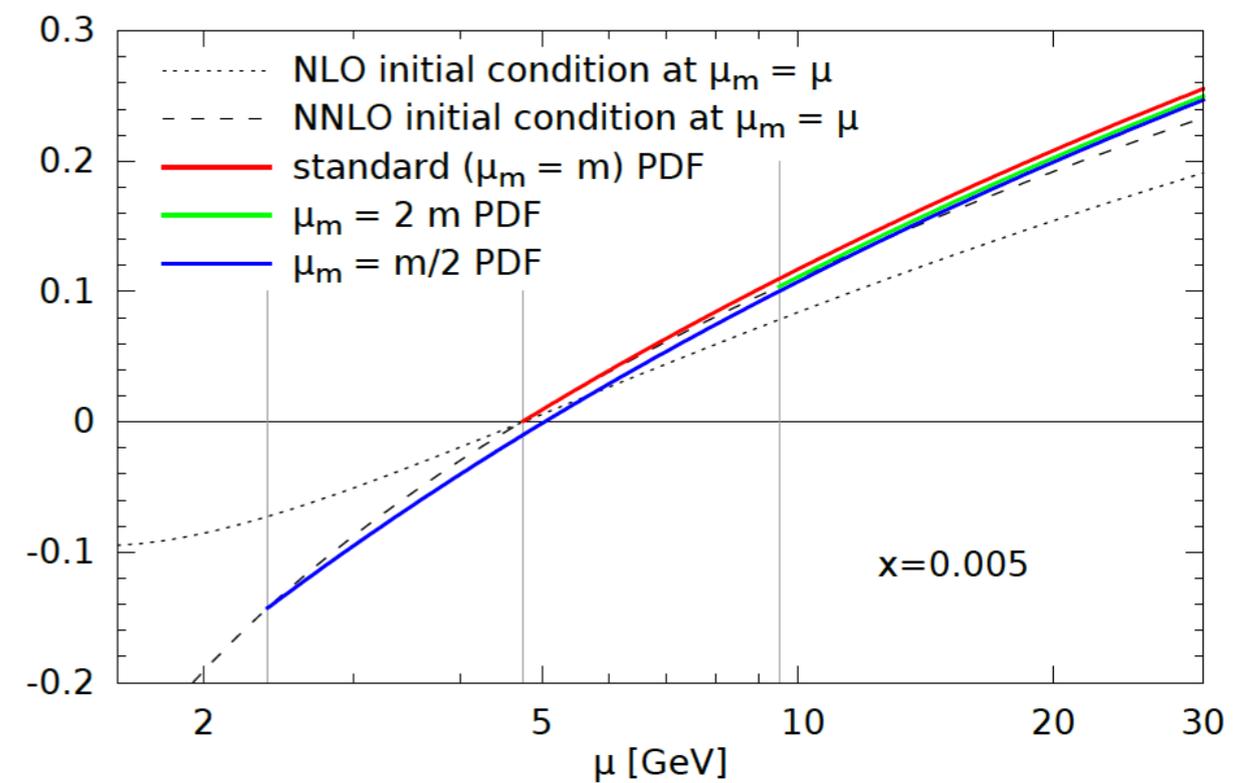
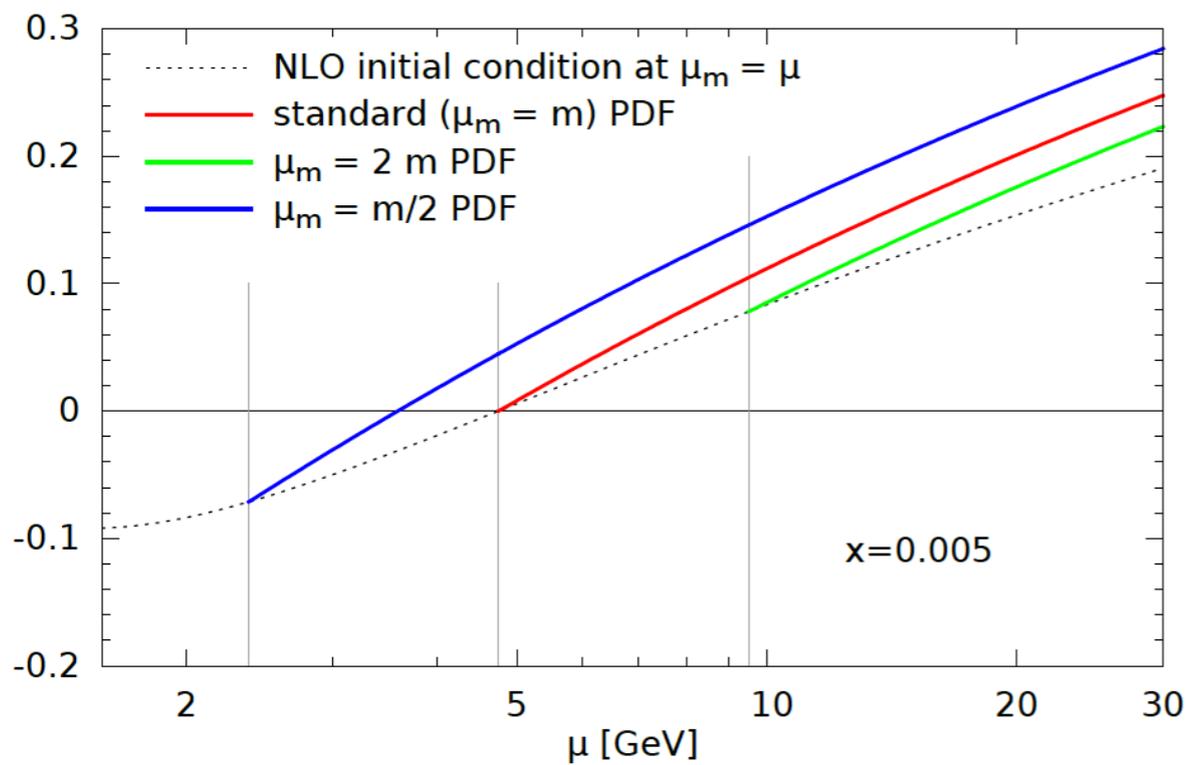


bottom PDF at NLO

NNLO



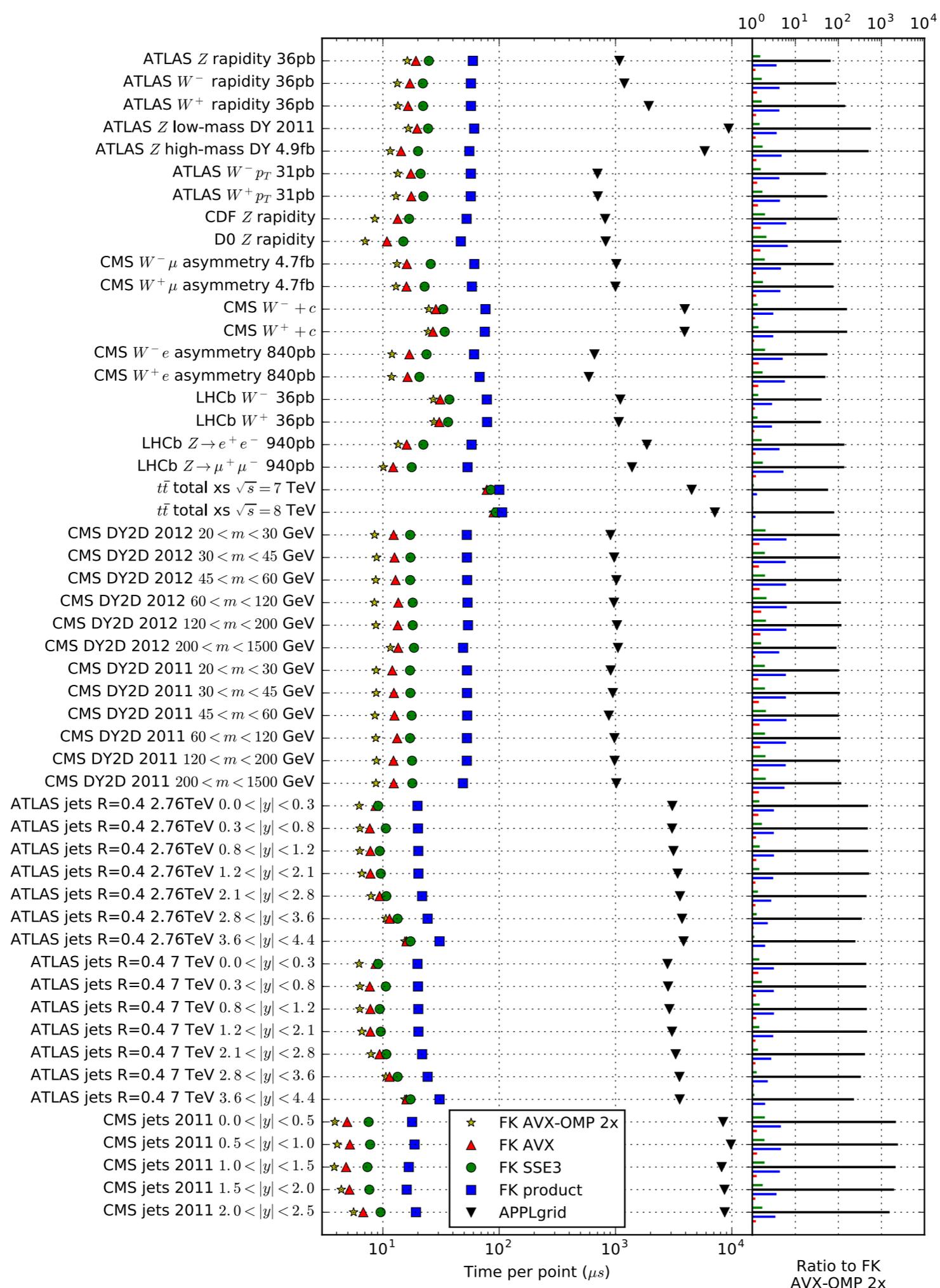
bottom PDF at NNLO



APFELgrid

A fast(er) interface for PDF fits

- 🍏 While being extremely useful tools, **APPLgrid** and **FastNLO** might not be appropriate to be directly employed in a global PDF fit where usually **thousands of iterations** are needed:
 - 🍏 need to calculate PDF and α_s **evolution in real time**.
 - 🍏 **not particularly fast** convolution.
 - 🍏 many tables need to be loaded with the concrete risk of **exceeding the memory limit** (pretty common on clusters).
- 🍏 We developed **APFELgrid** which, starting from an APPLgrid, combines the PDF evolution from APFEL to the hard cross sections producing *derived* tables (FK tables) to be directly convoluted with the initial scale PDFs.
- 🍏 APFELgrid relies on the precomputation of the evolution of α_s and PDFs:
 - 🍏 less flexible than APPLgrid as the evolution parameters (perturbative order, reference value of α_s , heavy-quark thresholds, etc.) cannot be changed.



[V. Bertone, S. Carrazza, N.P. Hartland,
 Comput.Phys.Commun. 212 (2017) 205-209]

APFEL⁺⁺

An object oriented rewriting of APFEL

- 🍏 APFEL core is currently based on **FORTRAN77**.
- 🍏 It thus provides “**singleton objects**”, *i.e.* it is not possible to instantiate different evolutions and/or structure functions with different parameters.
- 🍏 It includes a **large number of features**:
 - 🍏 limited modularity ⇒ **hard to maintain and extend**,
 - 🍏 static memory management ⇒ **large memory footprint** to ensure appropriate accuracy for all foreseeable applications.
- 🍏 **C++** provides a natural solution to these issues:
 - 🍏 possibility to instantiate any number of evolutions and structure functions,
 - 🍏 **modularity** ensured by the possibility to define objects,
 - 🍏 optimal memory management,
 - 🍏 based on C++11 standard (Lambda funcs., auto declaration, smart pointers, etc.)

APFEL++

An object oriented rewriting of APFEL

🍏 A good excuse to do better:

🍏 improve integration procedure (faster and more accurate):

```
Initialization.: elapsed time: 0.209144 seconds  
Tabulation.: elapsed time: 0.111195 seconds
```

🍏 improve interpolation procedure:

```
Interpolating 100000 times PDFs on the (x,Q) grid... elapsed time: 0.604006 seconds
```

🍏 overload operators to make convolutions in an easy way:

```
//-----  
Set<Distribution> Dglap::Derivative(int const& nf, double const& t, Set<Distribution> const& f) const  
{  
    return _SplittingFunctions(nf, exp(t/2)) * f;  
}
```

🍏 use the same technology for specific hadronic observables (e.g. double differential DY).

🍏 Exploit CPU acceleration techniques (AVX, SSE).

APFEL++

An object oriented rewriting of APFEL

```
vbertone@MacBook-Pro-di-Valerio.local: ~/Codes/apfelxx/tests — -b...
vbert...cern.ch  × vberto...-bash  vberto...-bash ...  vbe...bash ... >> +
Initialization... elapsed time: 0.212053 seconds
Evolution (4th order Runge-Kutta with 10 steps) from Q0 = 1.414214e+00 G
eV to Q = 1.000000e+02 GeV... elapsed time: 0.039274 seconds

AlphaQCD(Q) = 1.156047e-01

  x      u-ubar      d-dbar      2(ubr+dbr)      c+cbar      gluon
1.0e-05  3.1907e-03  1.9532e-03  3.4732e+01  1.5875e+01  2.2012e+02
1.0e-04  1.4023e-02  8.2749e-03  1.5617e+01  6.7244e+00  8.8804e+01
1.0e-03  6.0019e-02  3.4519e-02  6.4173e+00  2.4494e+00  3.0404e+01
1.0e-02  2.3244e-01  1.3000e-01  2.2778e+00  6.6748e-01  7.7913e+00
1.0e-01  5.4993e-01  2.7036e-01  3.8526e-01  6.4464e-02  8.5267e-01
3.0e-01  3.4622e-01  1.2833e-01  3.4600e-02  4.0132e-03  7.8898e-02
5.0e-01  1.1868e-01  3.0811e-02  2.3200e-03  2.3753e-04  7.6403e-03
7.0e-01  1.9486e-02  2.9901e-03  5.2355e-05  5.6022e-06  3.7082e-04
9.0e-01  3.3523e-04  1.6935e-05  2.5757e-08  4.3401e-09  1.1724e-06

vbertone@MacBook-Pro-di-Valerio:~/Codes/apfelxx/tests$
```

APFEL

```
vbertone@lxplus037.cern.ch: ~/hoppet-qed/example_f90 — ssh vberton...
vbert...cern.ch  vberto...-bash  vberto...-bash ...  vbe...bash ... >> +
WARNING in InitMTMNNLO: using parametrisation (less accurate) for A2PS
hg
Streamlined initialization completed!
Evolution done!

      Evaluating PDFs at Q = 100.000 GeV
  x      u-ubar      d-dbar      2(ubr+dbr)      c+cbar      gluon
1.0E-05  3.1907E-03  1.9532E-03  3.4732E+01  1.5875E+01  2.2012E+02
1.0E-04  1.4023E-02  8.2749E-03  1.5617E+01  6.7244E+00  8.8804E+01
1.0E-03  6.0019E-02  3.4519E-02  6.4173E+00  2.4494E+00  3.0404E+01
1.0E-02  2.3244E-01  1.3000E-01  2.2778E+00  6.6746E-01  7.7912E+00
1.0E-01  5.4993E-01  2.7035E-01  3.8526E-01  6.4466E-02  8.5266E-01
3.0E-01  3.4622E-01  1.2833E-01  3.4600E-02  4.0134E-03  7.8898E-02
5.0E-01  1.1868E-01  3.0811E-02  2.3198E-03  2.3752E-04  7.6398E-03
7.0E-01  1.9486E-02  2.9901E-03  5.2352E-05  5.6038E-06  3.7080E-04
9.0E-01  3.3522E-04  1.6933E-05  2.5735E-08  4.3368E-09  1.1721E-06

vbertone@lxplus037:~/hoppet-qed/example_f90$
vbertone@lxplus037:~/hoppet-qed/example_f90$
```

HOPPET

🍏 Perfect agreement between APFEL and HOPPET.

Other Recent Developments

- 🍏 **Intrinsic-charm** in DIS *a la* FONLL.
- 🍏 **Polarised DGLAP evolution** up to NNLO.
- 🍏 Independent factorisation and renormalisation **scale variations** both in the DIS structure functions and in the evolution,
- 🍏 framework for the **determination of FFs**.

In the Pipeline

- 🍏 Implementation of **TMD evolution** and **SIDIS cross sections**,
- 🍏 Implementation of the **polarised structure functions**,
- 🍏 **mass corrections** to SIA structure functions.

TMD Evolution (PDFs)

$$\begin{aligned} F_{f/P}(x, \mathbf{b}_T; \mu, \zeta) &= \sum_j C_{f/j}(x, b_*; \mu_b, \zeta_F) \otimes f_{j/P}(x, \mu_b) && : A \\ &\times \exp \left\{ K(b_*; \mu_b) \ln \frac{\sqrt{\zeta_F}}{\mu_b} + \int_{\mu_b}^{\mu} \frac{d\mu'}{\mu'} \left[\gamma_F - \gamma_K \ln \frac{\sqrt{\zeta_F}}{\mu'} \right] \right\} && : B \\ &\times \exp \left\{ g_{j/P}(x, b_T) + g_K(b_T) \ln \frac{\sqrt{\zeta_F}}{\sqrt{\zeta_{F,0}}} \right\} && : C \end{aligned}$$

TMD Evolution (PDFs)

$$\begin{aligned}
 F_{f/P}(x, \mathbf{b}_T; \mu, \zeta) &= \sum_j C_{f/j}(x, b_*; \mu_b, \zeta_F) \otimes f_{j/P}(x, \mu_b) && : A \\
 &\times \exp \left\{ K(b_*; \mu_b) \ln \frac{\sqrt{\zeta_F}}{\mu_b} + \int_{\mu_b}^{\mu} \frac{d\mu'}{\mu'} \left[\gamma_F - \gamma_K \ln \frac{\sqrt{\zeta_F}}{\mu'} \right] \right\} && : B \\
 &\times \exp \left\{ g_{j/P}(x, b_T) + g_K(b_T) \ln \frac{\sqrt{\zeta_F}}{\sqrt{\zeta_{F,0}}} \right\} && : C
 \end{aligned}$$

- $b_T \ll 1/\Lambda_{\text{QCD}}$
- matching to the collinear region
- factorises as hard and non-perturbative
- numerically cumbersome
- precompute using the APFEL technology

- CS evolution
- perturbative

- matching between the small and large b_T
- non perturbative
- parametrised and fitted to data

TMDs in SIDIS

🍏 In SIDIS, what enters the computation of the cross sections is:

$$\mathcal{L}_{\text{SIDIS}} = \int \frac{d^2 \mathbf{b}_T}{(2\pi)^2} e^{-i\mathbf{q}_T \cdot \mathbf{b}_T} F_{f/P}(x, \mathbf{b}_T; \mu, \zeta_F) D_{H/f}(x, \mathbf{b}_T; \mu, \zeta_D)$$

Fourier transform

PDFs

FFs

🍏 The ingredients are:

🍏 a set of evolved TMD-PDFs,

🍏 a set of evolved TMD-FFs,

🍏 the Fourier transform of its product.

🍏 Complex set of tasks that have to be performed optimally

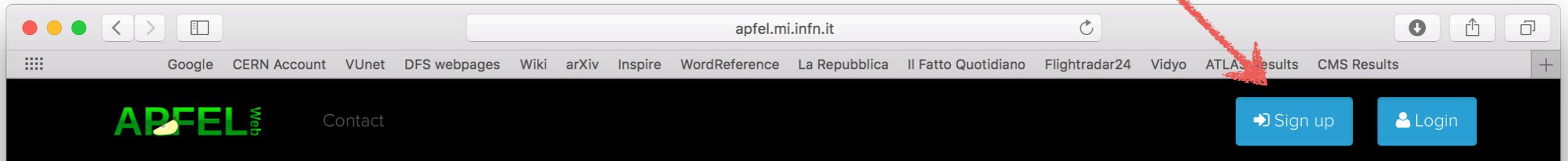
🍏 APFEL provides the ideal environment for this computation:

🍏 fast and accurate interpolation techniques,

🍏 precomputation of the time consuming bits.

APFEL Web

Go to <http://apfel.mi.infn.it> and sign up



Welcome to APFEL online cluster!

This web-application is a tool designed for High Energy Physics by providing a simple and intuitive interface to plot and compute the most common observables with Parton Distribution Functions (PDFs).

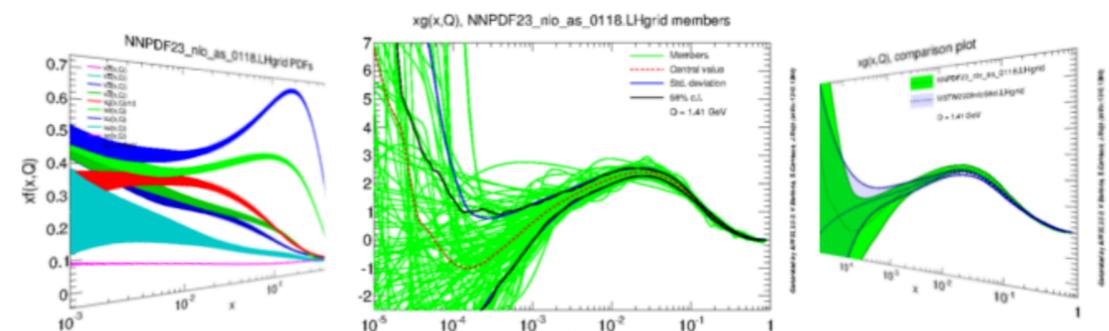
To begin to produce on-line plots, please [register](#) and [login](#)!

The APFEL library

APFEL, a PDF evolution library, is a computer library specialized in the solution of DGLAP evolution equations up to NNLO in QCD and to LO in QED, both with Pole and $\overline{\text{MS}}$ masses. With APFEL you can replace the evolution of LHAPDF sets and check the impact on the choice of evolution parameters. APFEL also computes deep-inelastic scattering processes using multiple schemes.

If you use the APFEL library or the online cluster in a scientific publication, please cite: V. Bertone, S. Carrazza and J. Rojo, "APFEL: A PDF Evolution Library with QED corrections", Comput. Phys. Commun. 185, 1647 (2014), [arXiv:1310.1394](#).

S. Carrazza et al., "APFEL Web: a web-based application for the graphical visualization of parton distribution functions", J. Phys. G: Nucl. Part. Phys. 42 057001, [arXiv:1410.5456](#). [Labtalk](#).



Web developers: D. Palazzo, S. Carrazza, A. Ferrara
APFEL developers: V. Bertone, S. Carrazza, J. Rojo. ([Contact](#))

APFEL Web

Go to <http://apfel.mi.infn.it> and sign up

The screenshot displays the APFEL Web registration page in a browser window. The browser's address bar shows the URL apfel.mi.infn.it. The page header includes the APFEL logo and navigation links for 'Home' and 'Sign up'. The main content area is titled 'APFEL registration' and contains the following text: 'Please complete the form below to access to the APFEL website:'. Below this text is a registration form with four input fields: 'Enter your e-mail address', 'Enter your password', 'Confirm your password', and 'Spin of the Standard Model Higgs?'. A blue 'Register' button is positioned below the form. To the right of the form, there is a QR code and an 'ANDROID APP ON Google play' badge. The browser's navigation bar at the top shows various search engines and links, with a red arrow pointing to the 'Sign up' button.

APFEL Web

Workspace

The screenshot shows the APFEL Web Workspace interface. A red arrow points from the 'Workspace' header to the left sidebar menu. The main content area shows a welcome message, a tweet with a plot, and a status table.

Workspace

- Home
- My Profile

PDF MANAGER

- My PDF sets
- Add PDF set
- Import a LHAPDF grid

TOOLS

- Plotting Tools

DOWNLOAD RESULTS

- View jobs

Welcome to APFEL Web

APFEL Web News & Documentation

Tweets by @apfelwebteam

01 Jun

APFEL Web @apfelwebteam
Check out the updated graphics interface in

[Embed](#) [View on Twitter](#)

APFEL Web Status

| Component | Status |
|---------------|---------|
| Cores | 100% |
| APFEL library | 2.4.0 |
| LHAPDF6 | 6.1.5 |
| LHAPDF5 | 5.9.1 |
| ROOT | 5.34/21 |
| APPLgrid | 1.4.56 |
| Overall | running |

APFEL Web Workflow

APFEL Web

Workspace



The screenshot displays the APFEL Web Workspace interface. At the top, a browser window shows the URL `apfel.mi.infn.it`. Below the browser, a navigation bar includes the APFEL logo, a 'Contact' link, and a 'Logout' button. A sidebar on the left contains the following menu items: 'Workspace', 'Home', 'My Profile', 'PDF MANAGER', 'My PDF sets', 'Add PDF set', 'Import a LHAPDF', 'TOOLS', 'Plotting Tools', and 'DOWNLOAD RESULTS', 'View jobs'. The main content area is titled 'My APFEL Web Gallery' and contains a grid of 20 plots. Each plot is a log-log graph showing the 'Ratio' on the y-axis and 'x' on the x-axis. The plots are arranged in a 5x4 grid. The first row contains plots for $xy(x,Q)$, $xu(x,Q)$, $xg(x,Q)$, and $x\bar{u}(x,Q)$. The second row contains plots for $xu(x,Q)$, $xg(x,Q)$, $xu(x,Q)$, and $xg(x,Q)$. The third row contains plots for $xu(x,Q)$, $xg(x,Q)$, $xu(x,Q)$, and $xg(x,Q)$. The fourth row contains plots for $xg(x,Q)$, $xg(x,Q)$, $x\bar{u}(x,Q)$, and $xg(x,Q)$. The fifth row contains plots for $x\bar{u}(x,Q)$, $xg(x,Q)$, $x\bar{u}(x,Q)$, and $xg(x,Q)$. Each plot compares a theoretical prediction (green shaded area) with a reference prediction (blue shaded area). The plots are generated with APFEL 2.0.0. The footer of the page includes 'APFEL Web documentation' and 'APFEL Web Workflow'.

APFEL Web

Add a new PDF set

The screenshot shows the APFEL Web interface in a browser window. The address bar displays `apfel.mi.infn.it`. The top navigation bar includes the APFEL logo, a 'Contact' link, and a 'Logout' button. The left sidebar contains a 'Workspace' section with 'Home' and 'My Profile' links, a 'PDF MANAGER' section with 'My PDF sets' and 'Add PDF set' (highlighted in blue), and 'TOOLS' and 'DOWNLOAD RESULTS' sections. The main content area is titled 'Set parameters for PDF' and features a 'LHAPDF grid setup:' section. This section includes a 'PDF Set:' dropdown menu with 'NNPDF30_nlo_as_0118' selected, a 'PDF Error:' dropdown menu with 'Montecarlo - Standard Deviation' selected, a 'Select member:' dropdown menu with '0' selected, and a 'Library for evolution:' dropdown menu with 'LHAPDF' selected. A blue 'Confirm' button is located below these fields. A red arrow points from the 'Add PDF set' option in the sidebar to the 'LHAPDF' dropdown menu. Another red arrow points from the bottom of the page to the 'LHAPDF' dropdown menu.

Workspace

- Home
- My Profile

PDF MANAGER

- My PDF sets
- Add PDF set**
- Import a LHAPDF grid

TOOLS

- Plotting Tools

DOWNLOAD RESULTS

- View jobs

Set parameters for PDF

LHAPDF grid setup:

PDF Set: NNPDF30_nlo_as_0118 a LHAPDF6 grid

PDF Error: Montecarlo - Standard Deviation

Select member: 0

Library for evolution: LHAPDF

[APFEL advanced evolution options](#)

Confirm

Use tabulated LHAPDF evolution...

APFEL Web

Add a new PDF set

Library for evolution: APFEL

[APFEL advanced evolution options](#)

APFEL evolution setup:

Theory: QCD

Solution: Exact

Perturbative order: LO (LO QED)

Scheme: VFNS

HQ Scheme: POLE

m_c , charm mass in (GeV): 1,275

m_b , bottom mass in (GeV): 4,18

m_t , top mass in (GeV): 173,07

$\alpha_S(Q_{\text{ref}})$: 0,118

Q_{ref} (GeV): 91,2

$\alpha(Q_{\text{ref}})$: 0,007496252

Q_{ref} (GeV): 1,777

μ_R/μ_F : 1,00

Maximum flavor PDFs: 6

Maximum flavor α : 6

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Plotting tools



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PDF MANAGER

- My PDF sets
- Add PDF set
- Import a LHAPDF grid

TOOLS

- Plotting Tools**

DOWNLOAD RESULTS

- View jobs

Choose a plotting tool and select your PDF set

Some jobs, like PDF luminosities, require some time to be finalized. Check the job status at [View jobs](#) page.

The plotting tools can be used for both the LHAPDF libraries: [LHAPDF5](#) and [LHAPDF6](#).

Tools for PDF basic plotting

- Plot PDF Members
- Plot Multiple PDF Flavors

Tools for PDF analysis & comparisons

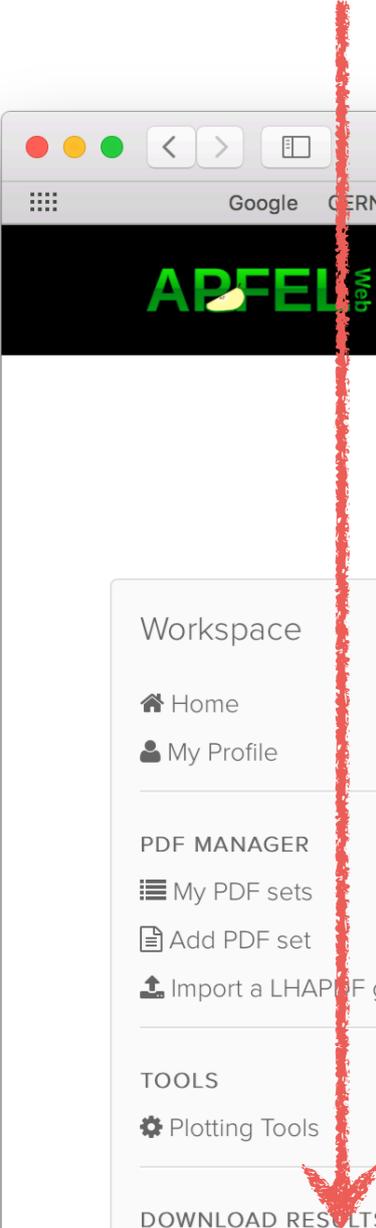
- Compare PDFs in x
- Compare PDFs in Q
- Compare PDF Luminosity
- All PDF Luminosities
- Compare PDF Correlations
- PDF Correlation Matrix

Tools for theoretical predictions from PDFs

- DIS in x
- DIS in Q
- APPLgrid Observables

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Choose a plotting tool and select your PDF set

Some jobs, like PDF luminosities, require some time to be finalized. Check the job status at [View jobs](#) page.

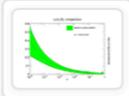
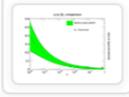
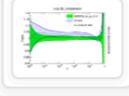
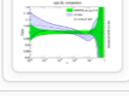
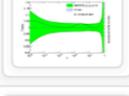
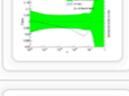
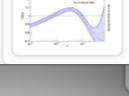
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| Image | Label | Status | Date | Actions |
|---|--------------------------|--------|---------------------------|---|
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|  | LH5_30 | Done | Oct. 22, 2016, 11:16 p.m. | Details Clone Erase |
|  | NN_vs_CT_NLO_up | Done | Aug. 10, 2016, 5:13 p.m. | Details Clone Erase |
|  | NN_vs_CT_NLO_gluon | Done | Aug. 10, 2016, 5:13 p.m. | Details Clone Erase |
|  | NN_vs_CT_LO_up | Done | Aug. 10, 2016, 5:12 p.m. | Details Clone Erase |
|  | NN_vs_CT_LO_gluon | Done | Aug. 10, 2016, 5:11 p.m. | Details Clone Erase |
|  | gluon_CT14_LO_vs_NLO_ext | Done | Aug. 1, 2016, 11:33 a.m. | Details Clone Erase |