PDFs at N^{3}LO in APFEL++

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Evolution for N^{3}LO

- A fundamental ingredient to use N^{3}LO computations in extractions of PDFs is the **evolution** accurate to the same order.

- The main ingredients to achieve N^{3}LO accuracy in PDF evolution are:

  - the $\boldsymbol{O(\alpha_s^4)}$ contribution to the anomalous dimensions, *i.e.* $\boldsymbol{\beta_3(n_f)}$ and $\boldsymbol{P^{(3)}(x, n_f)}$,

    - $\boldsymbol{\beta_3(n_f)}$ was computed long ago [van Ritbergen, Vermaseren, Larin, hep-ph/9701390].

    - The **non-singlet** component of $\boldsymbol{P^{(3)}(x, n_f)}$ exact in the planar limit has been computed relatively recently [Moch *et al.*, arXiv:1707.08315].

  - When a variable-flavour number scheme is used, **matching conditions** for the evolution of α_s and PDFs accurate to $\boldsymbol{O(\alpha_s^3)}$ are also necessary.

    - $O(\alpha_s^3)$ matching conditions for α_s are known (see *e.g.* [Chetyrkin *et al.*, hep-ph/0004189]).

    - Matching conditions for PDFs fully known only up to $O(\alpha_s^2)$ (in fact, matching conditions involving a heavy quark in the initial state are known to $O(\alpha_s)$).

Evolution for N^{3}LO

- Recently the MSHT group has carried out a determination of PDFs at *approximated* N^{3}LO [arXiv:2207.04739]

- The authors also released the relevant missing ingredients to perform approximated N^{3}LO in the VFNS:

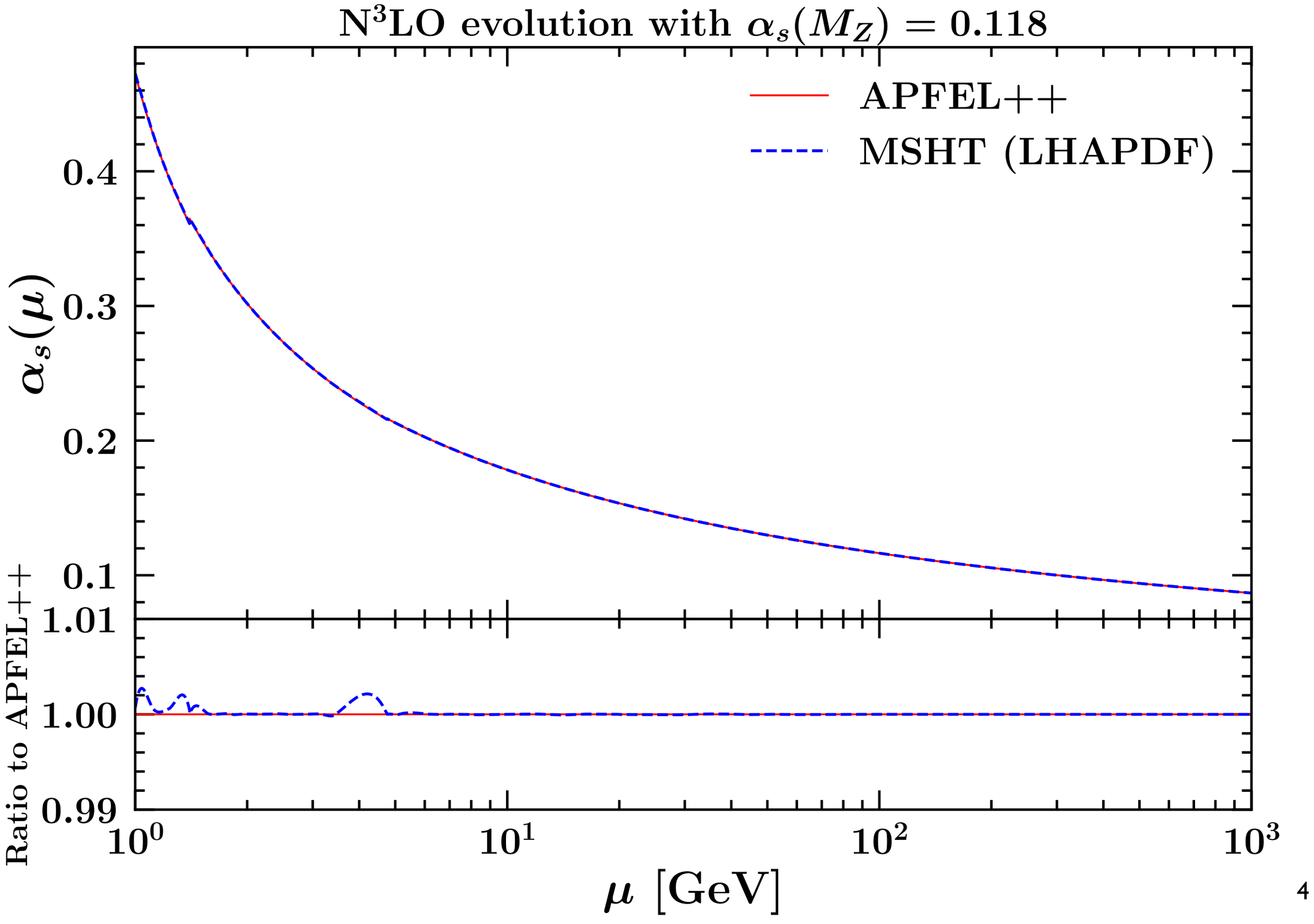
  - The **singlet** components of $P^{(3)}(x, n_f)$ and $O(\alpha_s^3)$ **matching functions** parameterised and fitted to the first known Mellin moments.

  - **Uncertainty** to gauge the accuracy of the parameterisations also provided.

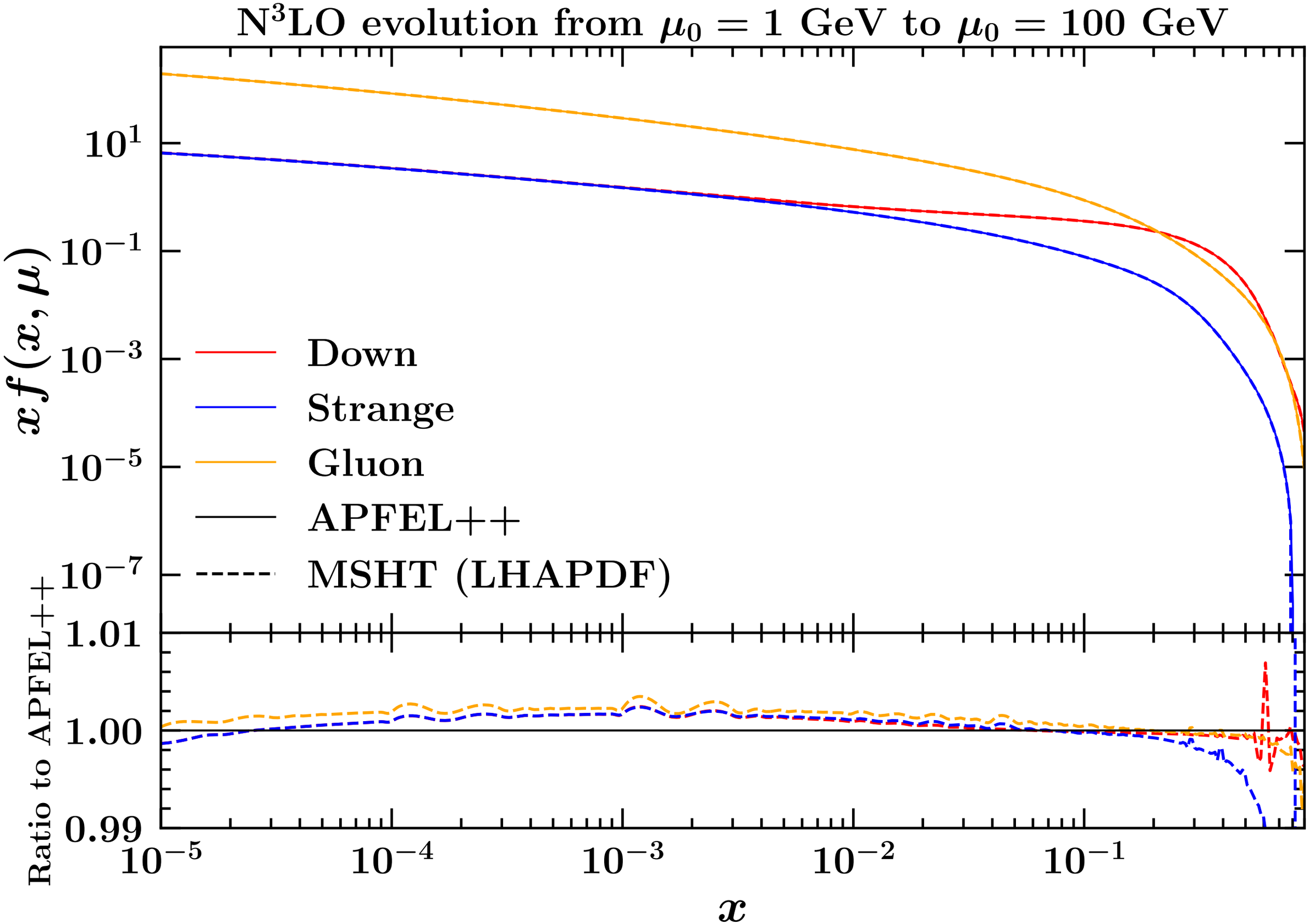
  - A fortran code with the expressions released at: https://github.com/MSHTPDF/N3LO_additions

- All the *currently known* ingredients necessary for PDF evolution at N^{3}LO are implemented in **APFEL++.** [https://github.com/vbertone/apfelxx]

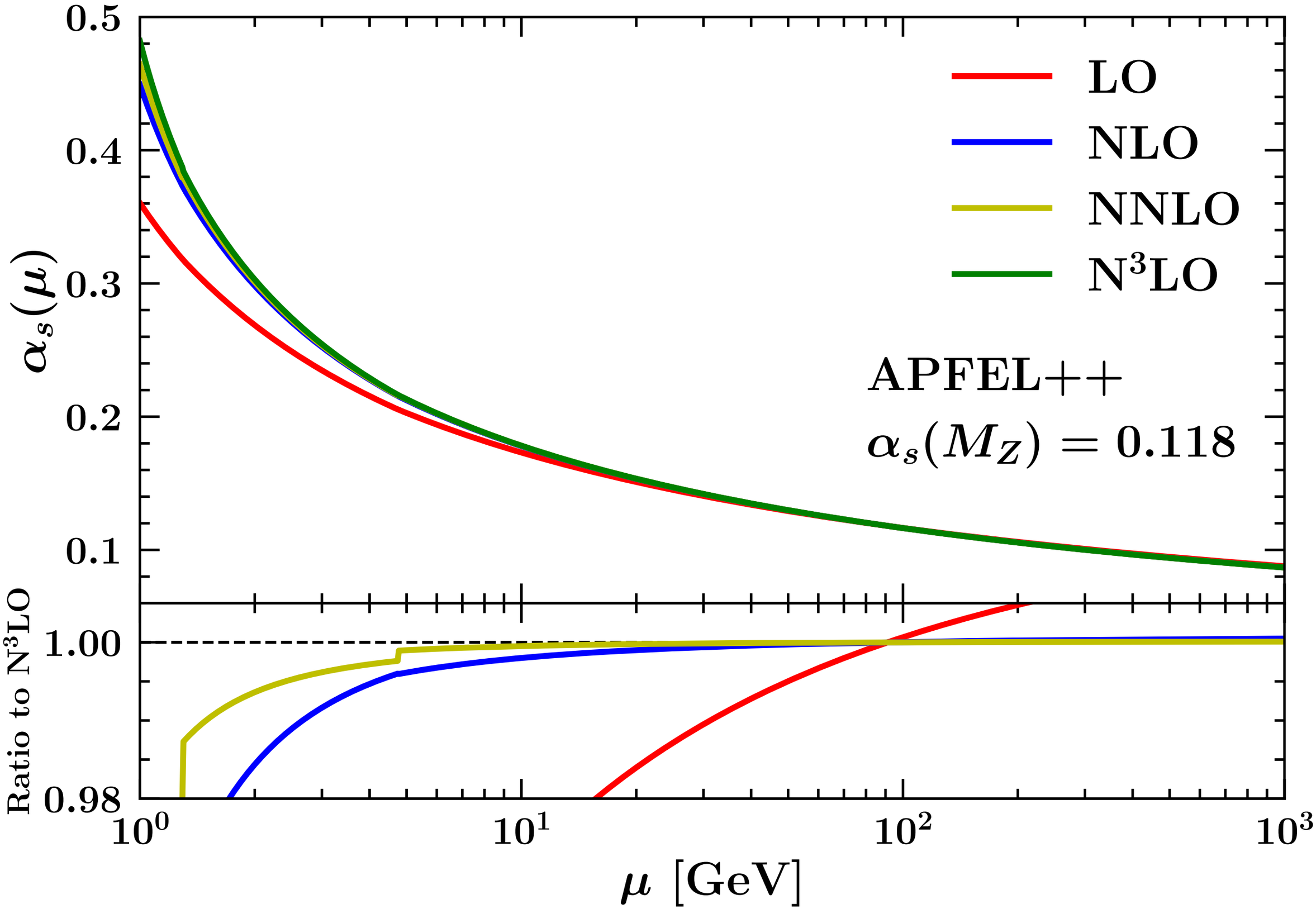
The strong coupling



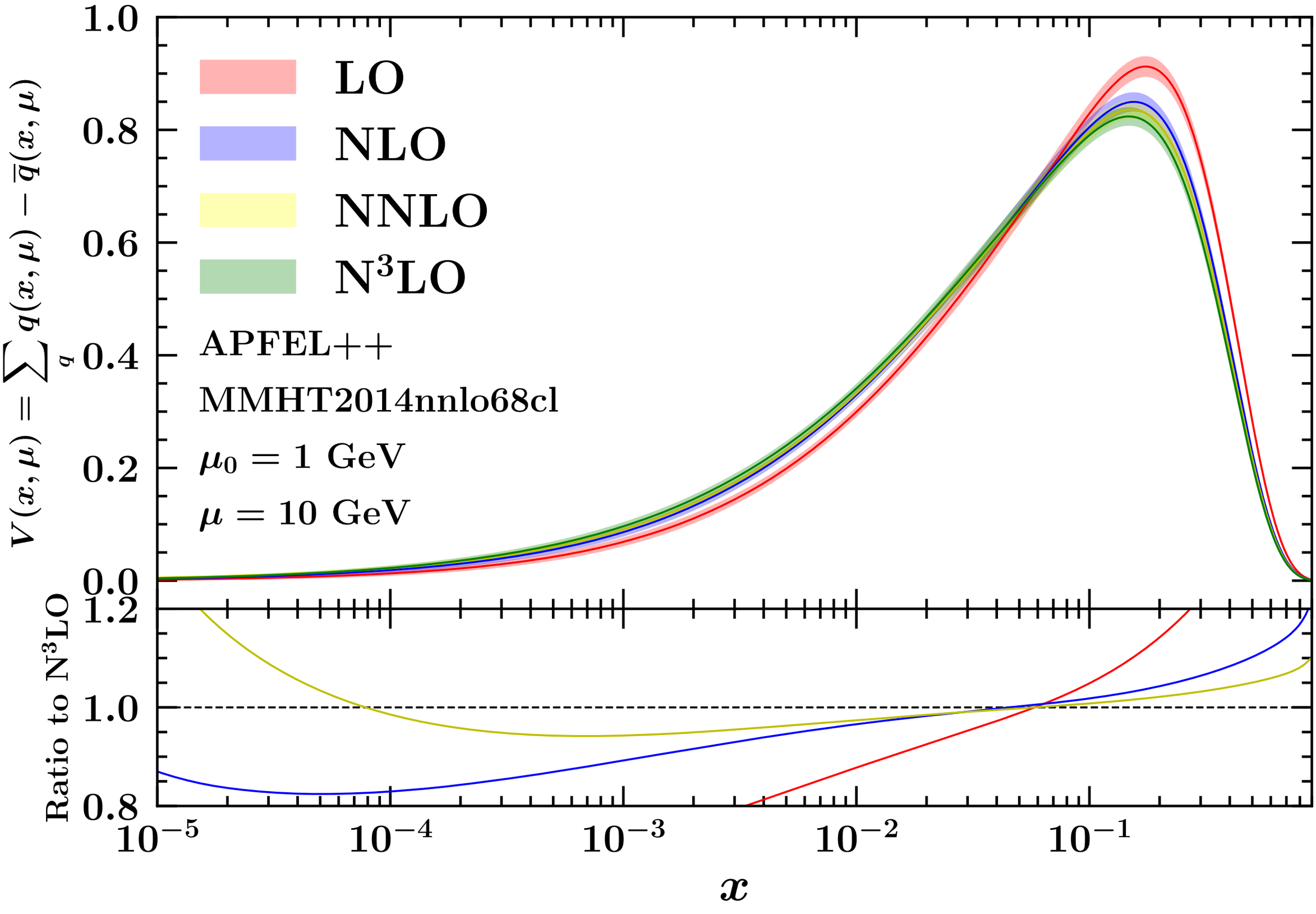
The PDFs


N³LO evolution from $\mu_0 = 1$ GeV to $\mu_0 = 100$ GeV
$xf(x,\mu)$
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
Down
Strange
Gluon
APFEL++
MSHT (LHAPDF)
Ratio to APFEL++
1.01
1.00
0.99
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
x

The strong coupling



The (valence) PDFs



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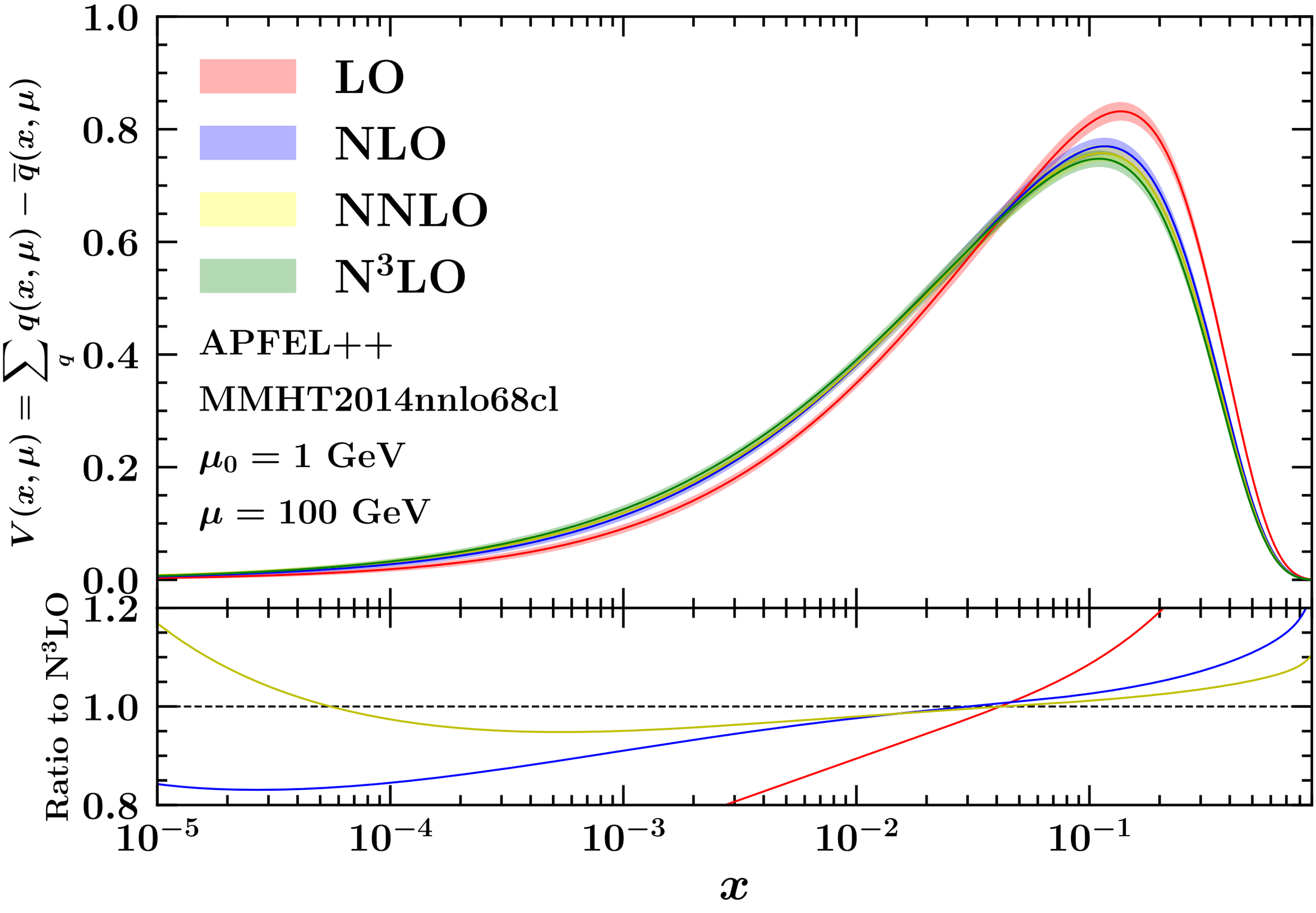
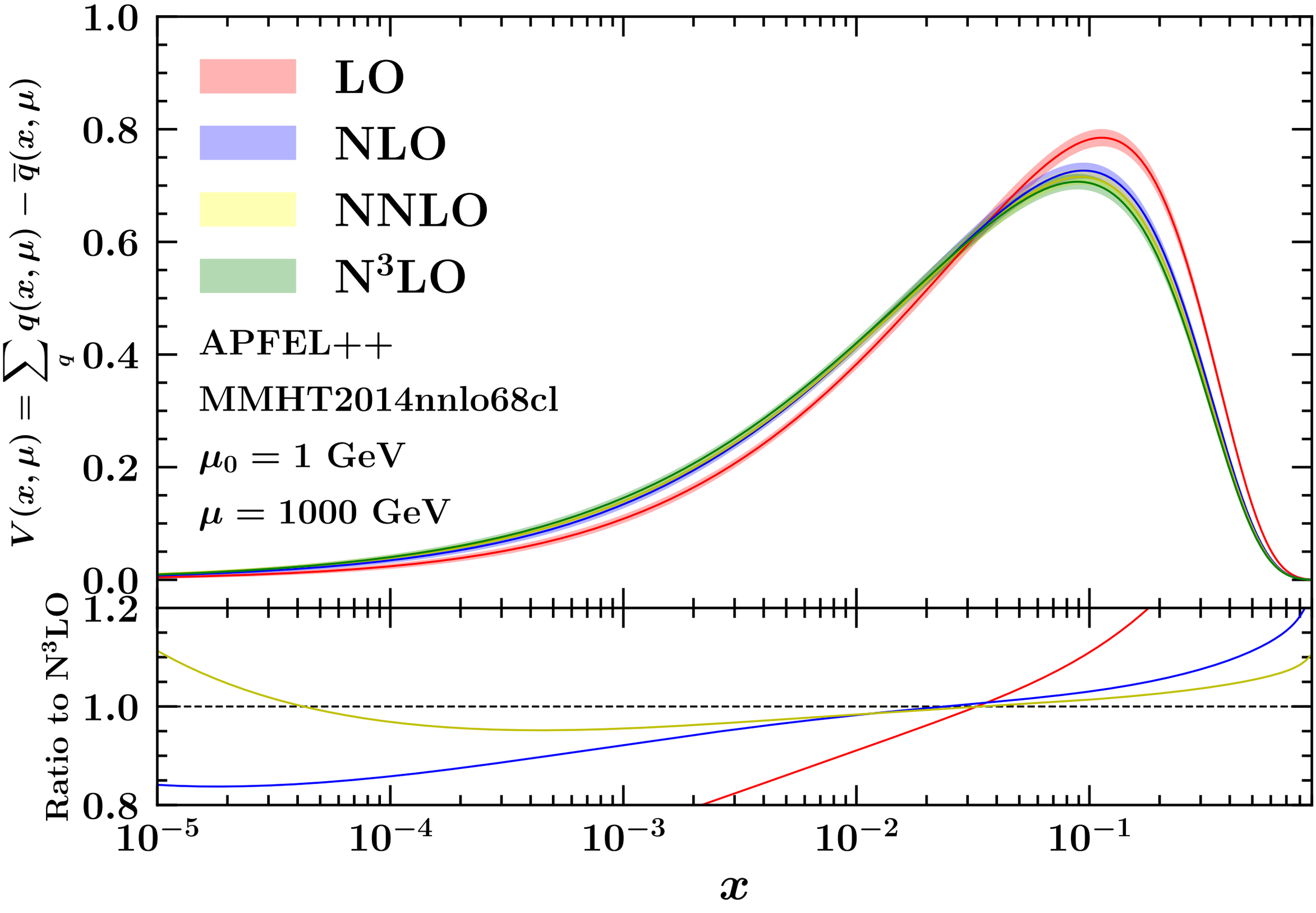
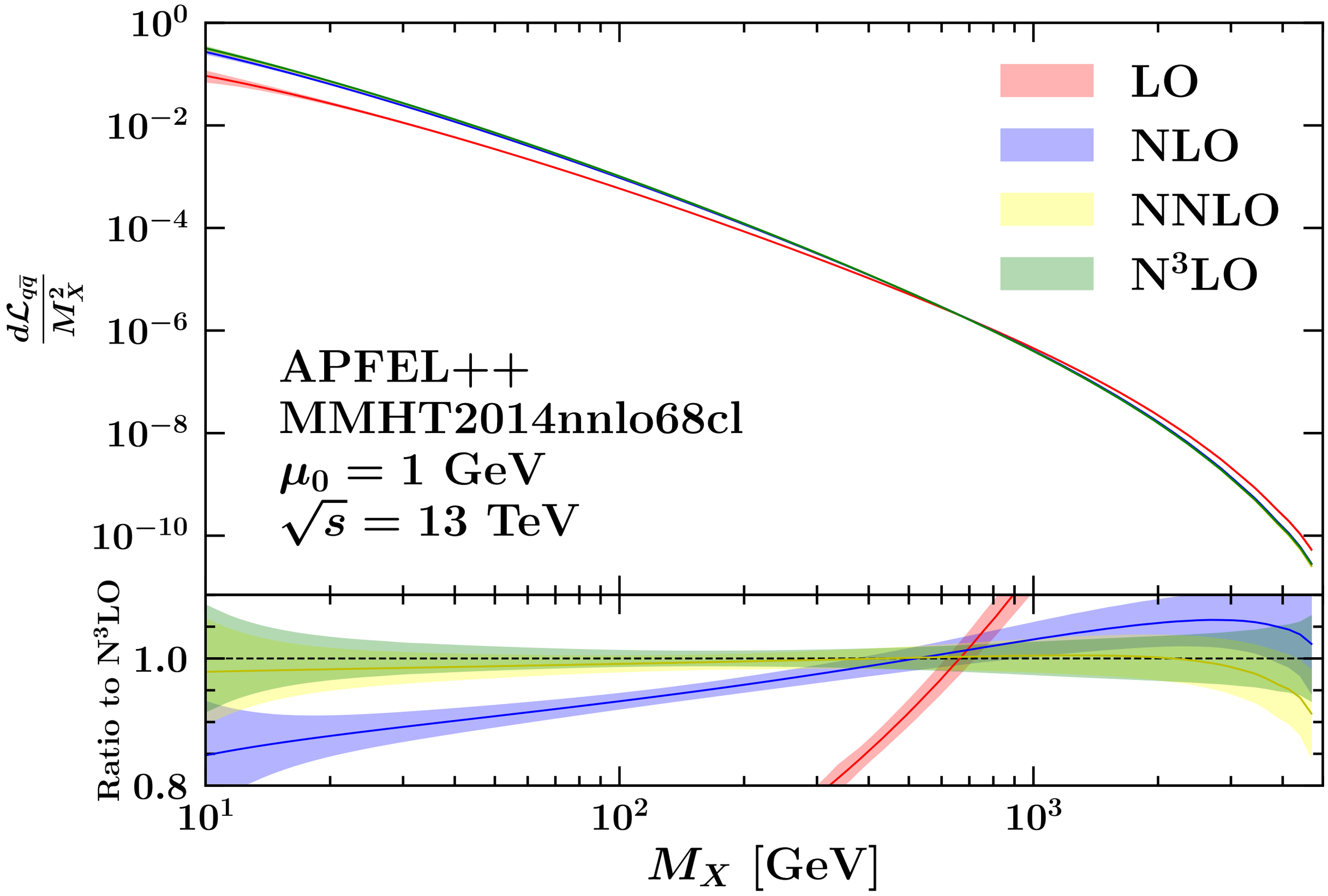


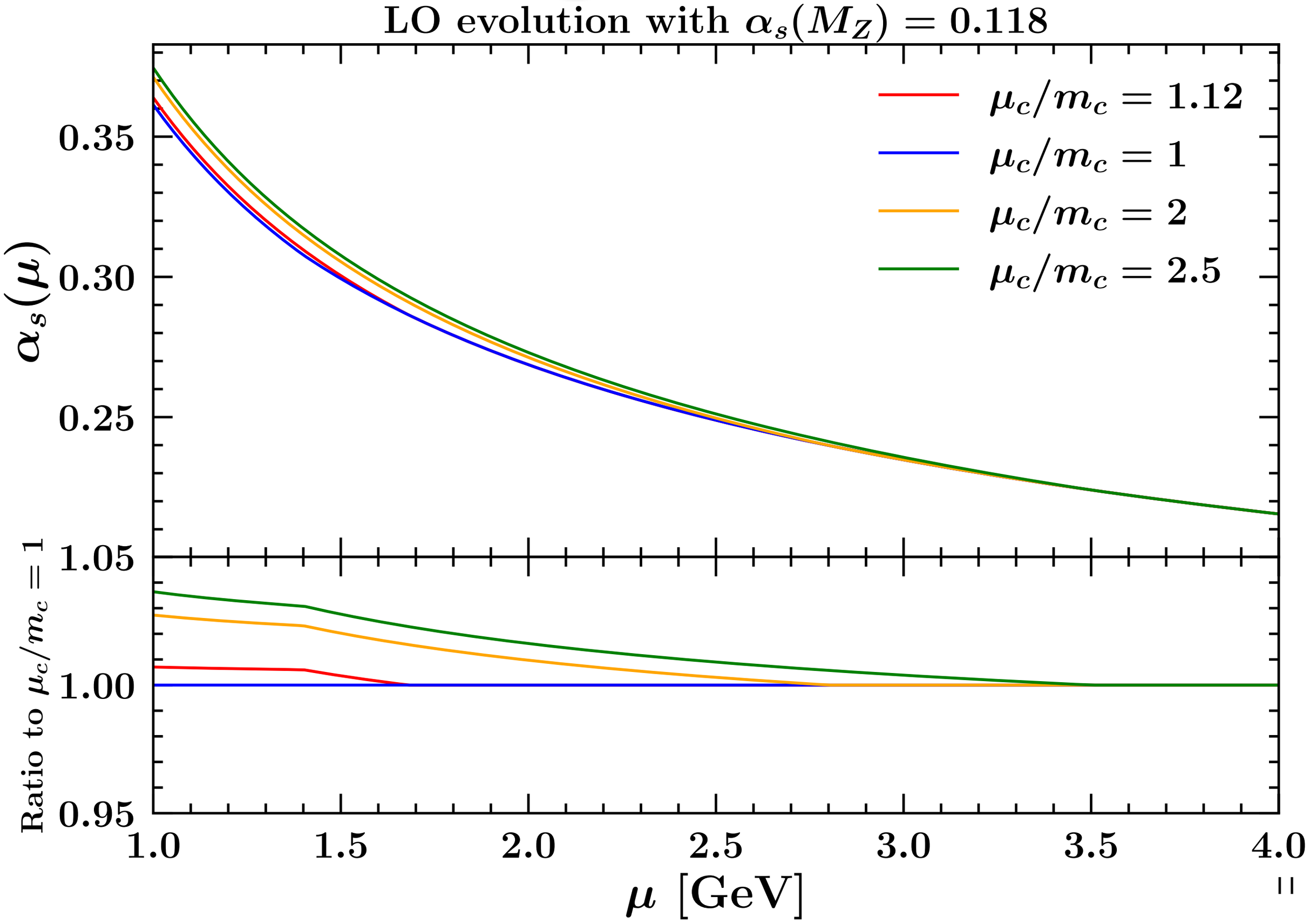
The (valence) PDFs



The parton luminosities



The matching conditions



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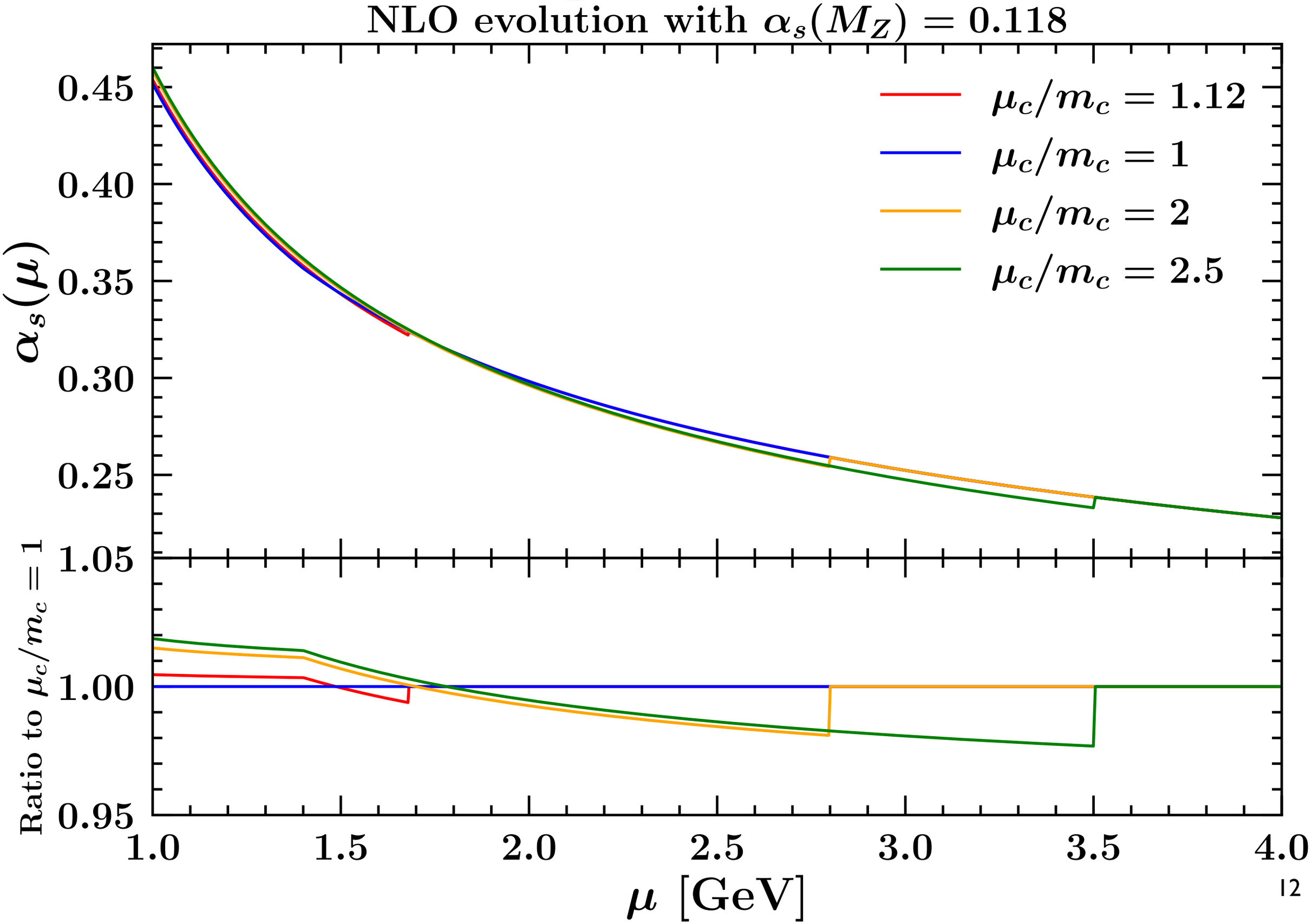

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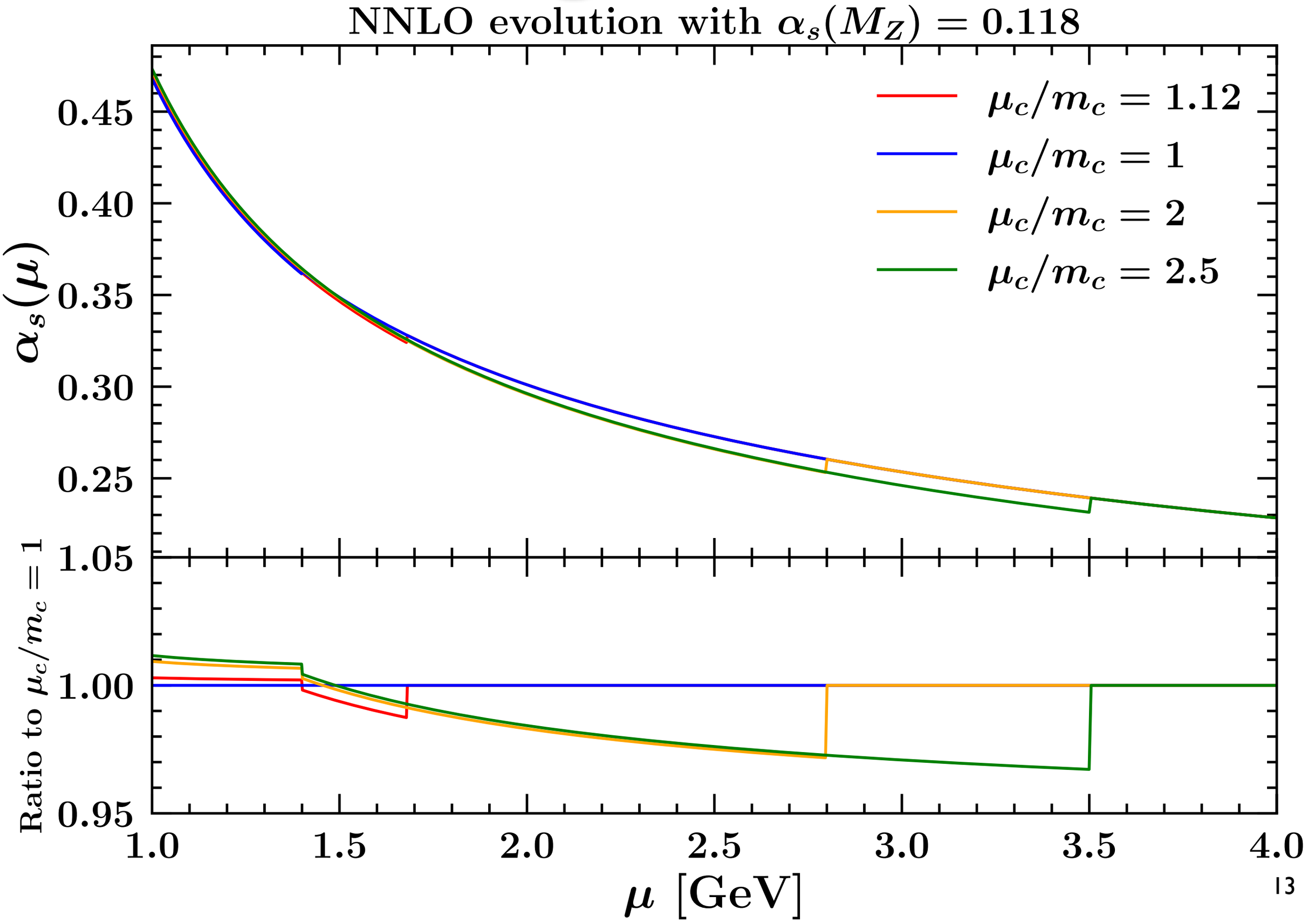

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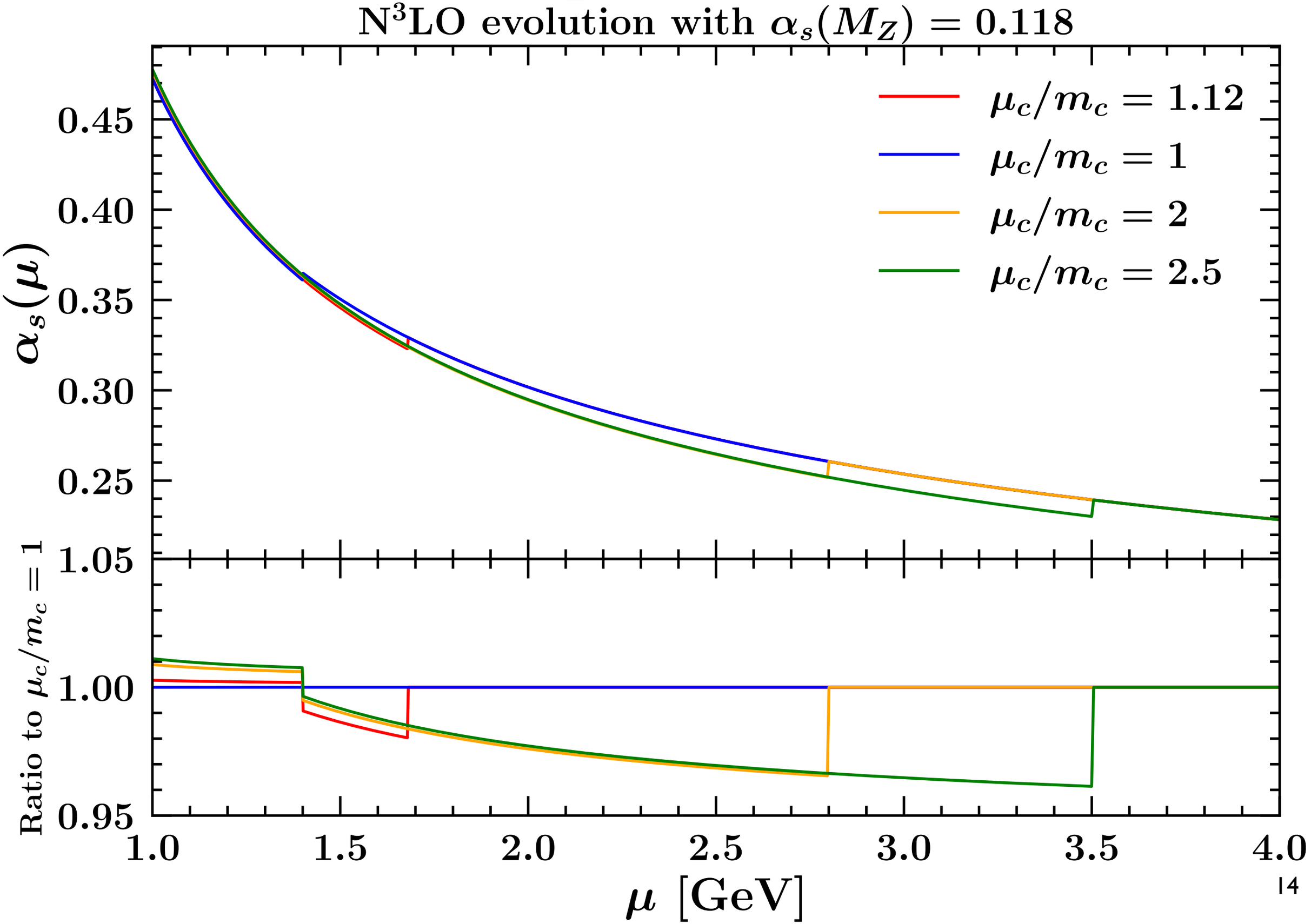

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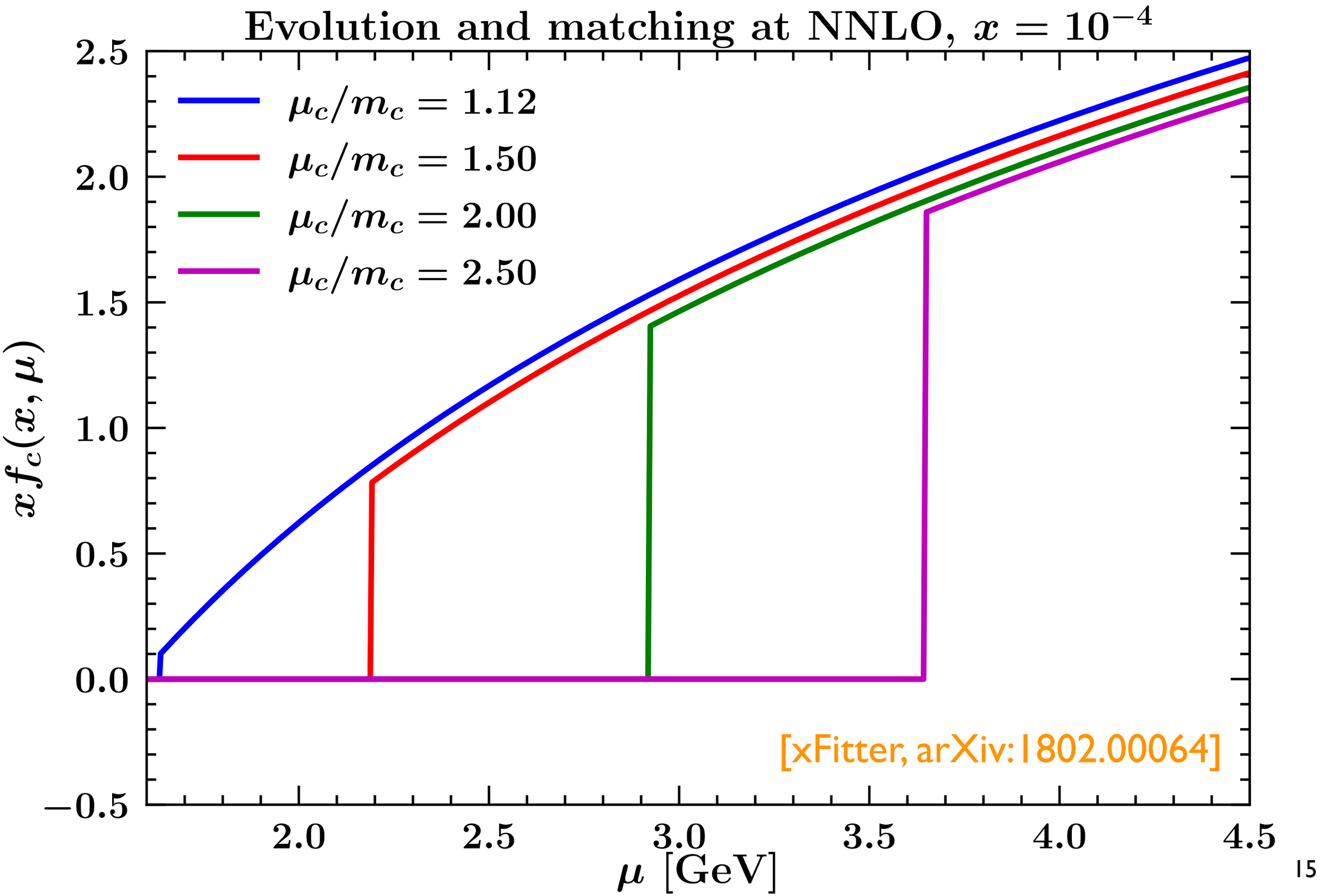

[xFitter, arXiv:1802.00064]

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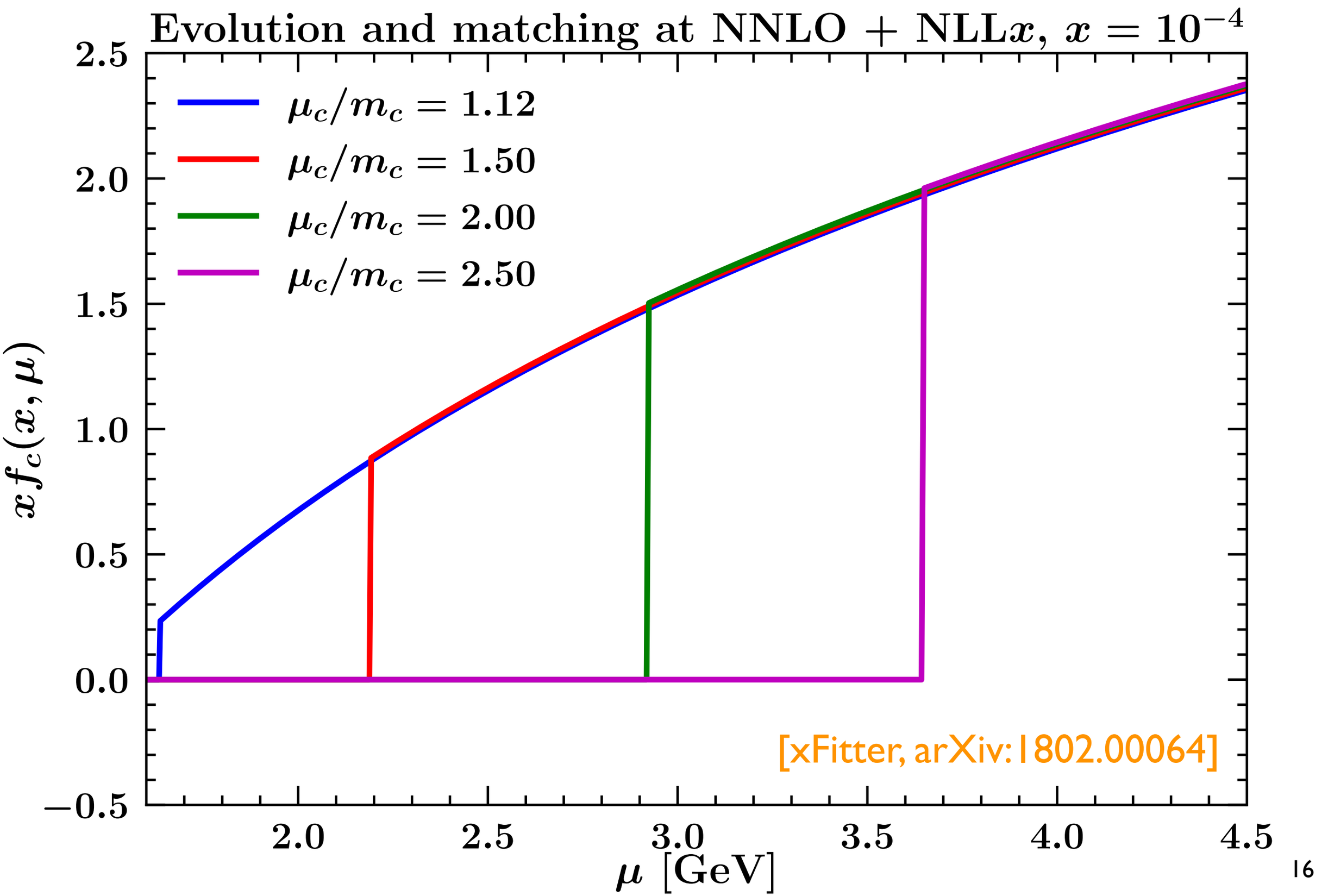


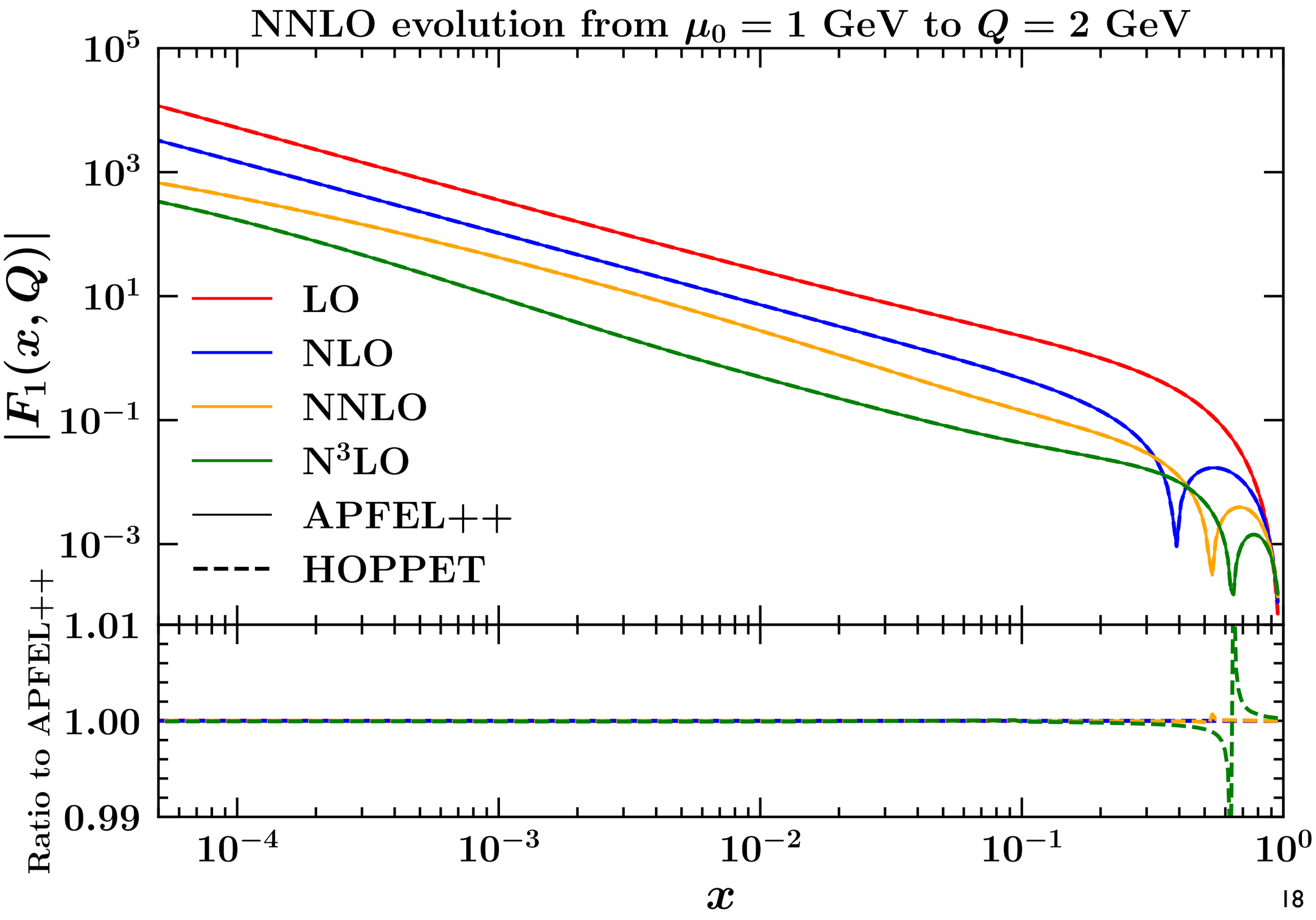
Structure functions

- N^{3}LO corrections to the DIS structure functions in the zero-mass scheme are known since quite long:
  - hep-ph/0209100,
  - hep-ph/0504242,
  - hep-ph/0411112,
  - hep-ph/0608307.

- Again the *currently known* ingredients necessary for computing structure functions to N^{3}LO are implemented in **APFEL++**.

- Presently, with the help of Alexander Karlberg, we are carrying out a benchmark of APFEL++ and HOPPET:
  - so far, neutral current F_2 and F_L (or F_1 and F_2) are in perfect agreement,
  - still working of F_3 to fix a small difference.
  - Also working on the charged-current structure functions.

Structure functions



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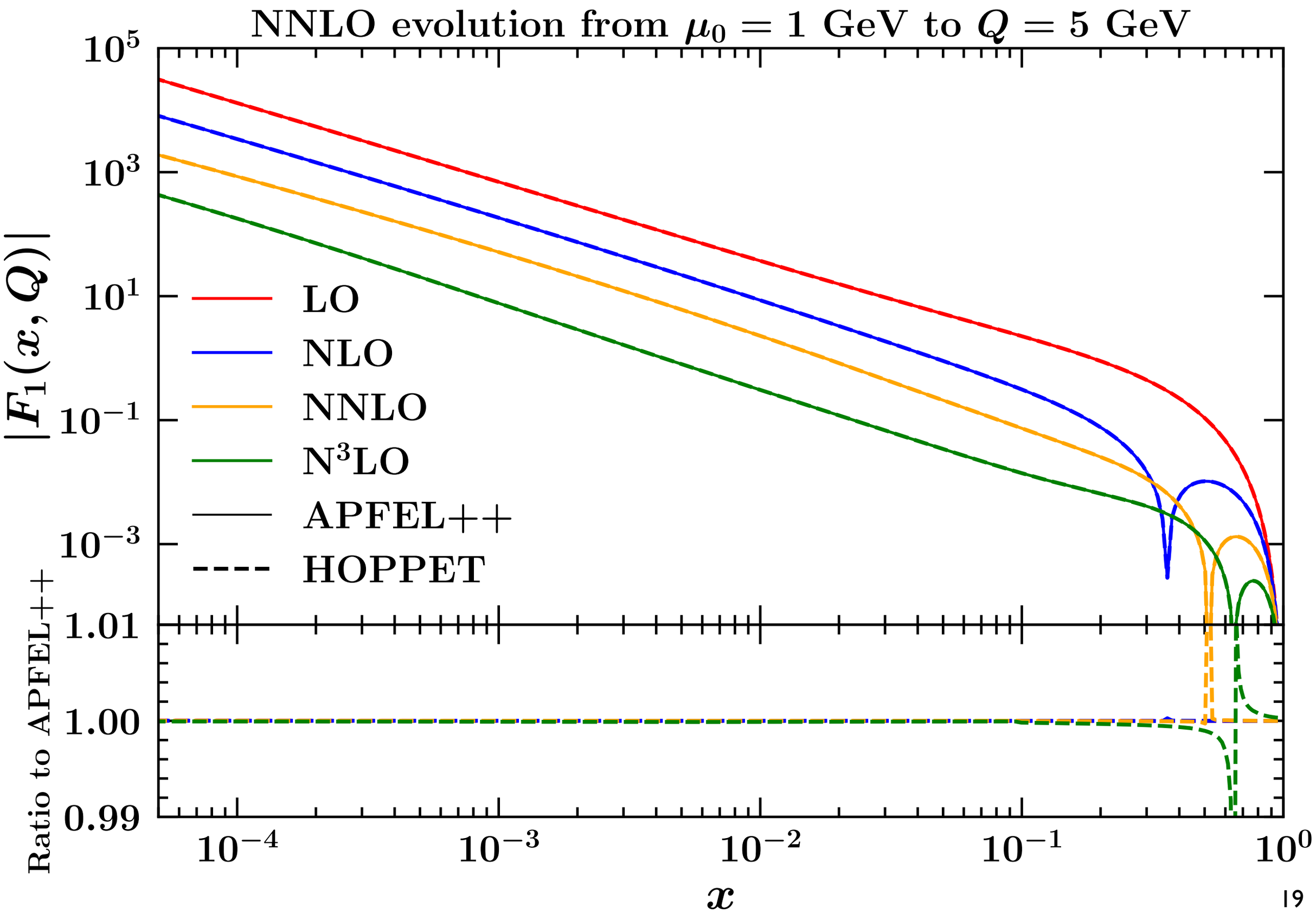

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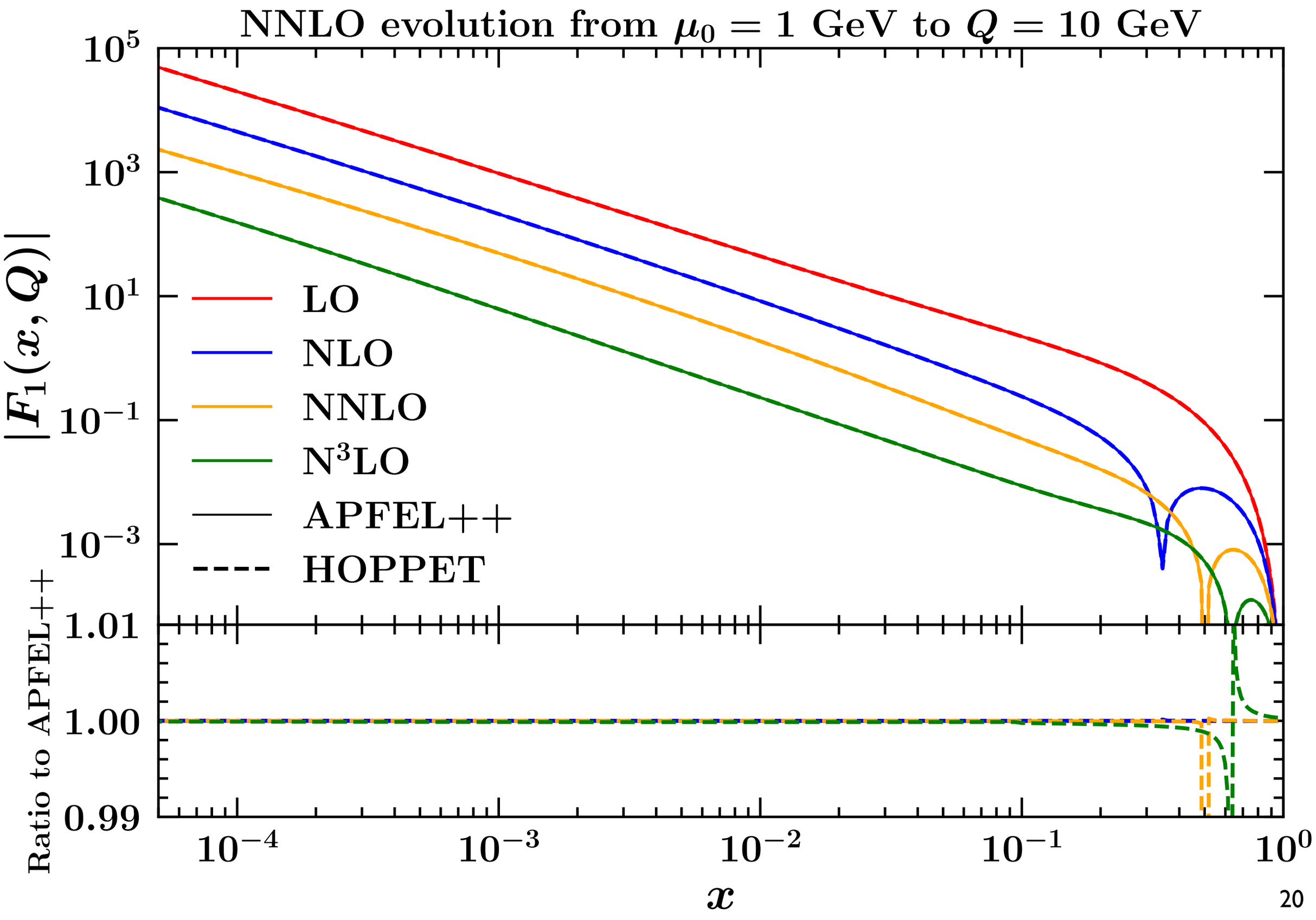

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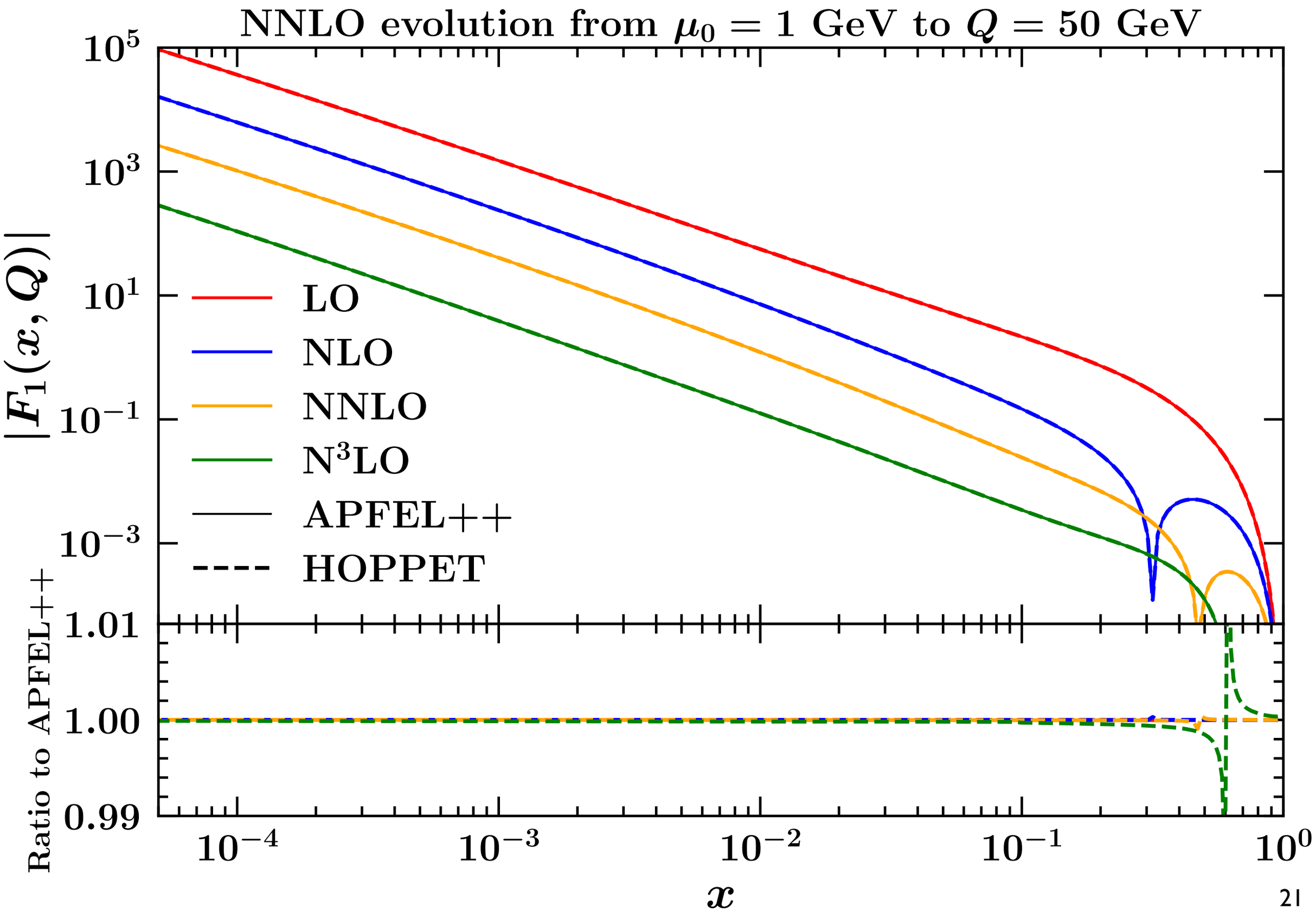

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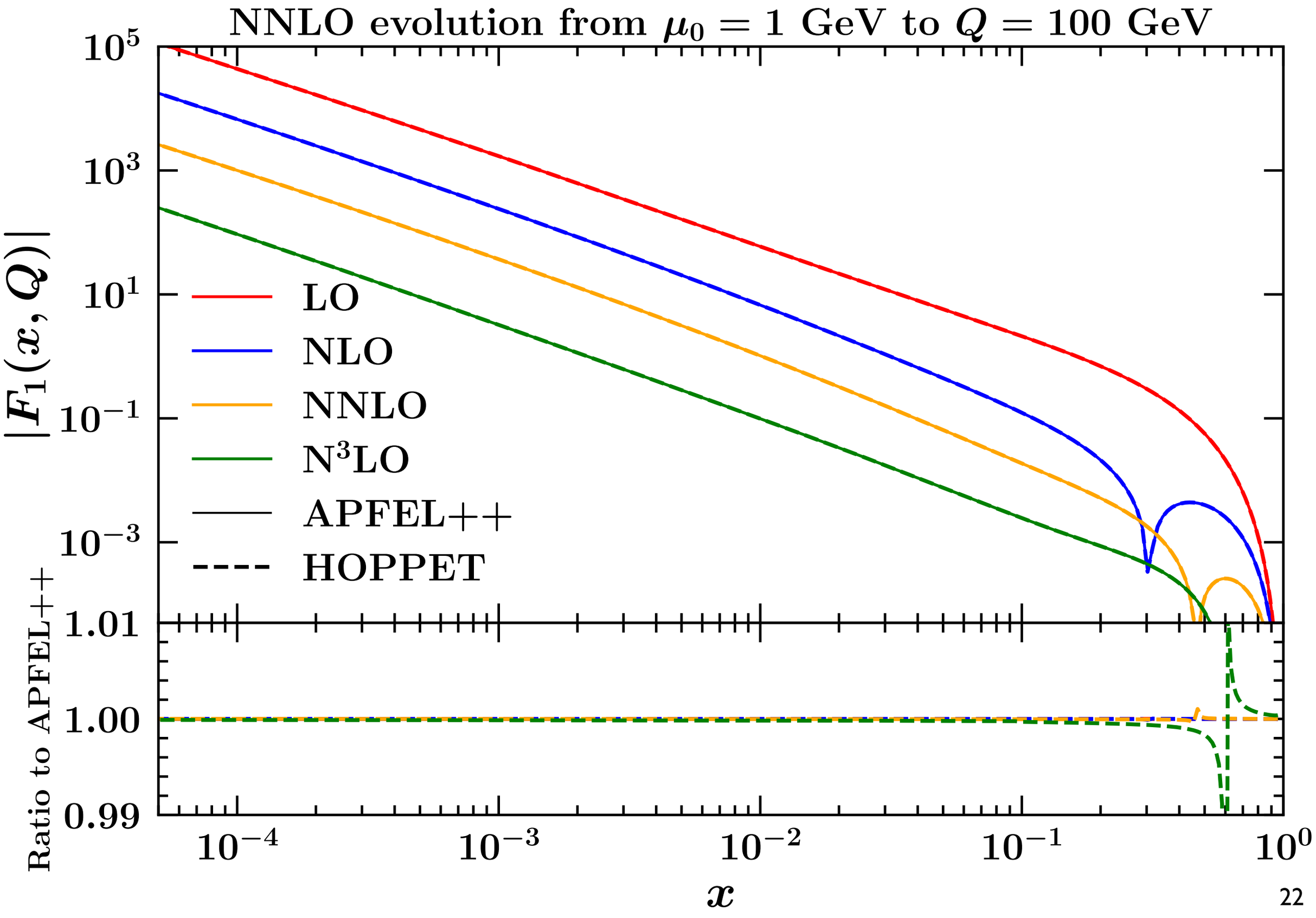

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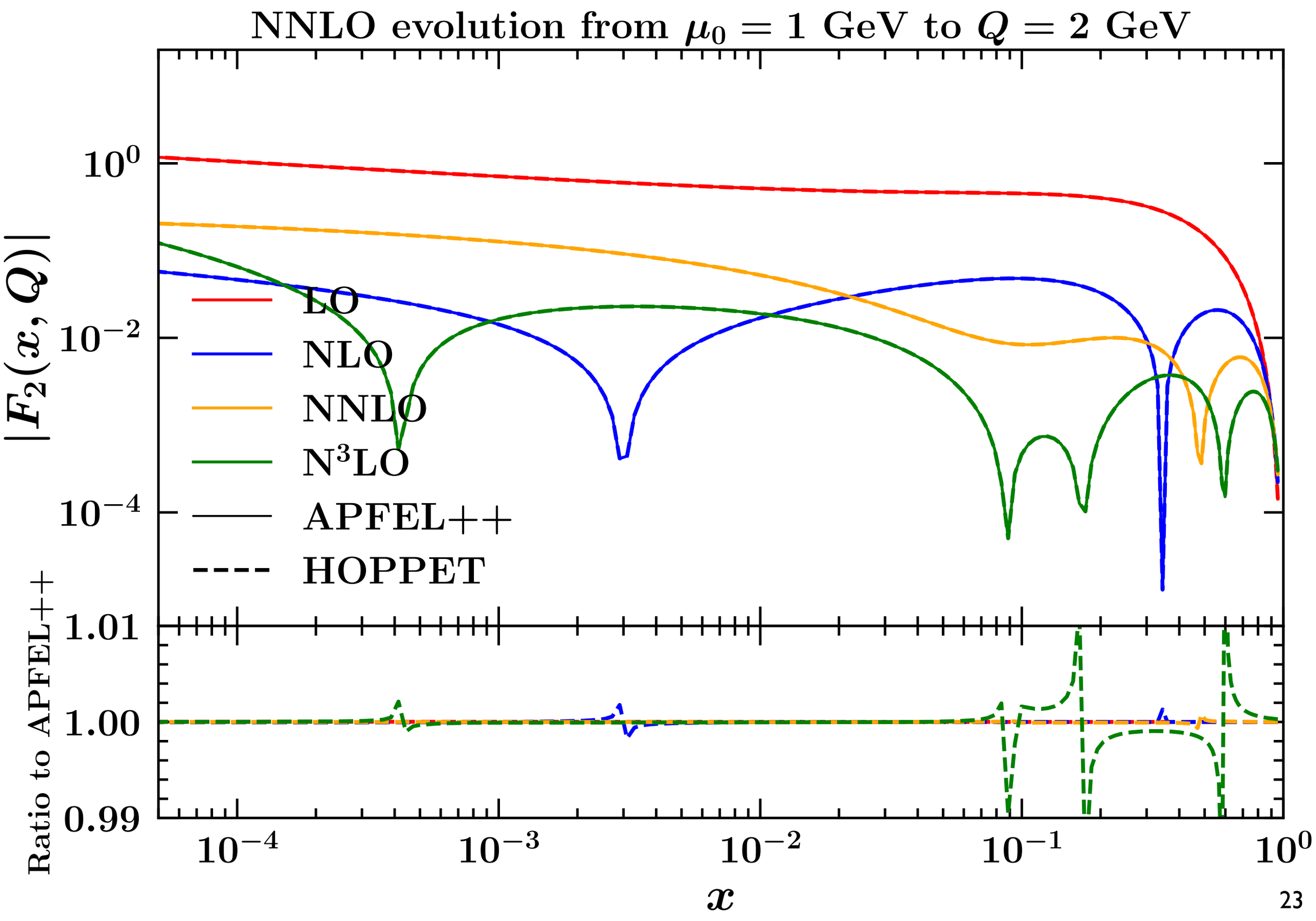

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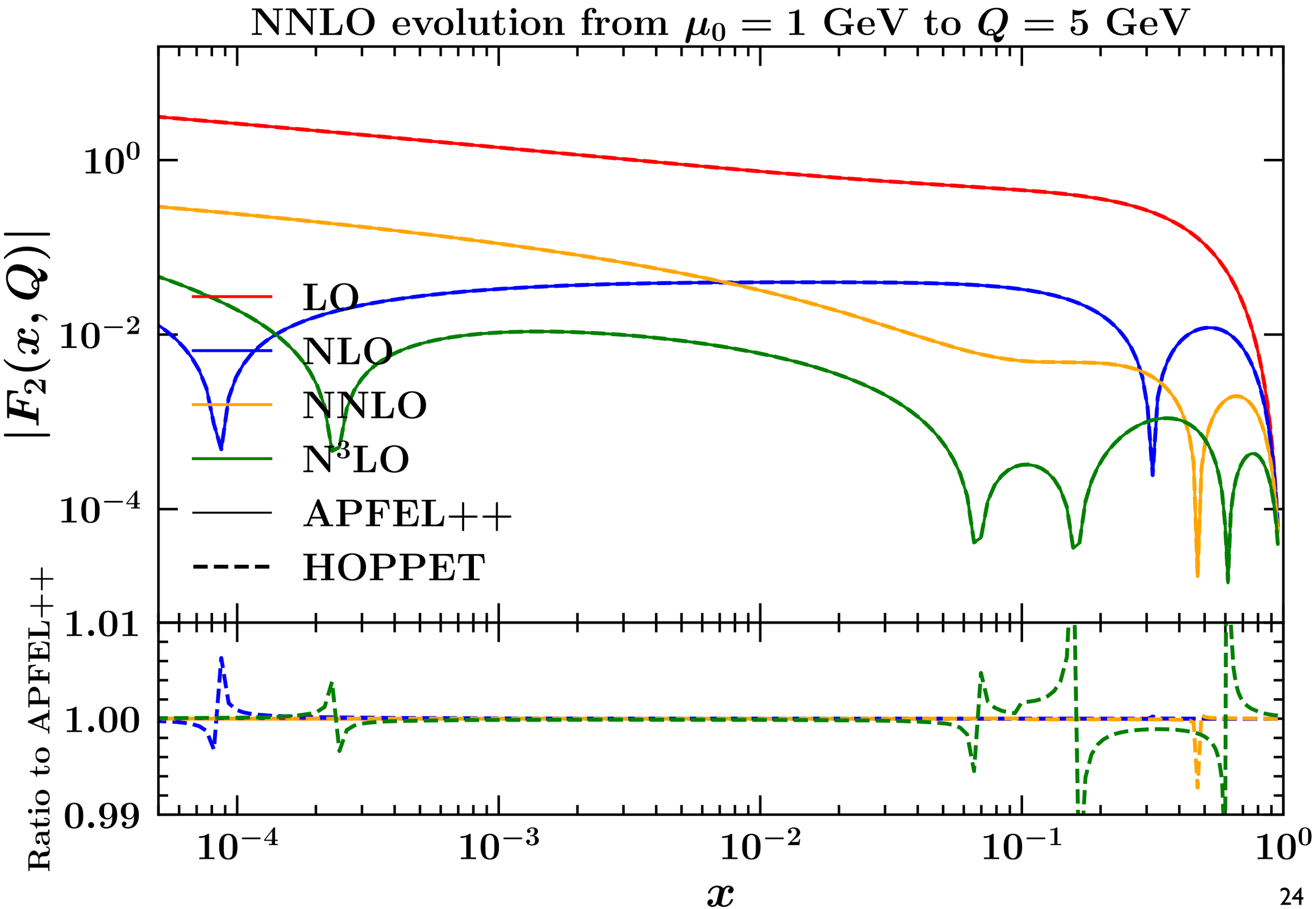

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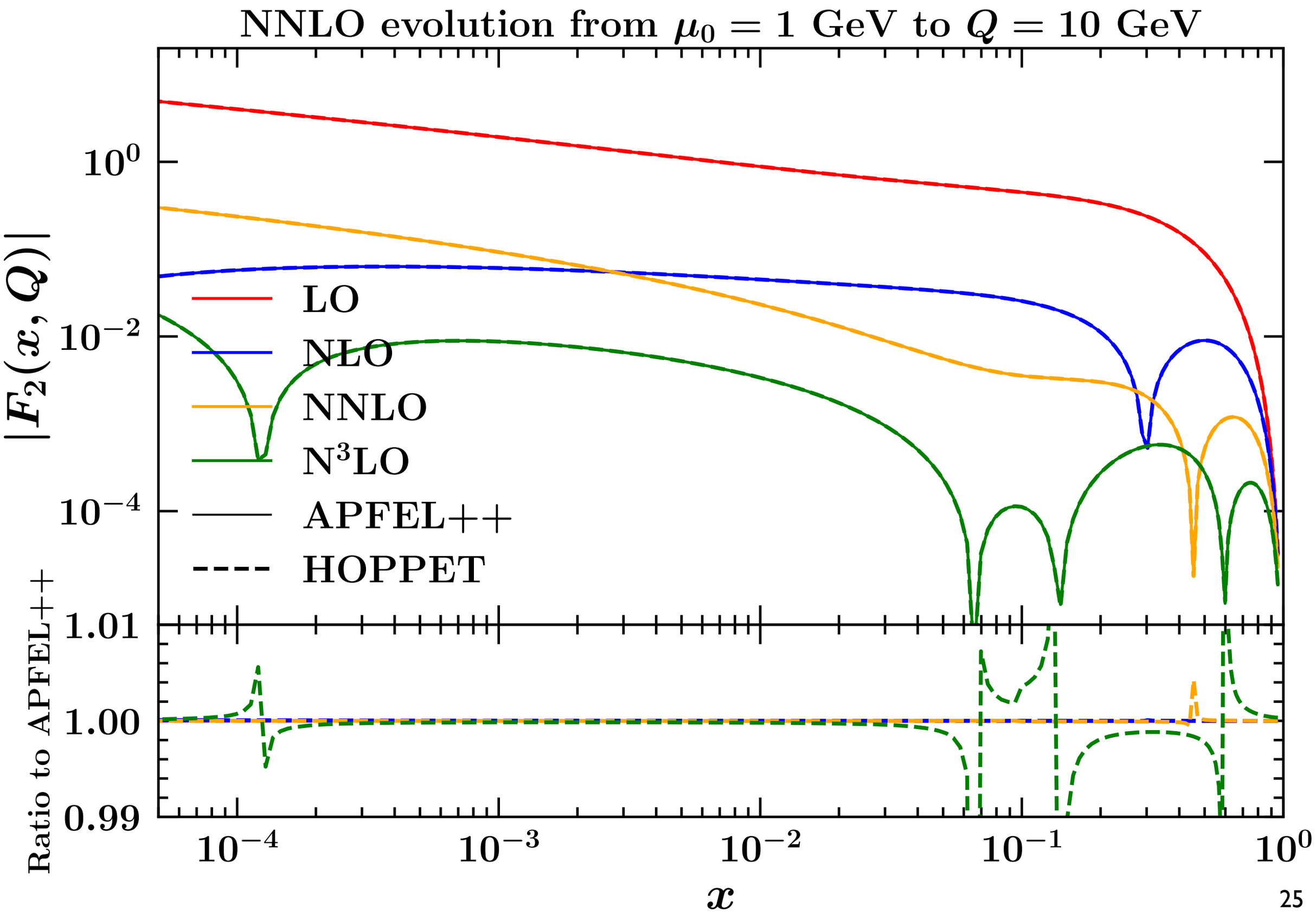

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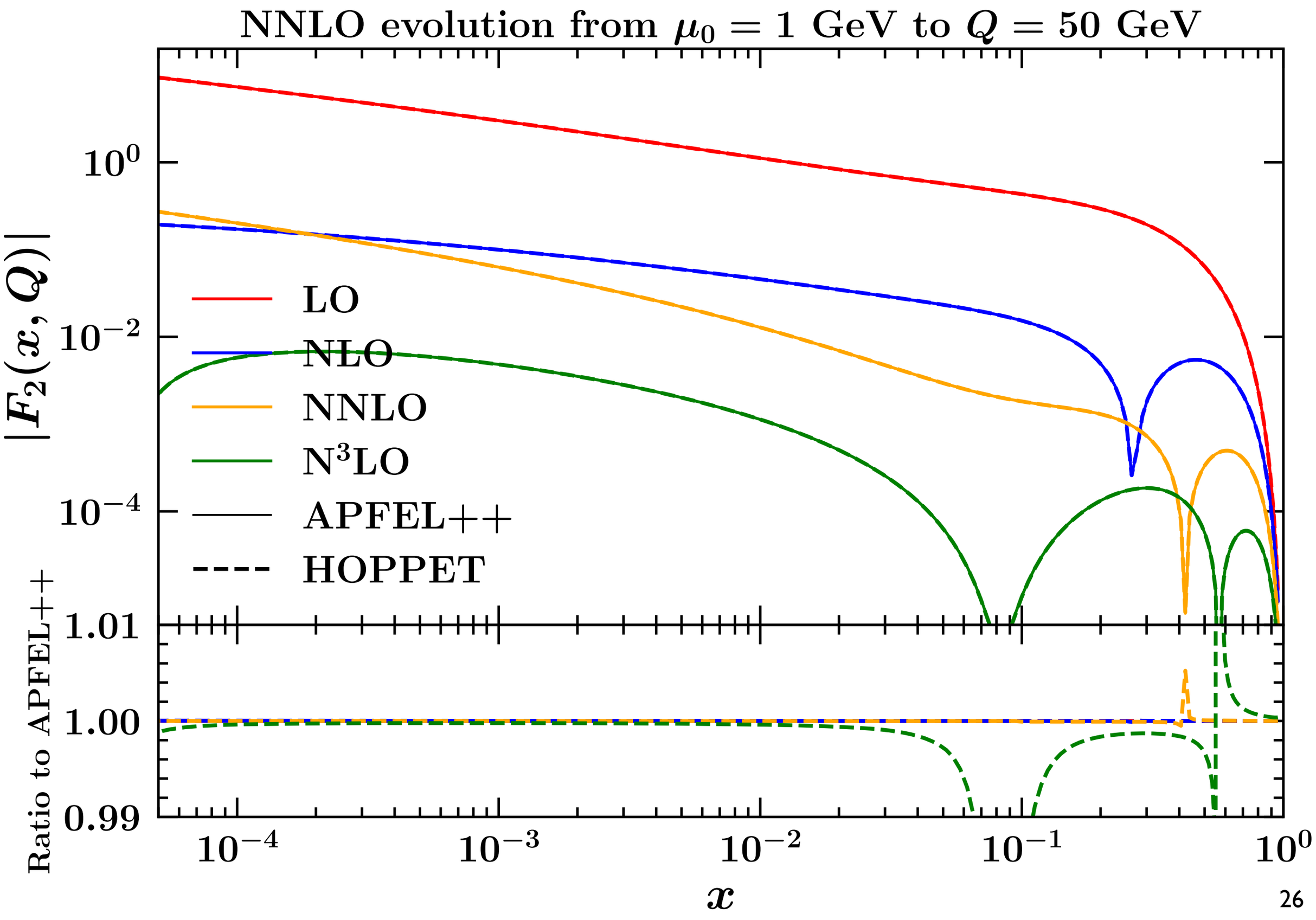

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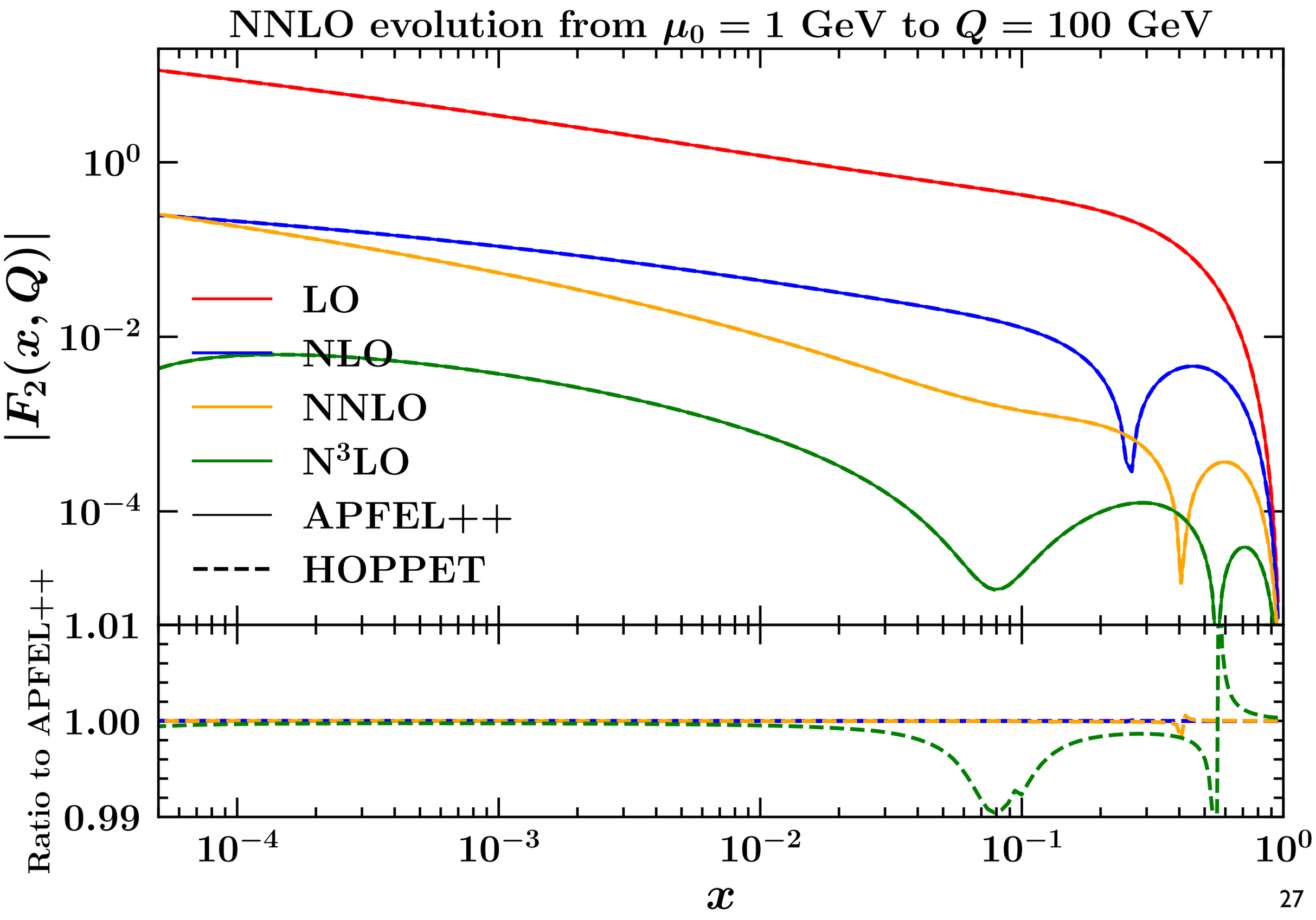

Structure functions