Parton distributions at small x

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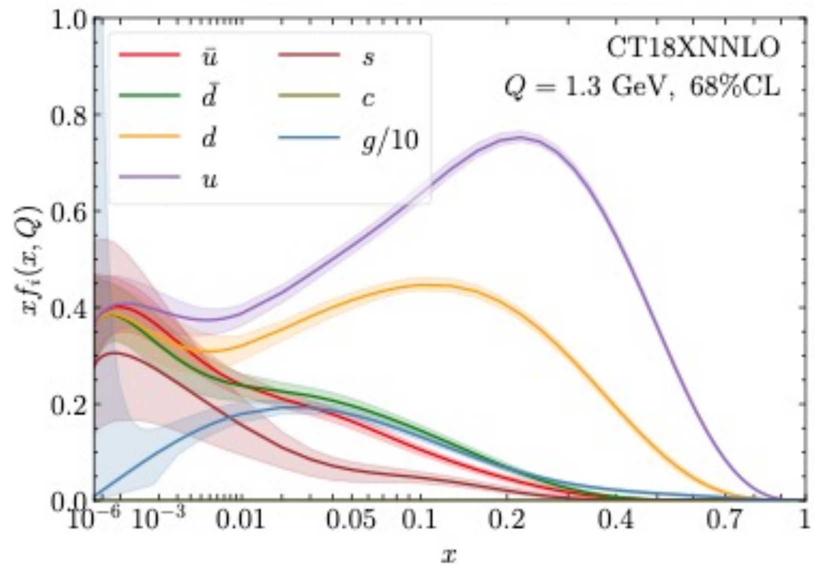

CTEQ-TEA (Tung et al.) collaboration

South China U.: T.-J. Hou

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Michigan State U.: J. Huston, J. Pumplin, D. Stump, C. Schmidt, C.-P. Yuan

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U. of Pittsburgh: K. Xie

arXiv: 1912.10053, 2108.06596
Available on
https://ct.hepforge.org

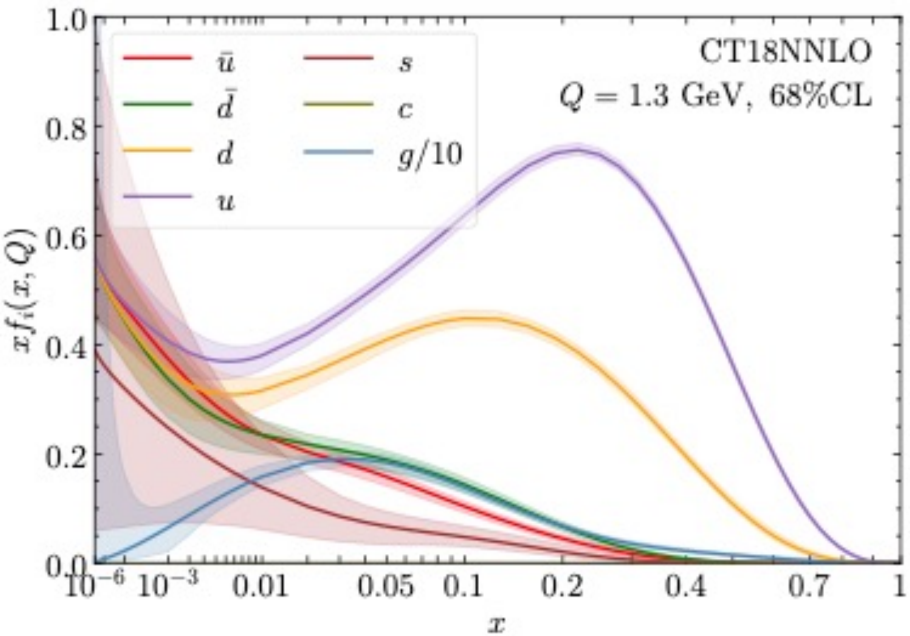
How to treat the DIS low-Q and small-x data?

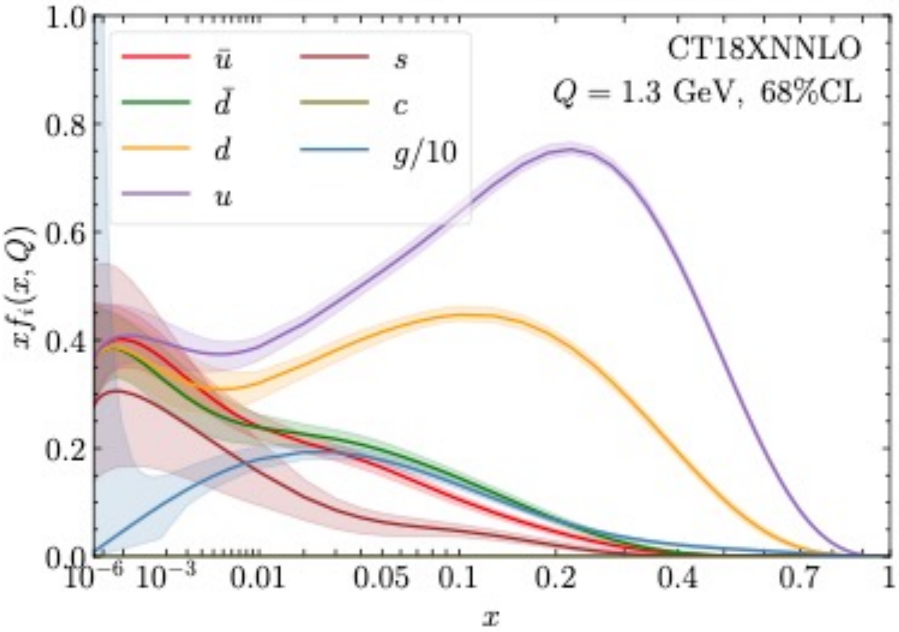
➢NNPDF & xFitter: BFKL to resum the small-x [1710.05935,1802.00064]
➢CT: an x-dependent DIS scale, motivated by saturation models [1912.10053]

PDF ensemble	Factorization scale in DIS	ATLAS 7 Z/W data included?	CDHSW $F_2^{p,d}$ data included?	Pole charm mass, GeV
CT18	$\mu_{F,DIS}^2 = \mathrm{Q}^2$	No	Yes	1.3
CT18X	$\mu_{F,DIS}^2 = 0.8^2\left(Q^2 + \frac{0.3\ GeV^2}{x^{0.3}}\right)$	No	Yes	1.3
CT18A	$\mu_{F,DIS}^2 = \mathrm{Q}^2$	Yes	Yes	1.3
CT18Z	$\mu_{F,DIS}^2 = 0.8^2\left(Q^2 + \frac{0.3\ GeV^2}{x^{0.3}}\right)$	Yes	No	1.4

CT18 parton distributions

Four PDF ensembles: CT18 (default), A, X, and Z



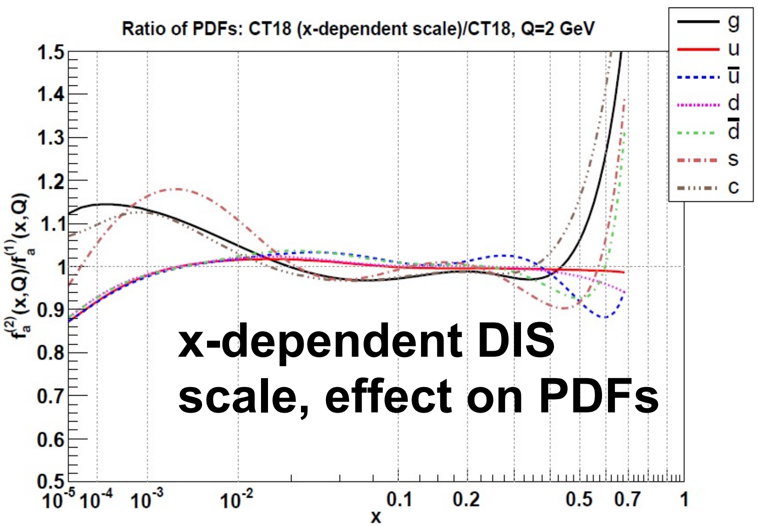


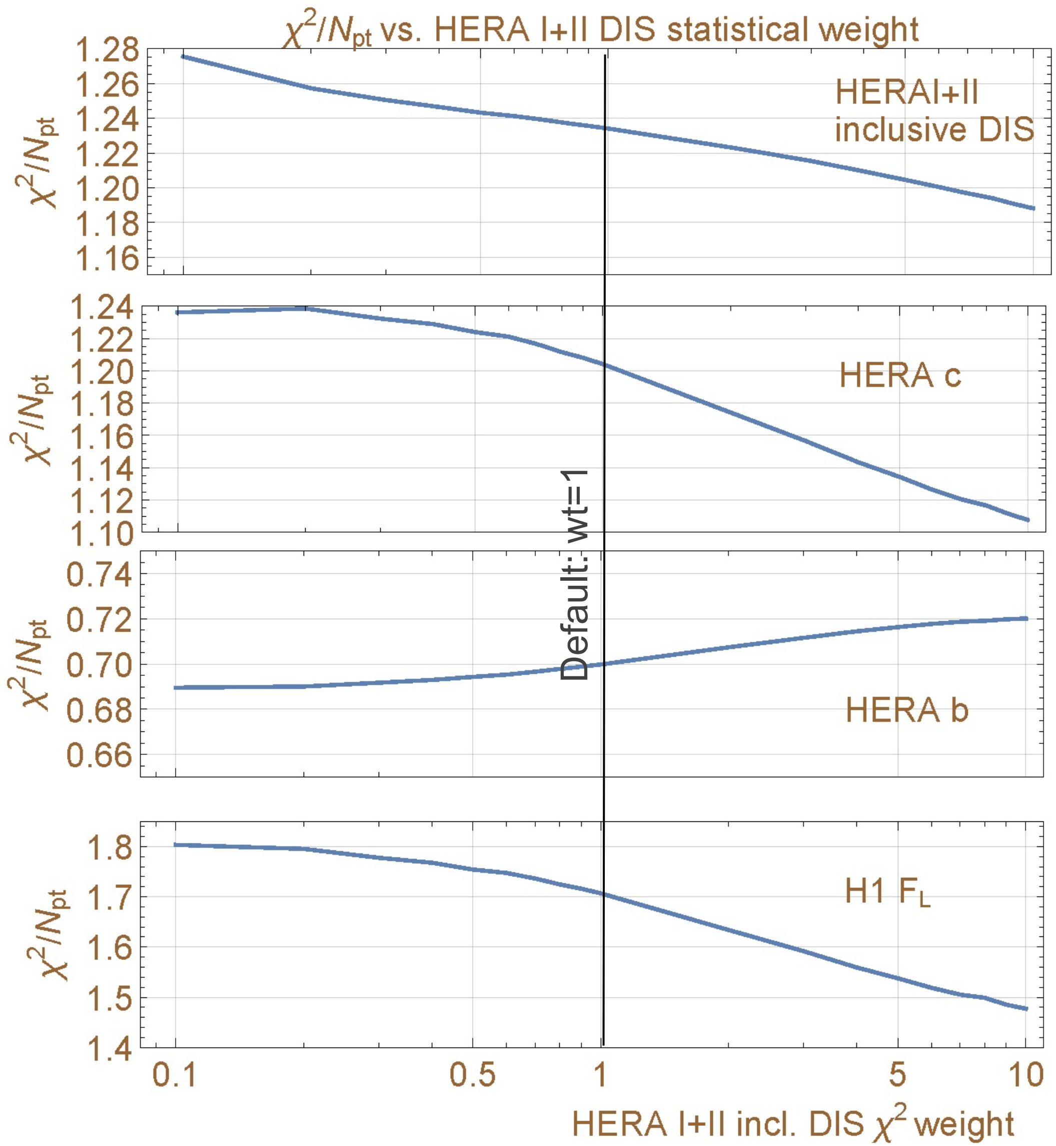
CT18X get a better chi^2 by around 70 units.
CT18X enhances (reduces) gluon (light-quark) PDFs at $x \sim 10^{-4}$

CT18X and Z: a special factorization scale in DIS

The CT18Z fits uses a $\mu_{DIS,X}$ scale that reproduces many features of NNLO-NLLx fits with $\ln(1/x)$ resummation by the NNPDF [arXiv:1710.05935] and xFitter [1802.0064] groups.

$$\mu_{DIS,X}^2 = 0.8^2 \left(Q^2 + \frac{0.3\ GeV^2}{x^{0.3}} \right)$$

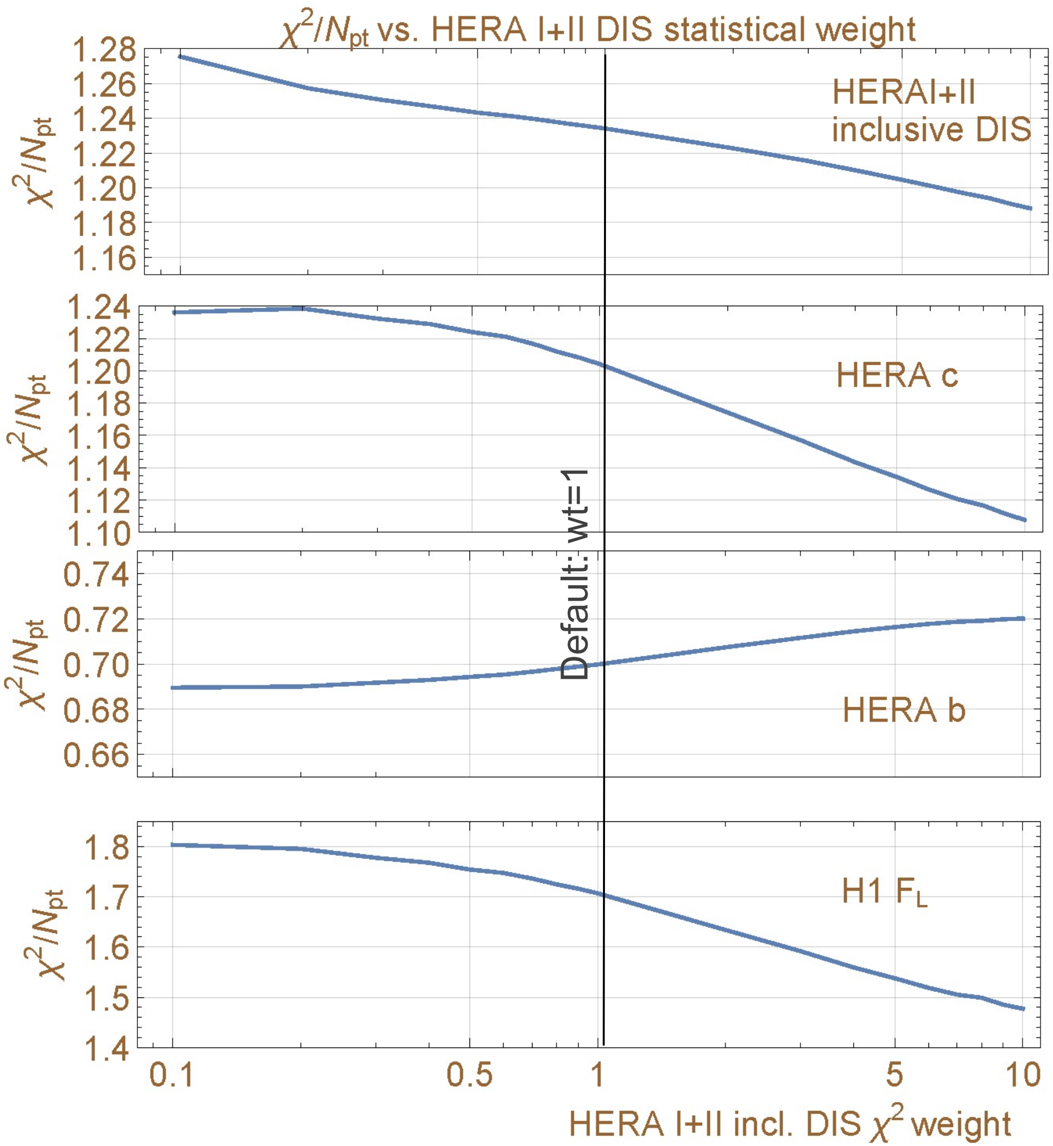




CT18X and Z: a special factorization scale in DIS

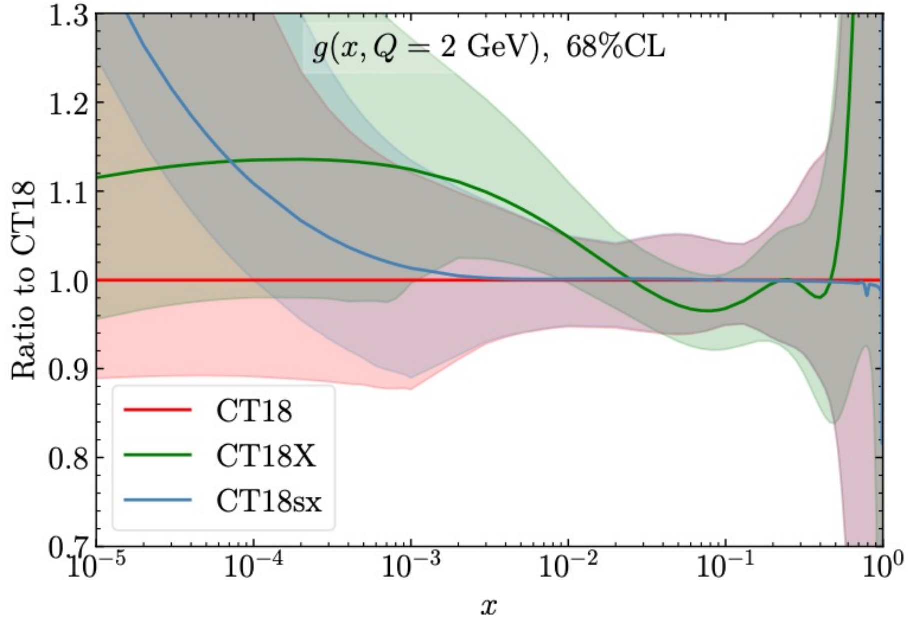
Right: when the χ^2 weight for the **inclusive** HERA I+II DIS is increased to $wt = 10$ to suppress pulls from the other experiments, χ^2_{CT18Z}/N_{pt} for HERA I+II DIS **and** HERA charm production decreases to about the same levels as in HERA-only NNLO+NLLx fits by other groups.

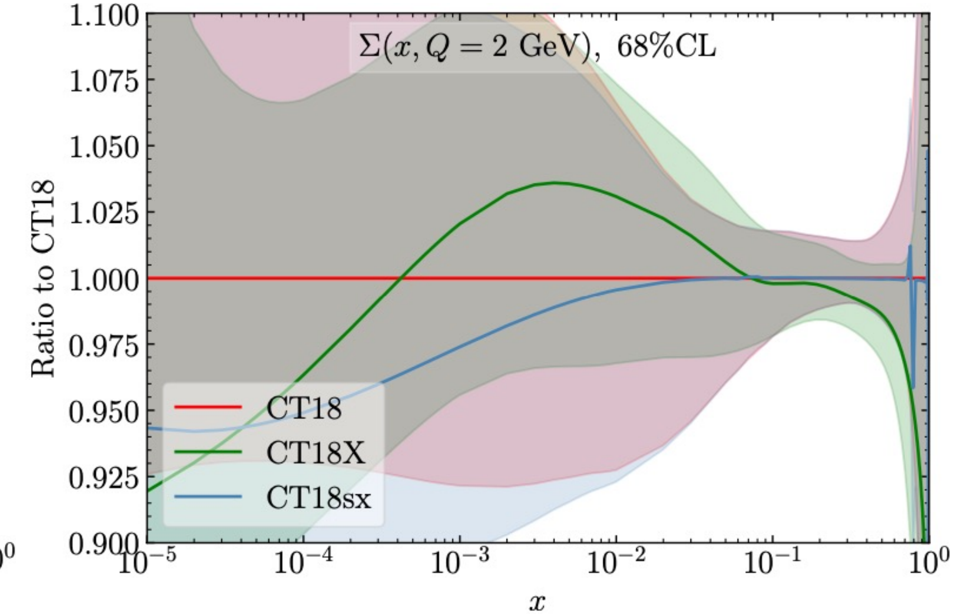
- **NNLO with an x-dependent scale is statistically indistinguishable from BFKL resummation in the CT18 x-Q region (Q > 2 GeV)**

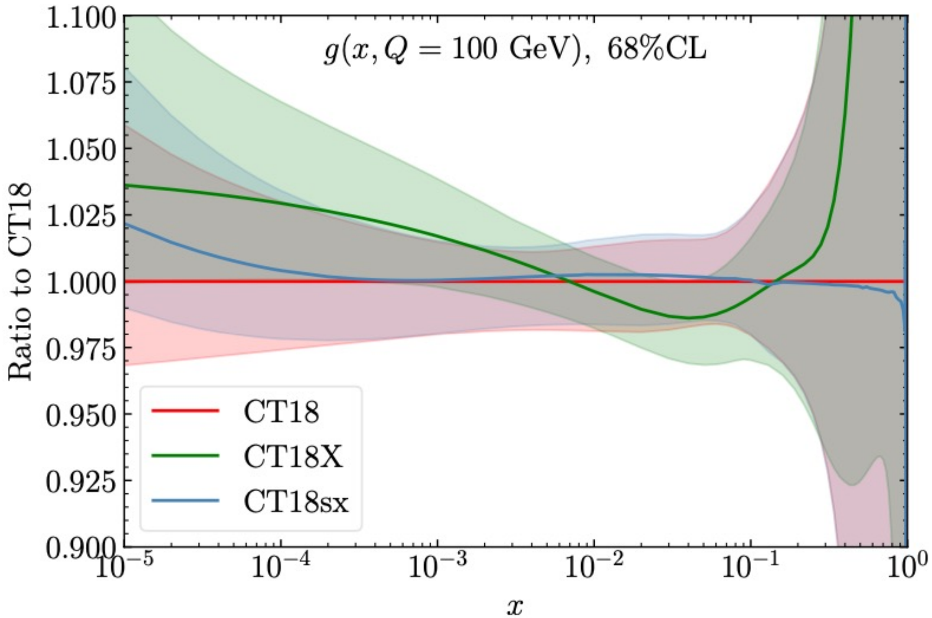


CT18X vs CT18sx (small-x resumed to NLLx)

With HELL, M. Bonvini, 1805.08785

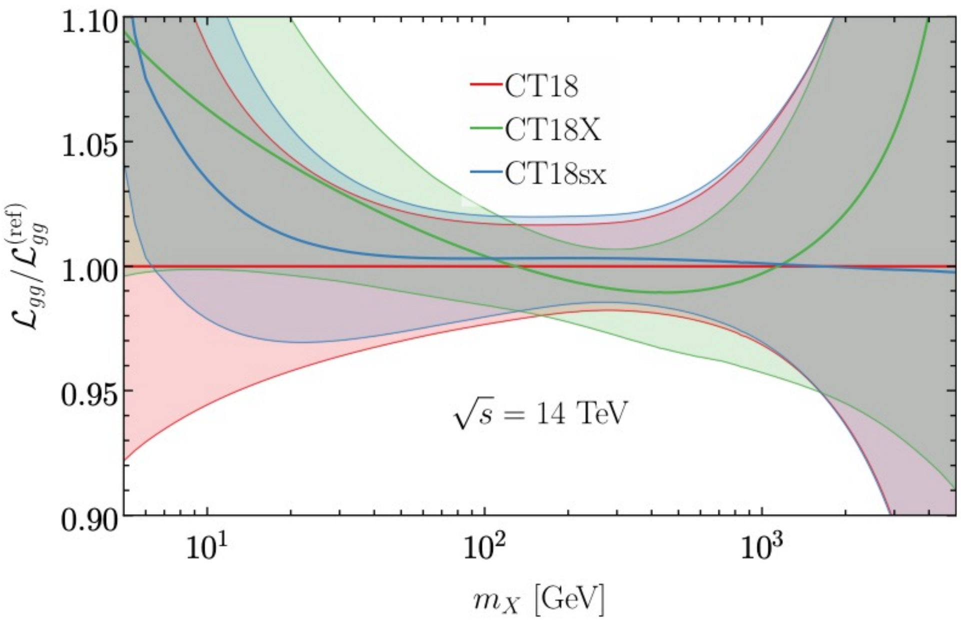


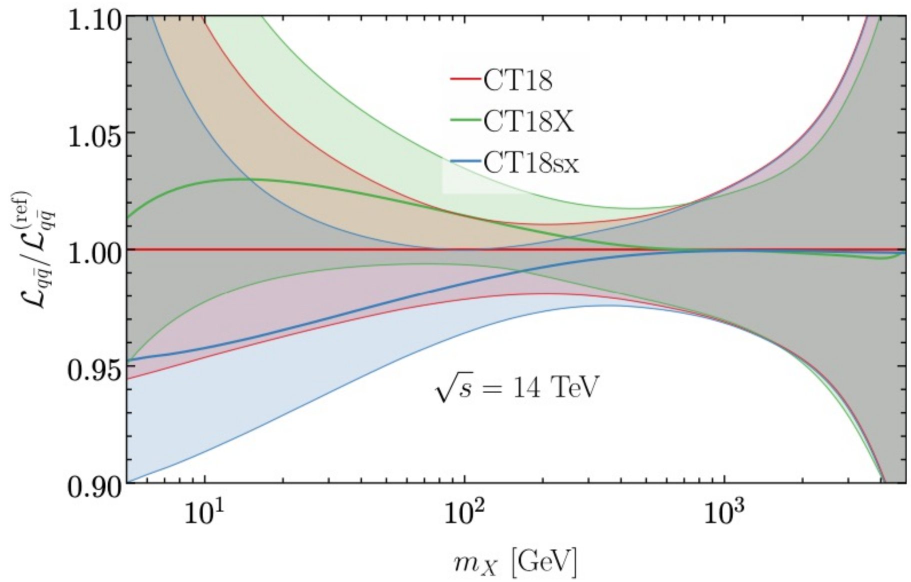


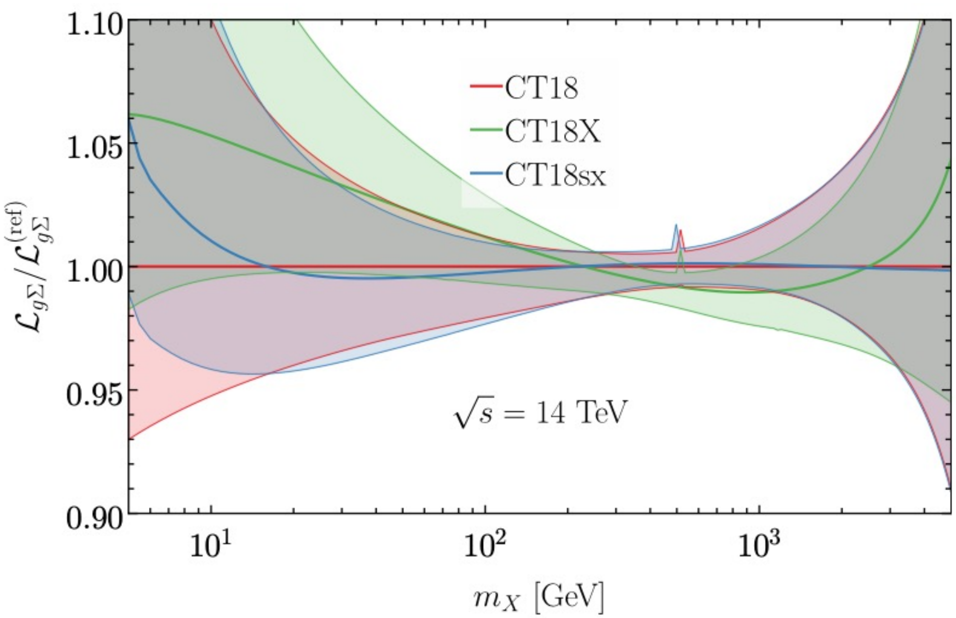


- Both x-dependent scale (CT18X) and small-x resummation (CT18sx) enhance (reduce) the gluon (singlet) PDF at low Q and low x.
- At high Q or high x, the impact of both the x-dependent scale and small-x resummation die out.
- Similar effects obtained by NNPDF [1710.05935] and xFitter [1802.00064]

Parton luminosities



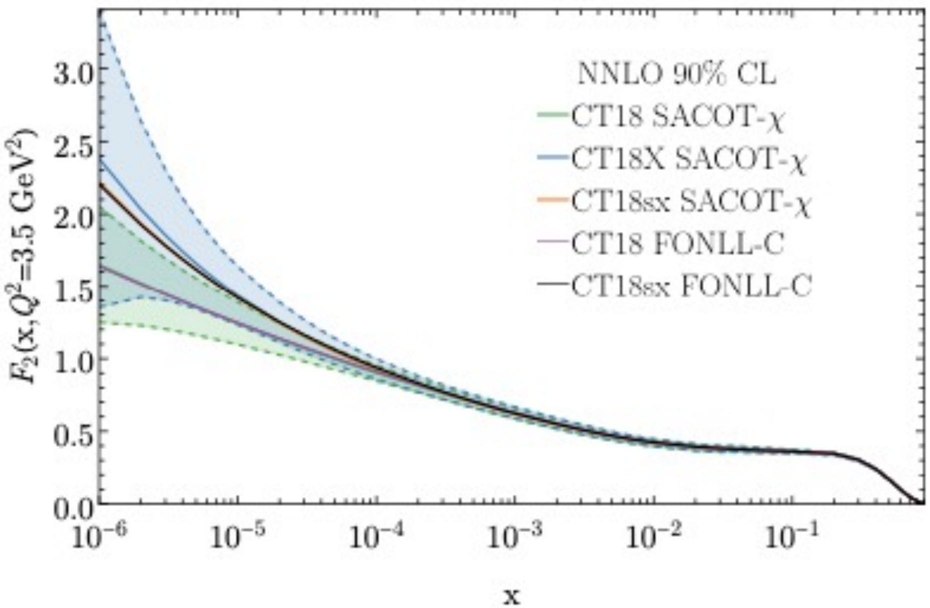


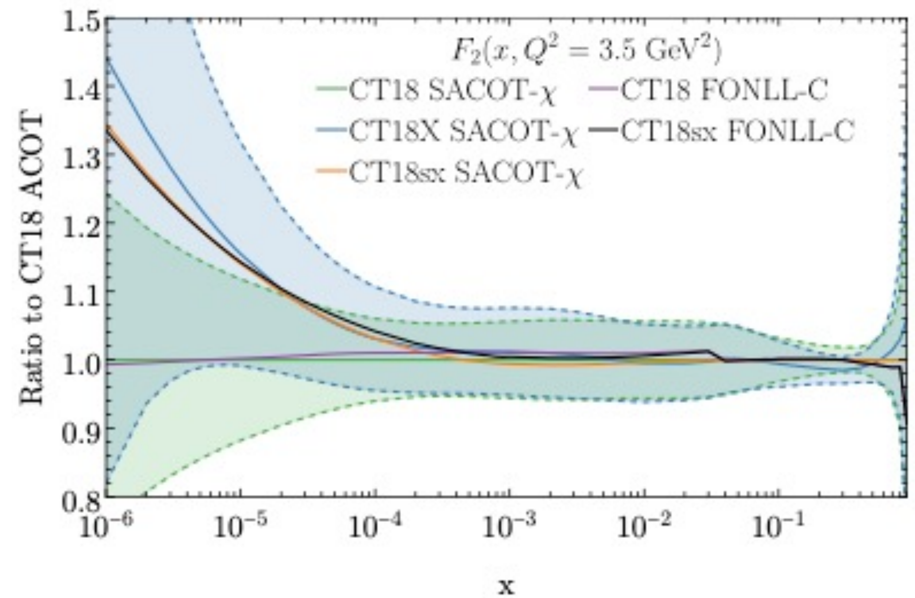


- The small-x effect impacts the parton luminosity at small invariant-mas region significantly.
- It enhance the gluon-gluon, quark-gluon parton luminosity.
- For the q-qbar luminosity at intermediate invariant mass, the CT18X and CT18sx pull to the opposite directions.

Structure function F2 at low Q

2108.06596





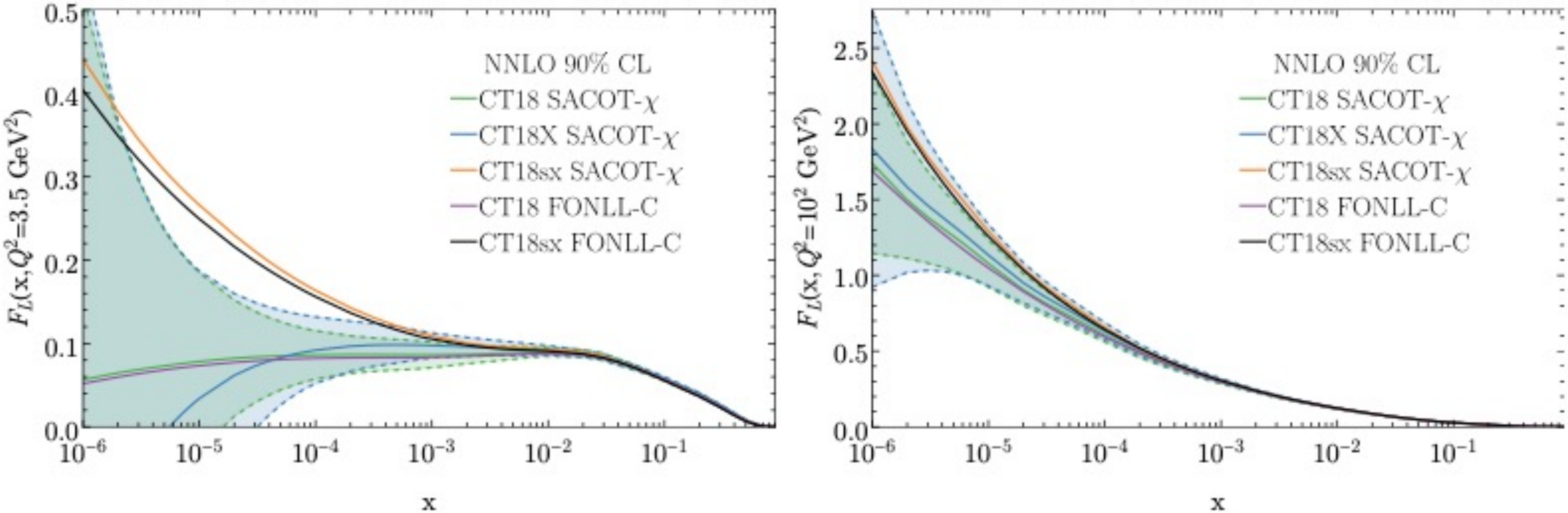
- CT uses the SACOT heavy-quark scheme. Small-x resummation is performed in the FONLL scheme that close to the SACOT.
- The small-x resummed F2 is obtained with APFEL, and folded in a K-factor approach:

$$F^{\text{NLLx, SACOT}}(\text{CT18sx}) = F^{\text{NNLO, SACOT}}(\text{CT18}) \underbrace{\frac{F^{\text{NLLx}}(\text{CT18sx})}{F^{\text{NNLO}}(\text{CT18})}}_{\equiv K_1,\text{FONLL}} .$$

- For F2, the CT18X is indistinguishable with CT18sx down to $x{\sim}10^{-5}$. It only takes off below this x value.
- At higher Q, the impact of CT18X and CT18sx on F2 is comparably small (see backup slides).

Structure function FL

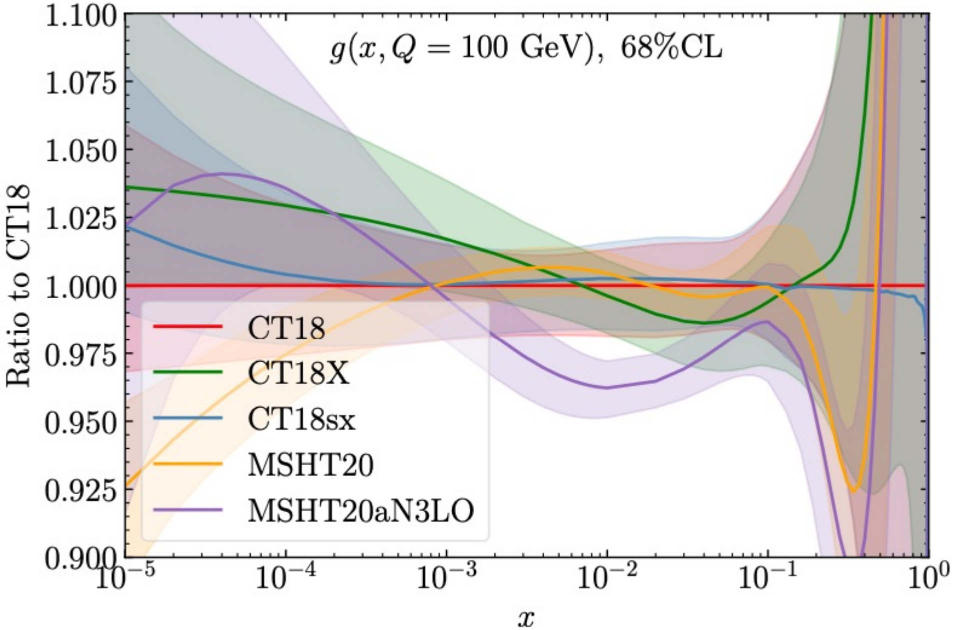
2108.06596

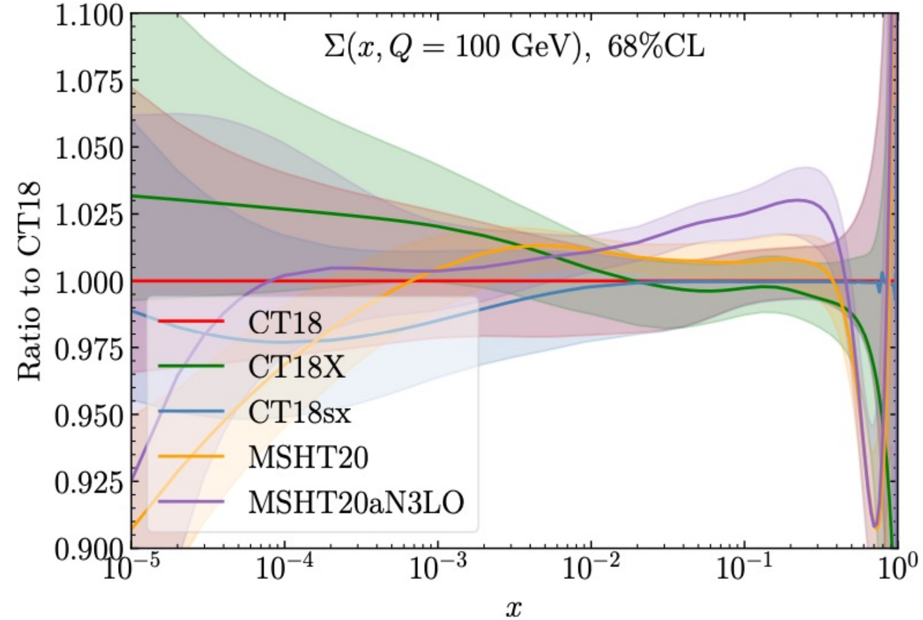


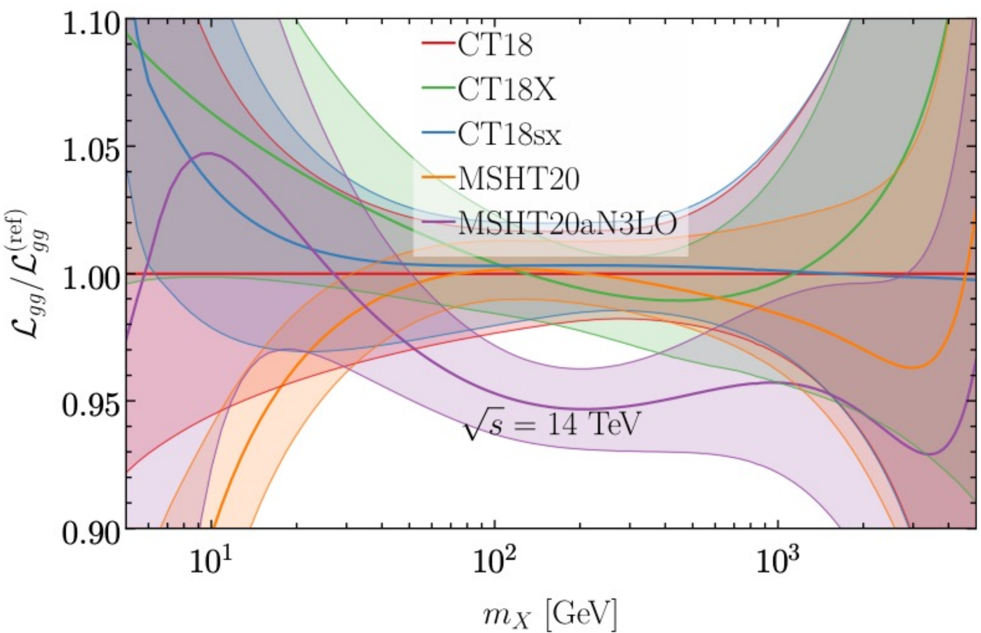
- At low Q, CT18X prediction agrees better than CT18 with the H1 FL data. At x< $5 \cdot 10^{-5}$, CT18X (CT18sx) predicts reduction (enhancement) of FL.
- At high Q, both gives enhancement to FL, while the CT18X prescription is sizably smaller.
- It would be very interesting to see which is preferred by LHeC.

In comparison with N3LO PDFs

MSHT20 2012.04684, aN3LO 2207.04739







- N3LO evolution also enhances gluon PDFs in the small-x region
- aN3LO PDFs including both evolution effect and the Wilson coefficient in a global analysis
- See Lucian's talk for details

Conclusion

- Both the small-x resummation and the saturation data scale prescription improve the goodness-of-fit for HERA I+II DIS data
- Both CT18X and CT18sx enhance the gluon and reduce the singlet PDF.
- At high x or high Q, they become indistinguishable within PDF errors.
- At x<10^-5 and Q<2 GeV, NLLx and NNLO+saturation scale may predict different FL behavior.