Impact of HERA I+II measurements on the CTEQ-TEA (CT) Parton Distribution Function Analysis

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Outline

- Brief overview of CT14 global analysis

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- CT14 prediction for HERA I +II data
- Impact of HERA I + II data on the CT PDF analysis
- Conclusion

Experimental Data for CT14

CT14 differs from CT10 PDFs in several respects:

new HERA data:

- Combined HERA charm production measurements ($F_2^{(c)}$)
- measurements of the longitudinal $F_L(x, Q^2)$ in DIS neutral currents

new Tevatron data:

- Tevatron Run 1 CDF and D0 inclusive jet data are dropped,
- old D0 data (0.75 fb^{-1}) superseded by the new D0 (9.7 fb^{-1}) W-electron rapidity asymmetry data.

LHC 7 TeV run I data included

- ATLAS and LHCb W and Z production,
- ATLAS, CMS and LHCb W-lepton charge asymmetry,
- ATLAS and CMS inclusive jet data.

CT14 has 2995 data points

Theory Analysis in CT14

- CT14 has 28 shape parameters, and CT10 has 25.
- CT14 has more flexible parametrizations – gluon, d/u at large x, and both d/u and dbar/ubar at small x, strangeness (assuming sbar = s)

which result in improved agreement with some data sets. For example: by adding additional parameters to the {u,ubar} and {d,dbar}, somewhat better agreement was obtained for the BCDMS and NMC data at low values of Q.

- Non-perturbative parametrization form:

$$x\, f_a(x) = x^{a_1}\,(1-x)^{a_2}\, P_a(x)$$

where $P_a(x)$ is expressed as a linear combination of Bernstein polynomials to reduce the correlation among its coefficients.

- Produce 90% C.L. error PDF sets from Hessian method, scaled by 1/1.645 to obtain 68% C.L..

Theory Analysis in CT14

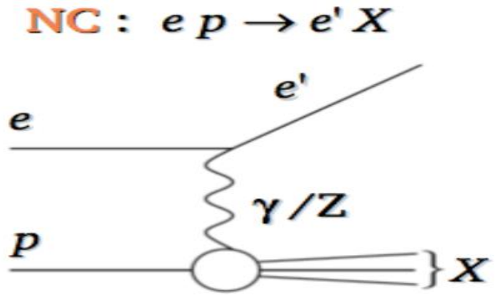
- Choose exp. data with $Q^2 > 4$ GeV^2 and $W^2 > 12.5$ GeV^2 to minimize high-twist, nuclear correction, etc., and focus on perturbative QCD predictions.
- PDFs (u, d, s (anti-) quarks and the gluon) are parametrized at Q=1.3 GeV.
  PDFs at any other scale Q can be obtained from pQCD, via solving DGLAP evolution equations.
- Take $\alpha_s(Mz) = 0.118$ for NLO and NNLO; just like CT10 series, we also provide α_s-series PDFs.
- Use s-ACOT-χ prescription for heavy quark partons,
  and take pole mass Mc =1.3 GeV and Mb=4.75 GeV in our calculation,
- In our global fit we have taken NNLO calculations for neutral-current DIS, DY, W, Z cross sections, except charged-current DIS and jet (at NLO), but with NNLO PDF.
- Correlated systematic errors are taken into account when we do global fit.
- Check Hessian method results by Lagrangian Multiplier method which does not assume quadratic approximation in chi-square calculations.

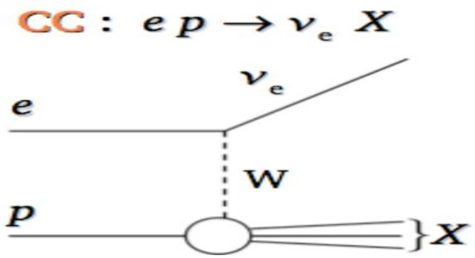
Impact of HERA I+II data to CT PDFs

CTEQ

HERAI +II data

- H1 and ZEUS experiments at HERA for neutral current and charged current e+p, e-p scattering collected ~1/fb of data.
- Ep =920, 820, 575 and 460 GeV and Ee=27.5 GeV.





arXiv:1506.06042

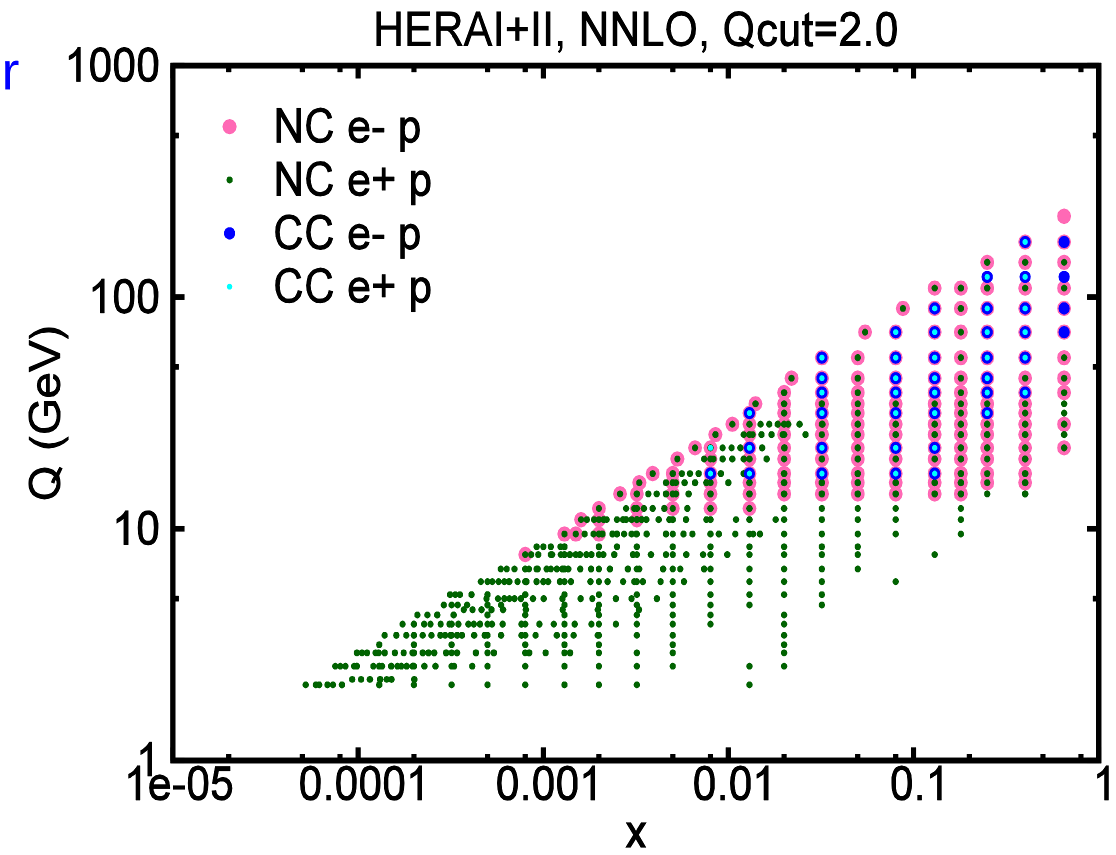
Cross sections for NC interactions have been published for

$0.045 < Q^2 < 50000\ \mathrm{GeV}^2 \qquad 6.\,10^{-7} < x_{Bj} < 0.65$

Cross sections for CC interactions have been published for

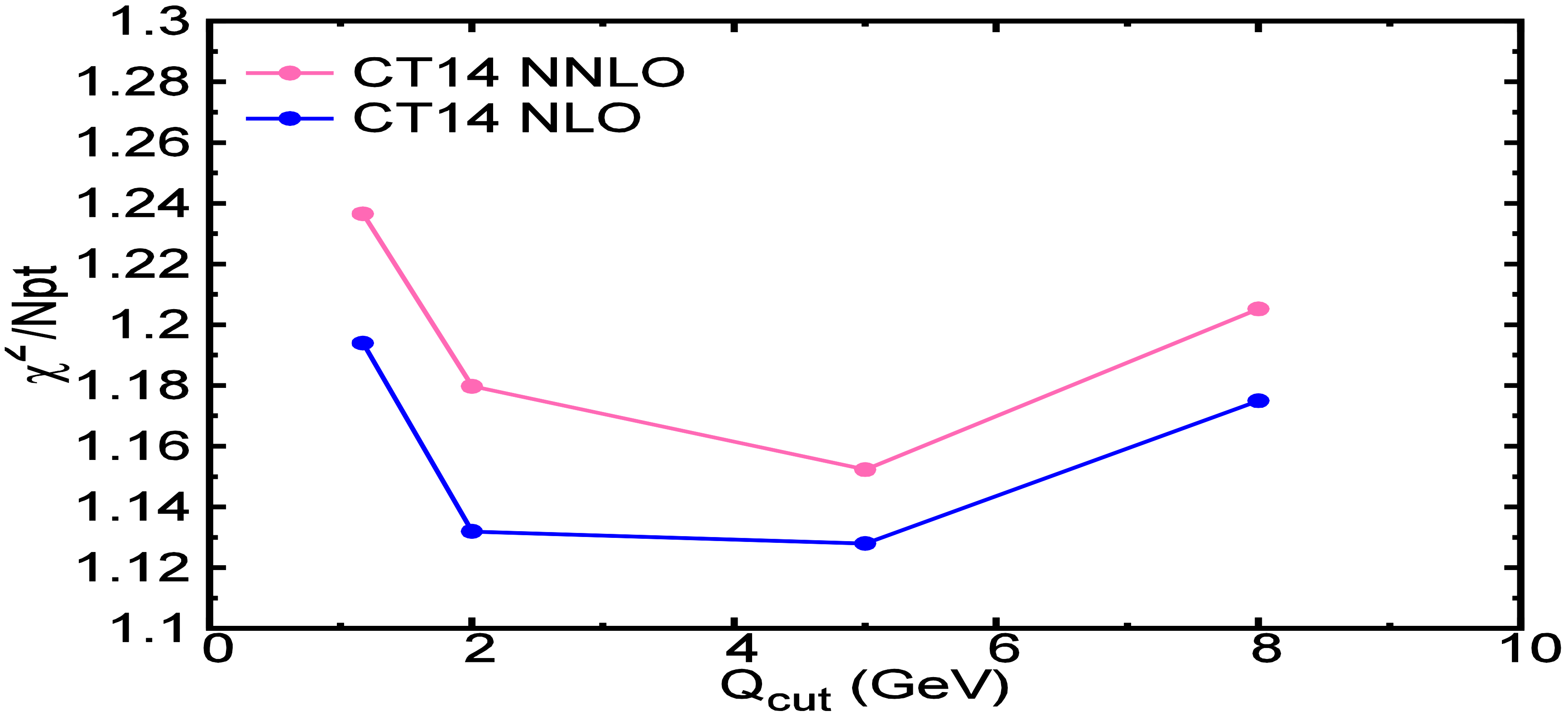
$$200 \le Q^2 \le 50000\,\mathrm{GeV}^2 \text{ and } 1.3 \cdot 10^{-2} \le x_{\mathrm{Bj}} \le 0.40$$

- HERAI+II data has 1119 data points with $Q^2 > 4\ GeV^2$ and $W^2 > 12.5\ GeV^2$, 162 correlated systematic errors, and 7 procedural uncertainties; separated into four sets, depending on whether e+ or e- beam, neutral or charged current, at various collider energies.
- HERA-1 data has 579 data points with $Q^2 > 4\ GeV^2$ and $W^2 > 12.5\ GeV^2$, 110 correlated systematic errors, and 4 procedural uncertainties.



- CT14 with HERA1 has 2995 data points.
- After replacing the HERA I with HERA I+II data, there are 3497 data points in total.

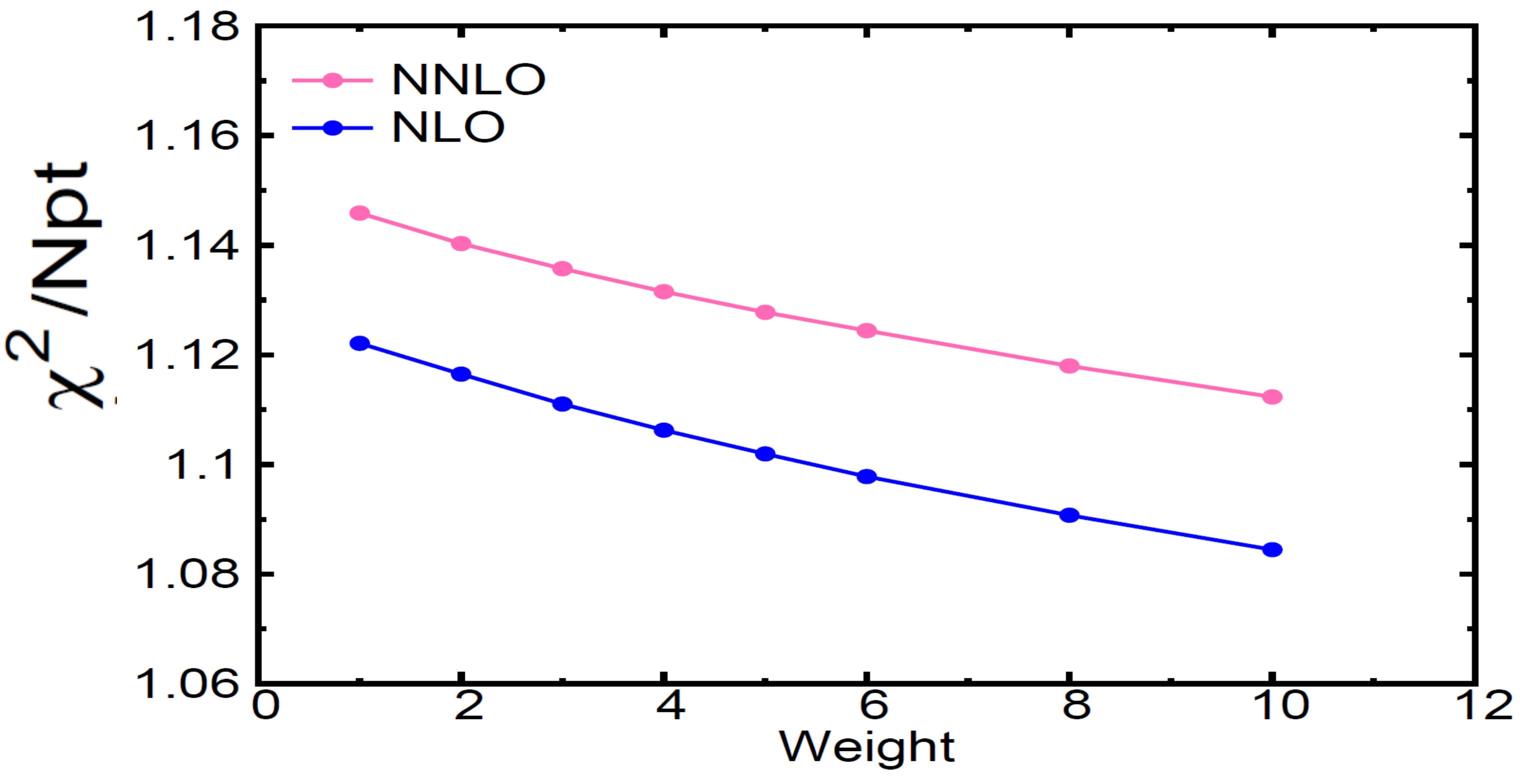
CT14 prediction for HERA I+II



As Qcut increases, the chi2/Npt of HERA I+II data decreases , but it starts to increase after Qcut=5 both for NLO and NNLO

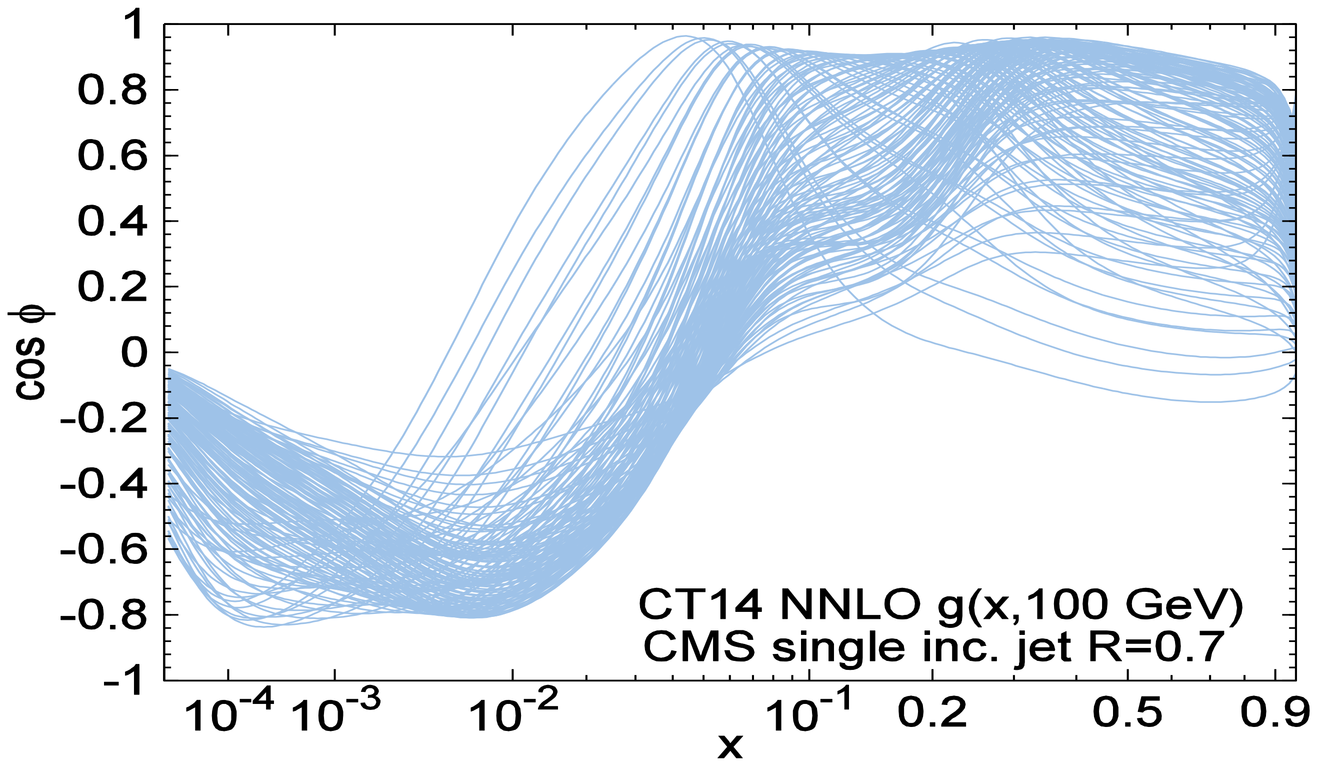
Our nominal Qcut is 2 GeV.
Chi2/Npt of CT14 NLO fit is smaller than CT14 NNLO fit.

Impact of HERA I + II to CT PDFs



Replace HERA I combined data by the new HERA I + II combined data in the CT14 – like PDF analysis.
If we increase the weight of the of HERA I + II combined data in the global fit, its chi2/Npt decreases, as it should be, because it can fit better. However, when the weight of this data is too large (say 8 or 10), the chi2/Npt of BCDMS F2 muon-deuteron data and CMS jet data increase by noticeable amount.

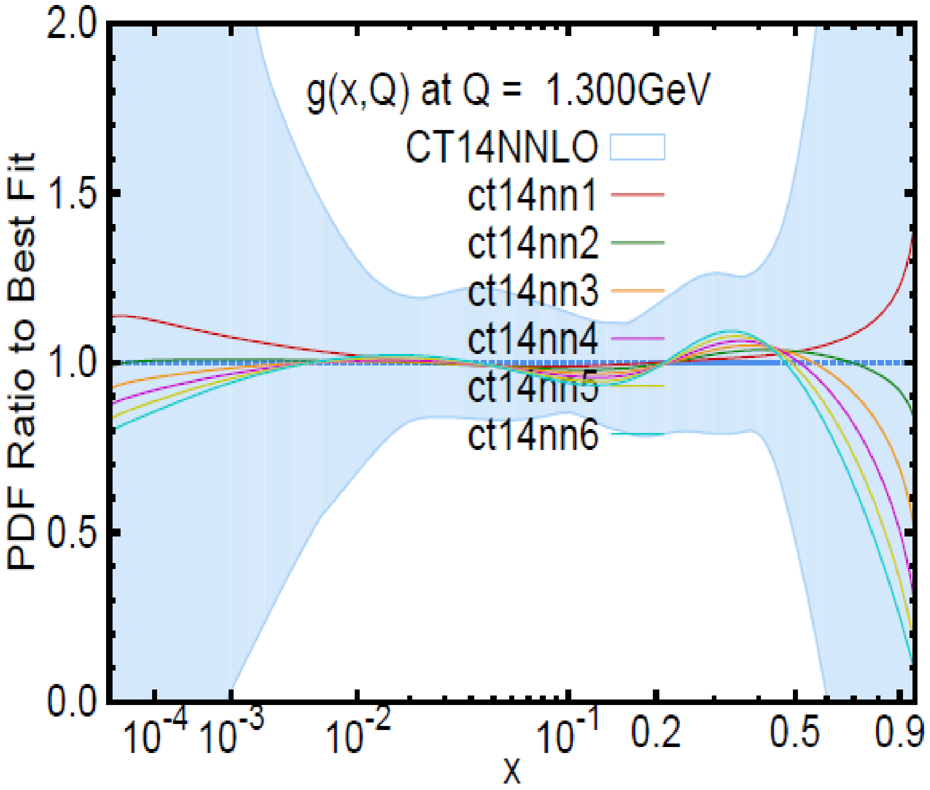
Correlation angle (g-PDF vs. CMS jet data)

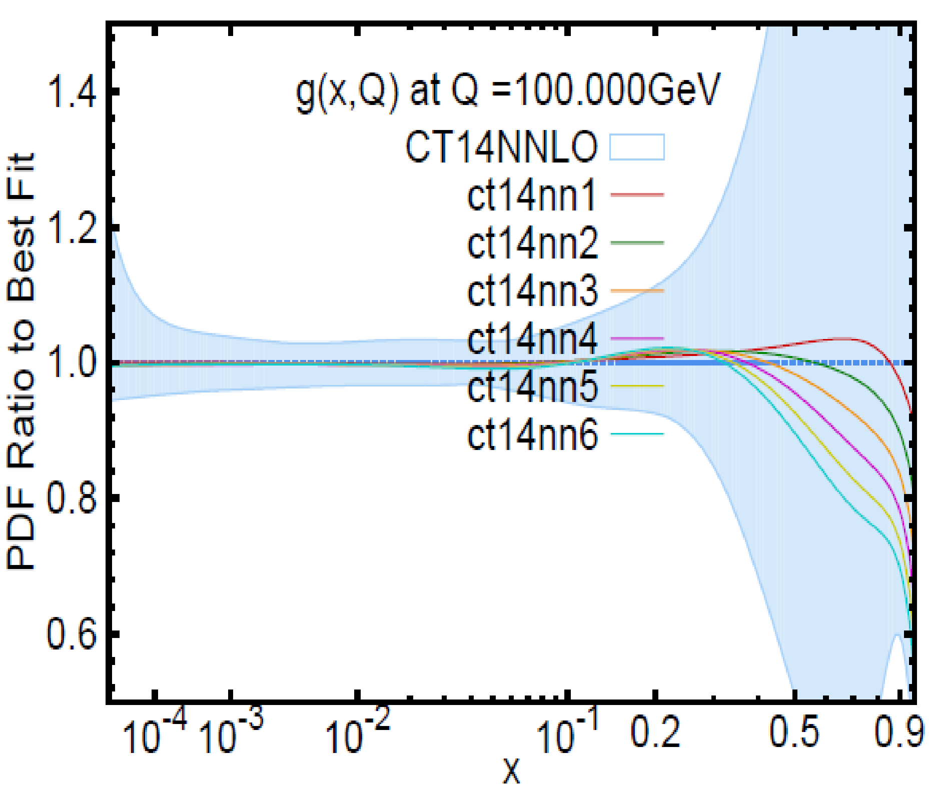


- Jet data is highly correlated to g-PDF at large x region and anti-correlated in small-x region.
- Precision HERA data are sensitive to g-PDF in small-x region, hence, correlated to CMS jet data.

Comparison of the PDFs

g-PDFs

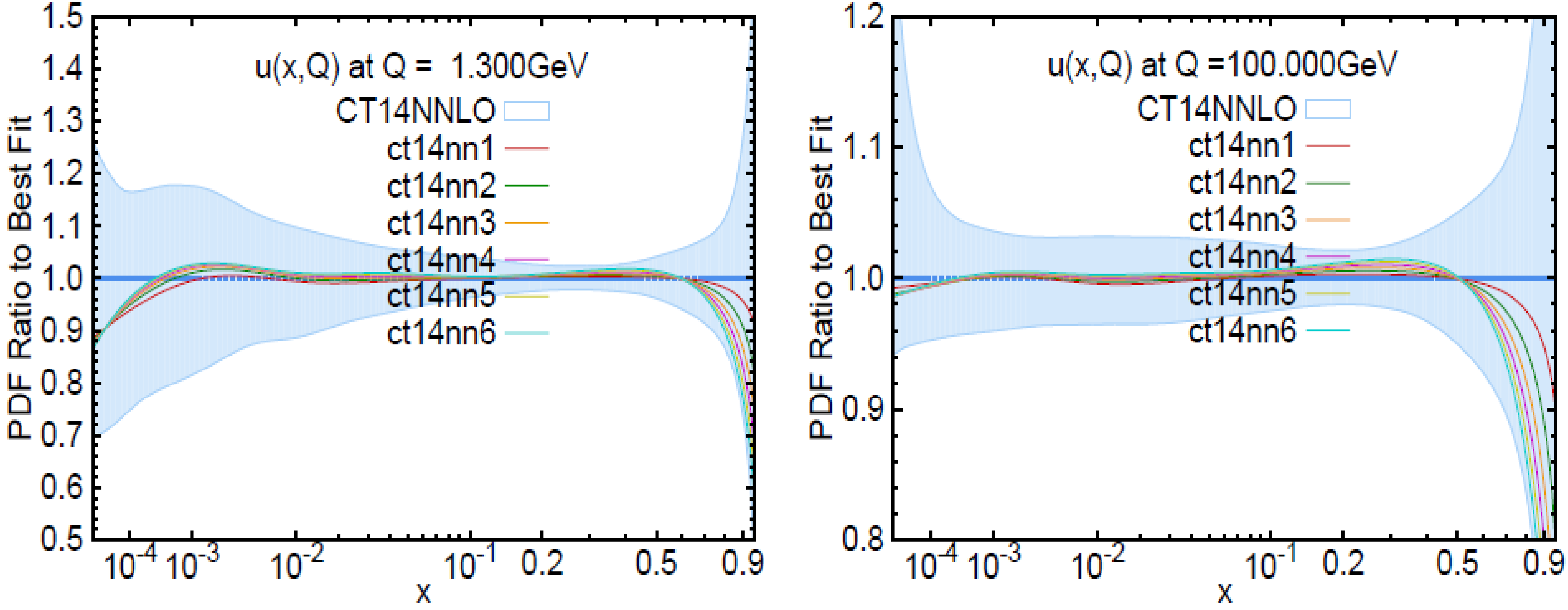




With the larger weight (~ 6) on HERA I + II data ,at x around 0.3 gluon is larger by about 10% at Q=1.3 GeV. At 100 GeV that difference becomes smaller around x=0.2, as expected because in that case perturbative evolution will become more important.

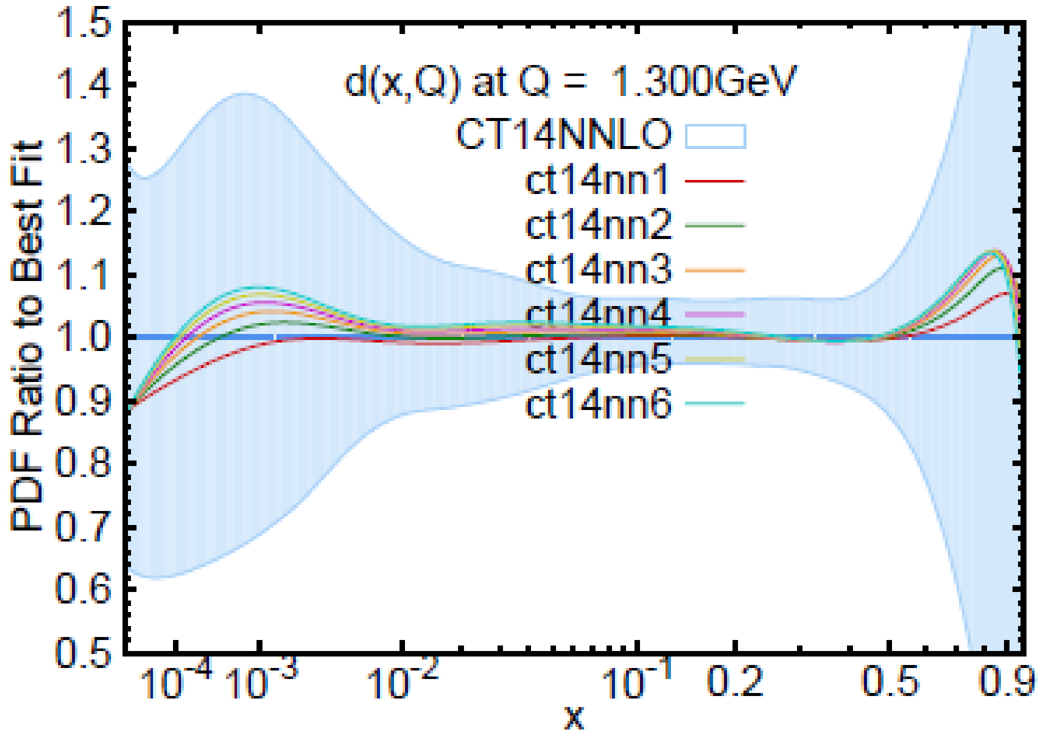
Another feature is that at small and large x regions we also see some variations but again all are within the error band of the CT14. With a larger weight to HERA data, g–pdf decreases at large and small x region as compared to CT14.

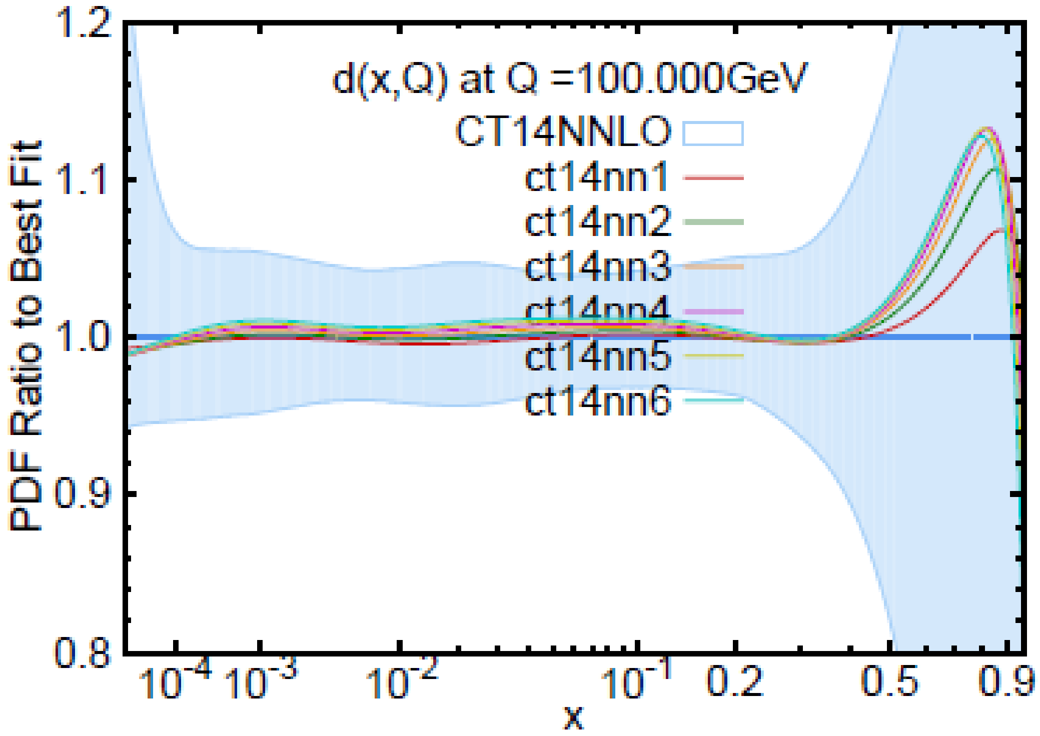
u-PDFs



With the larger weight (~ 6) on HERA I + II data, at x around 0.3 or 0.4, we see some small difference there.
Sizable changes occur at large and small x regions, but well within the error band of CT14.
u –pdf decreased at large x region as compared to CT14.

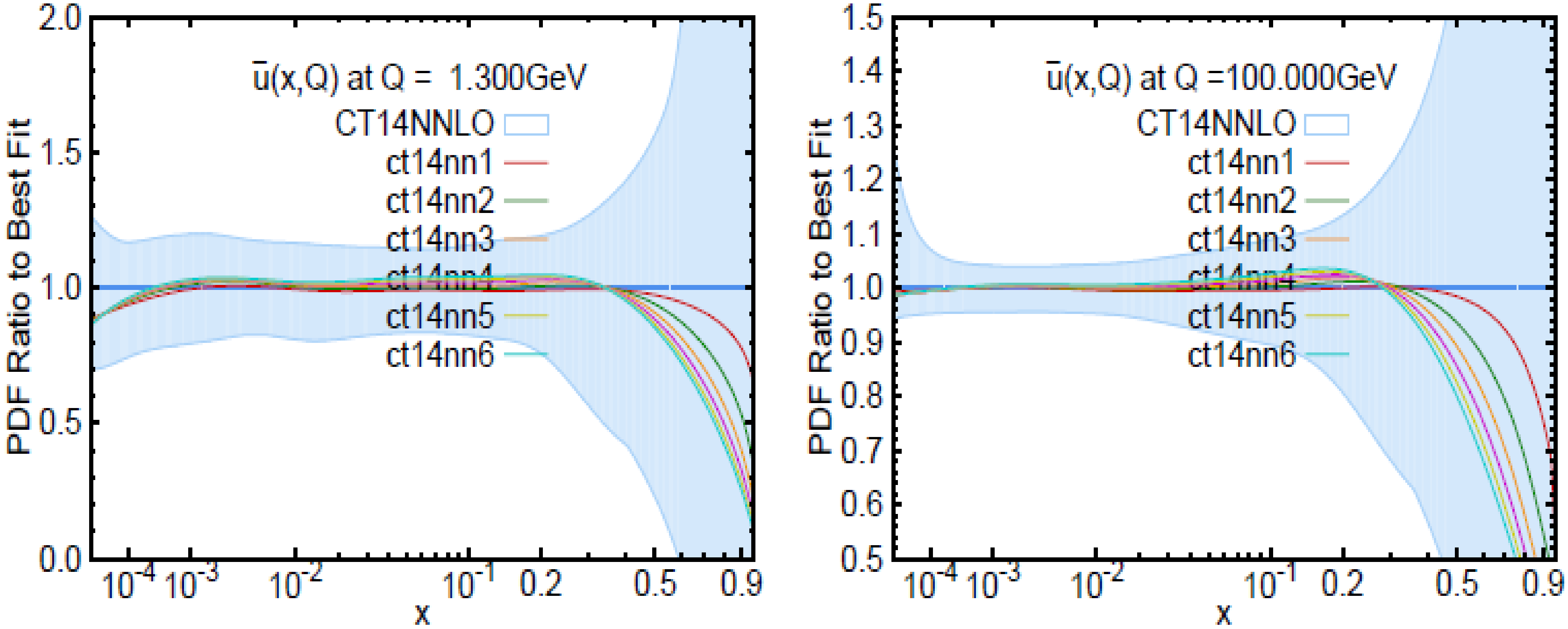
d-PDFs





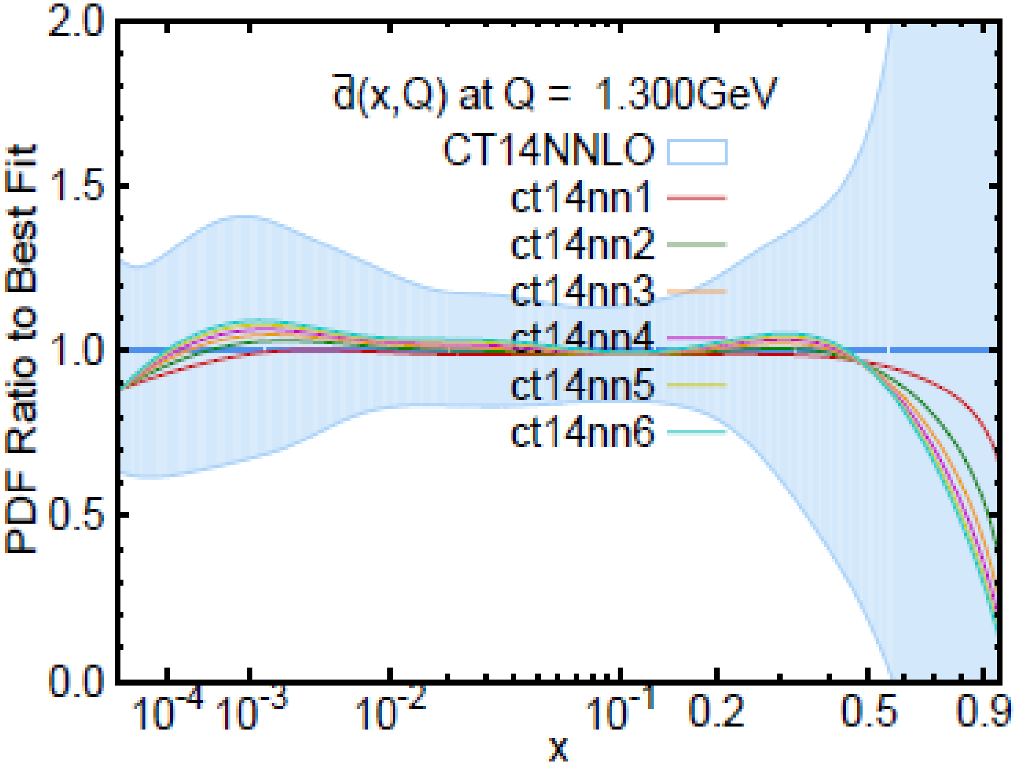
With the larger weight (~ 6) on HERA I + II data, , at x around 0.1, we se some small difference there.
Sizable changes occur at large and small x regions, but well within the error band of CT14.
d –PDF increased at large x region as compared to CT14.

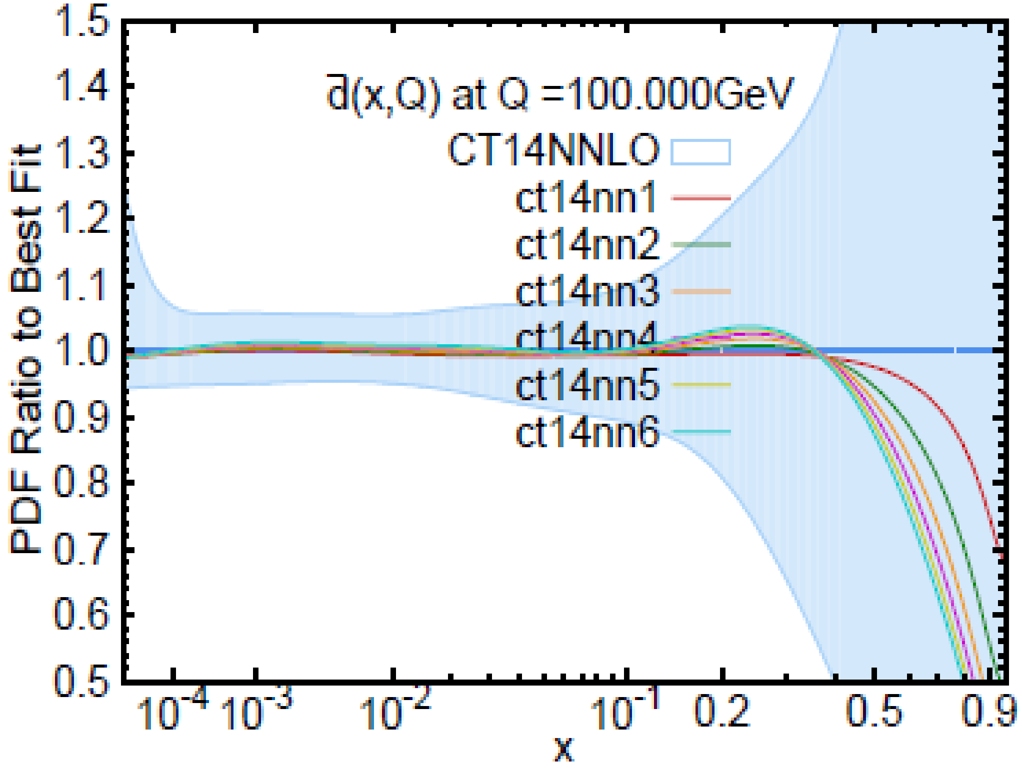
ubr-PDFs



With the larger weight (~ 6) on HERA I + II data, sizable changes occur at large x region, but well within the error band of CT14.
ubr–PDF decreased at large x region as compared to CT14.

dbr-PDFs

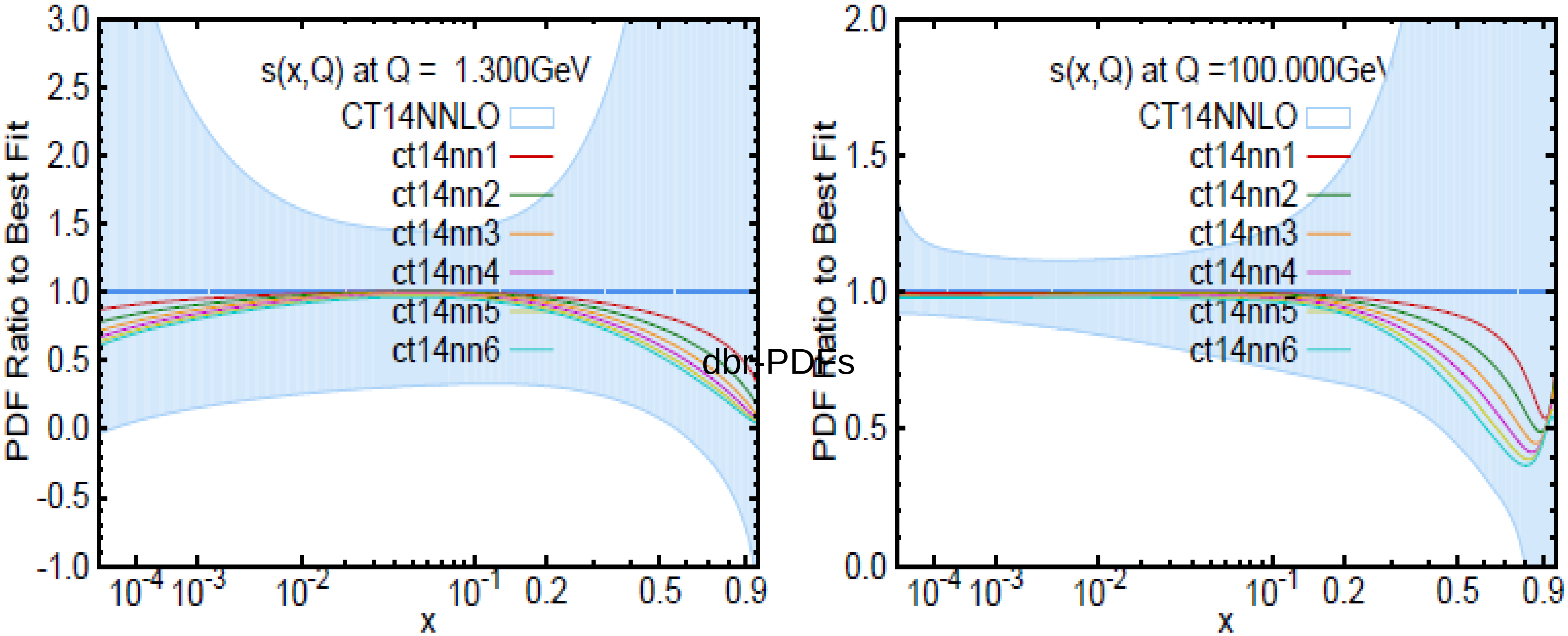




Small variation occurs at x around 0.2 to 0.4
Sizable changes occur at large x region, but well within the error band of CT14.
dbr–PDF decreased at large and small x region as compared to CT14.

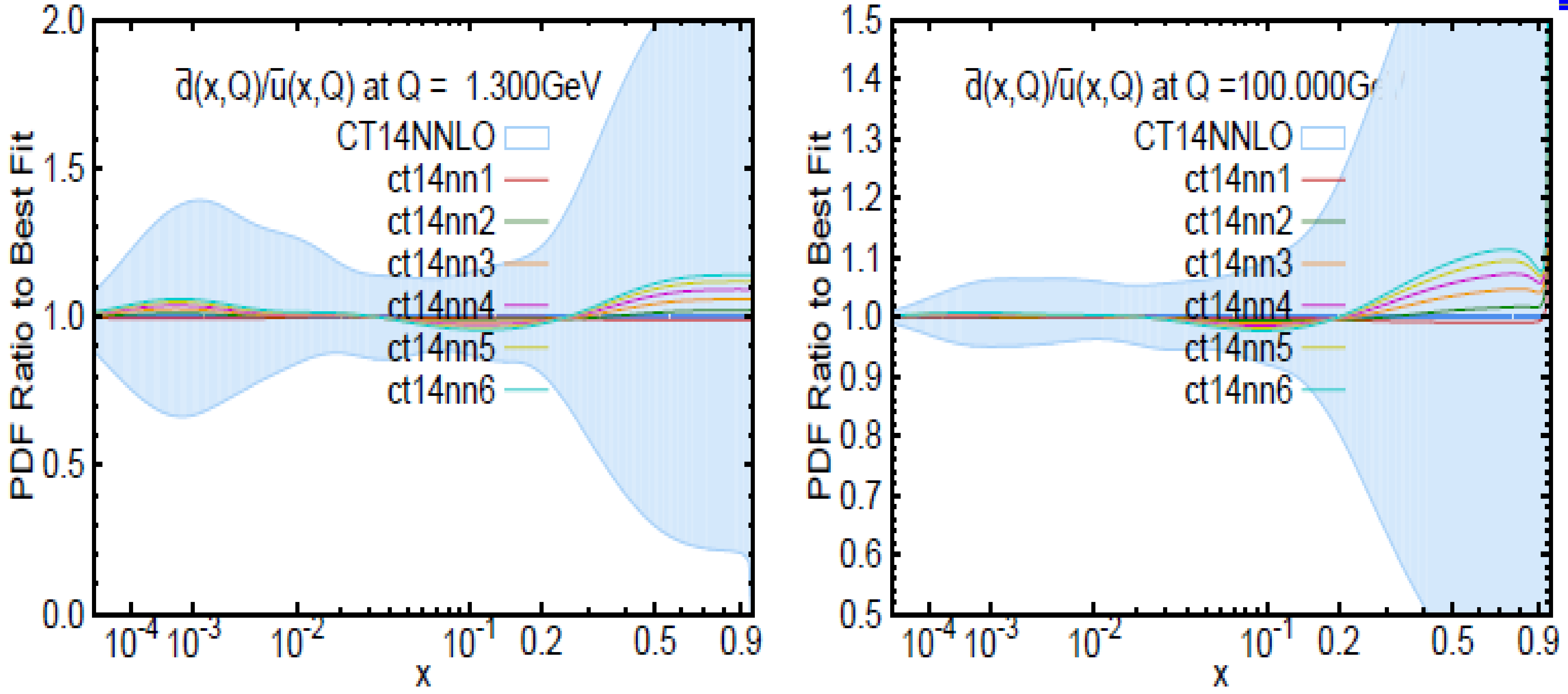
S-PDFs

CTEQ



With the larger weight (~ 6) on HERA I + II data , s-PDF decreased at large x region as compared to CT14.

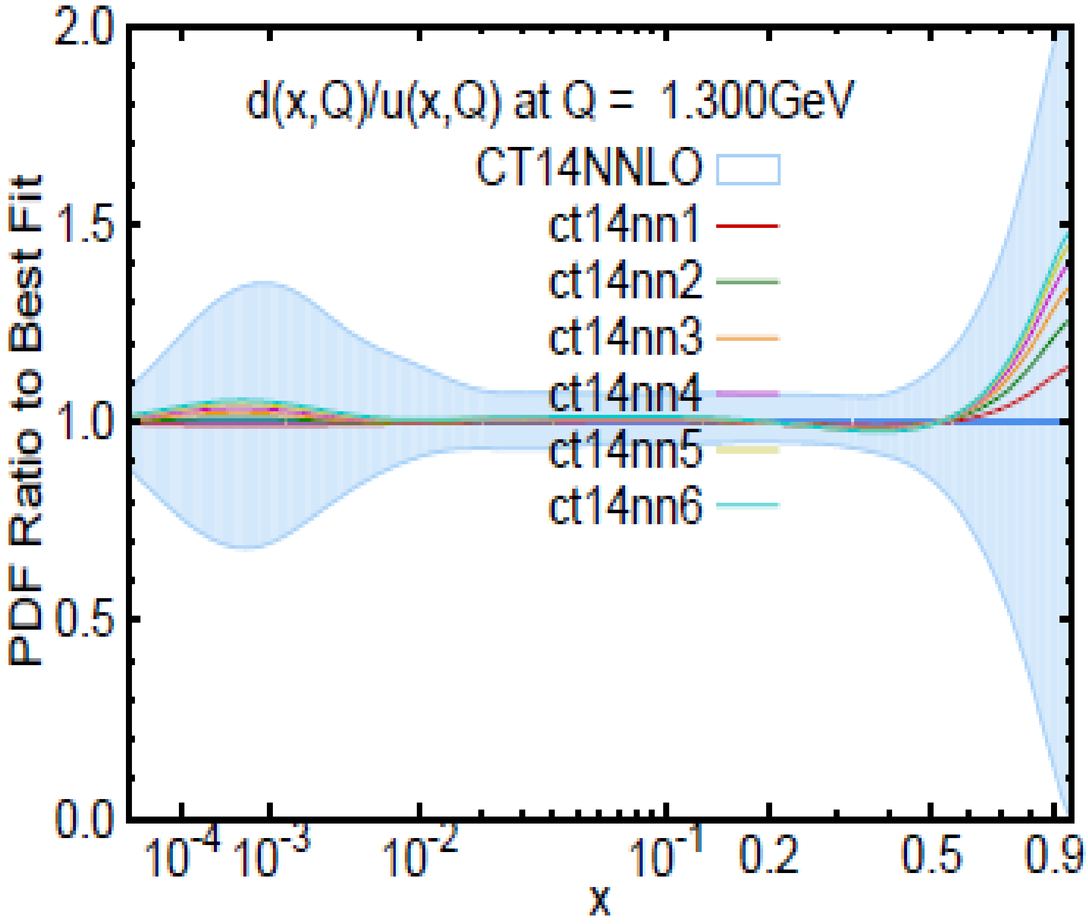
dbr/ubr-PDFs

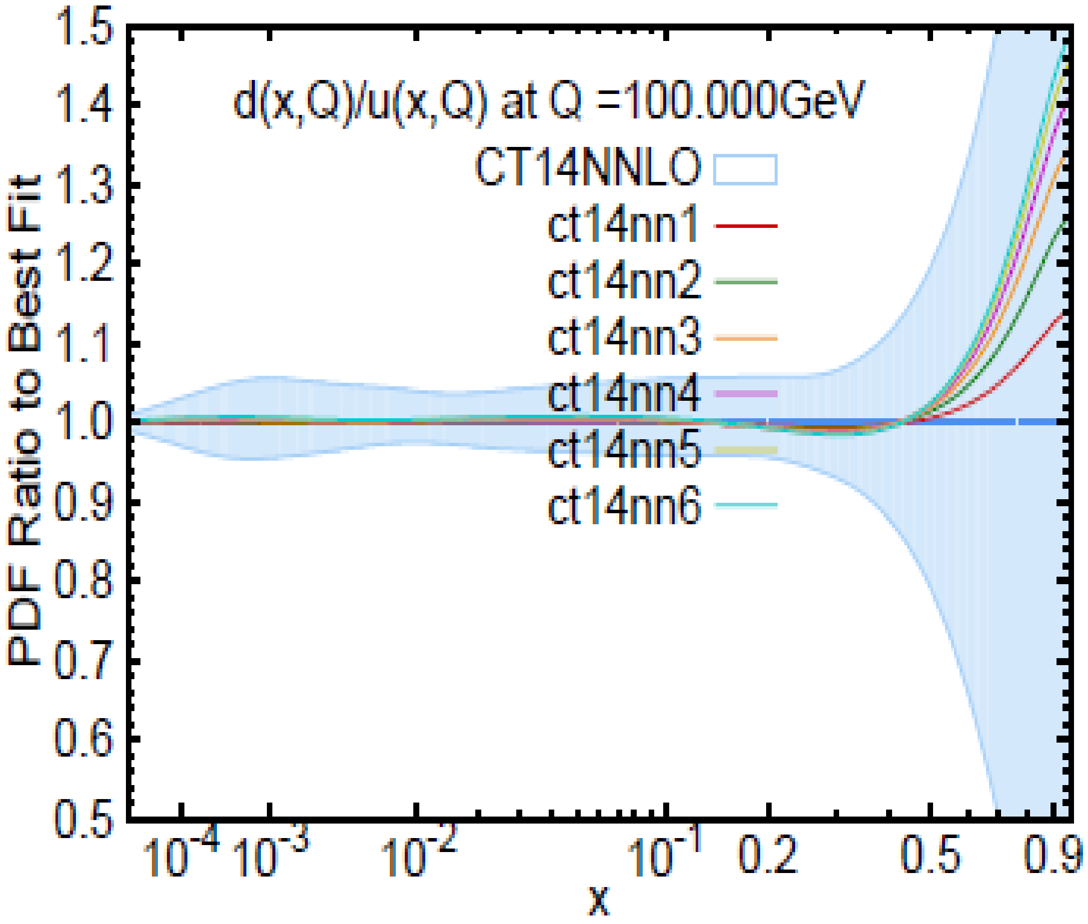


dbr/ubr –PDF increased at large x region as compared to CT14 both at Q=1.3 GeV and 100 GeV.

Sizable changes occur at large x regions, but well within the error band of CT14.

d/u-PDFs

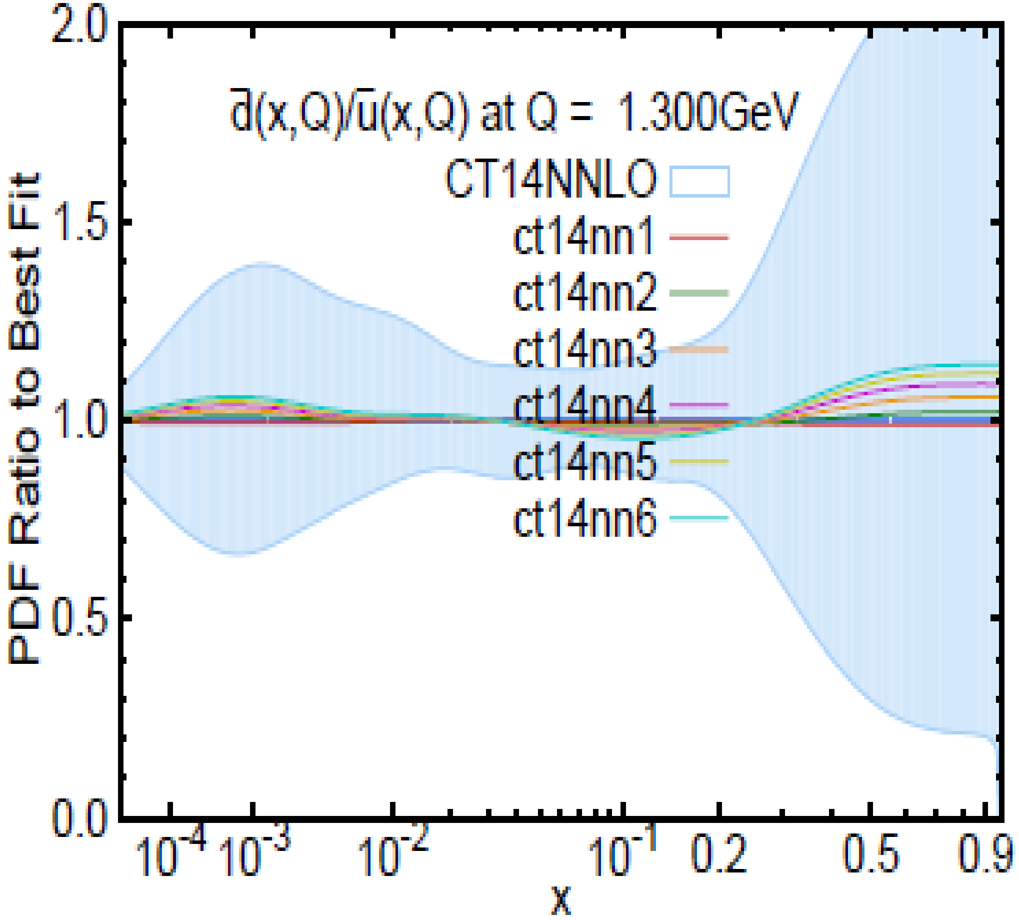


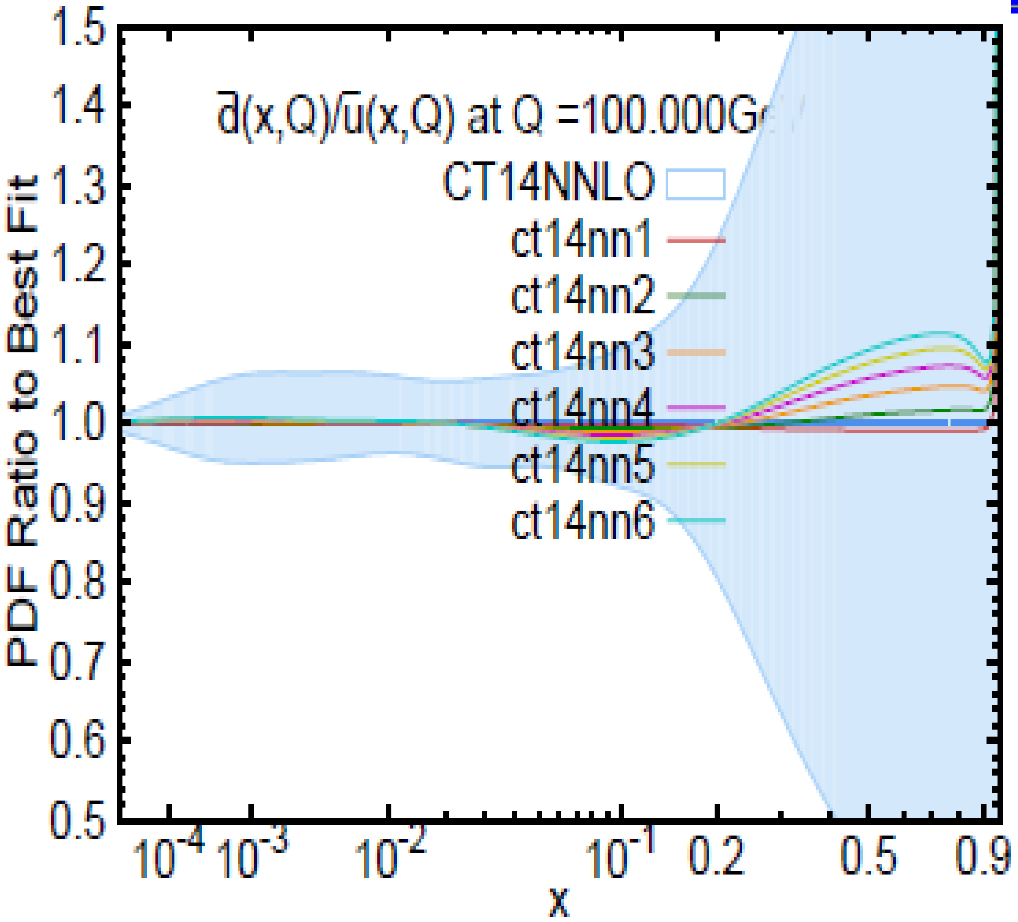


d/u –PDF increased at large x region as compared to CT14 both at Q=1.3 GeV and 100 GeV

Sizable changes occur at large x regions, but well within the error band of CT14

dbr/ubr-PDFs





dbr/ubr –PDF increased at large x region as compared to CT14 both at Q=1.3 GeV and 100 GeV.

Sizable changes occur at large x regions, but well within the error band of CT14.

Conclusion

- CT14 has more flexible parametrization form and took a different assumption about the behavior of d/u as x near 1, and dbar/ubar as x approaches to 0.
- CT14 is different from CT10, after including the LHC Run 1 (ATLAS, CMS, LHCb) W, Z and jet data and the new Tevatron D0 W-electron asymmetry data.
- We showed CT14 prediction for HERA I+II combined data.

  Our NLO fit yields a smaller Chi2/Npt than NNLO fit.
- Including HERA I+II data with a larger weight in the CT14 PDF analysis leads to somewhat different central PDFs, but well within the CT14 error band.
- In future CT analysis, we will add HERA I+II and new LHC data (e.g., low and high mass Drell-Yan, top quark differential distributions).

Thank you very much!