NUCLEAR PDFS: STATUS AND PERSPECTIVES FROM P-PB DATA AT THE LHC

PÍA ZURITA

UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

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OUTLINE

- What are nPDFs?
- nPDFs in the market
- Some remarks
- Bayesian re-weighting & the LHC
- Hadro-production
- Summary

WHAT ARE NPDFS?

$$d\sigma(lp \to l^{'} + X) = \sum_a f_a \otimes d\hat{\sigma}_{la \to l' X}$$

$$d\sigma(lp \to l^{'} + X + h) = \sum_{a,c} f_a \otimes d\hat{\sigma}_{la \to c} \otimes D_c^h$$

$$d\sigma(pp \to l^+ l^-) = \sum_{a,b} f_a \otimes f_b \otimes d\hat{\sigma}_{ab \to l\bar{l}}$$

$$d\sigma(pp \to X + h) = \sum_{a,b,c} f_a \otimes f_b \otimes d\hat{\sigma}_{ab \to c} \otimes D_c^h$$

$d\hat{\sigma}$ → HARD f_a & D_c^h → SOFT

WE ASSUME FACTORIZATION HOLDS

$$d\sigma(lA \to l^{'} + X) = \sum_a f_a^A \otimes d\hat{\sigma}_{la \to l' X}$$

$$d\sigma(lA \to l^{'} + X + h) = \sum_{a,c} f_a^A \otimes d\hat{\sigma}_{la \to c} \otimes D_c^h$$

$$d\sigma(pA \to l^+ l^-) = \sum_{a,b} f_a^A \otimes f_b \otimes d\hat{\sigma}_{ab \to l\bar{l}}$$

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SAME DGLAP SCALE EVOLUTION

SAME HARD SCATTERING CROSS SECTIONS

DETERMINATION THROUGH A

GLOBAL QCD ANALYSIS

$$\chi^2 = \sum_i \omega_i \frac{(d\sigma_i^{exp} - d\sigma_i^{th})^2}{\Delta_i^2}$$

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DATA SETS

ERROR TREATMENT

WEIGHTS

THEORY

PARAMETERIZATION

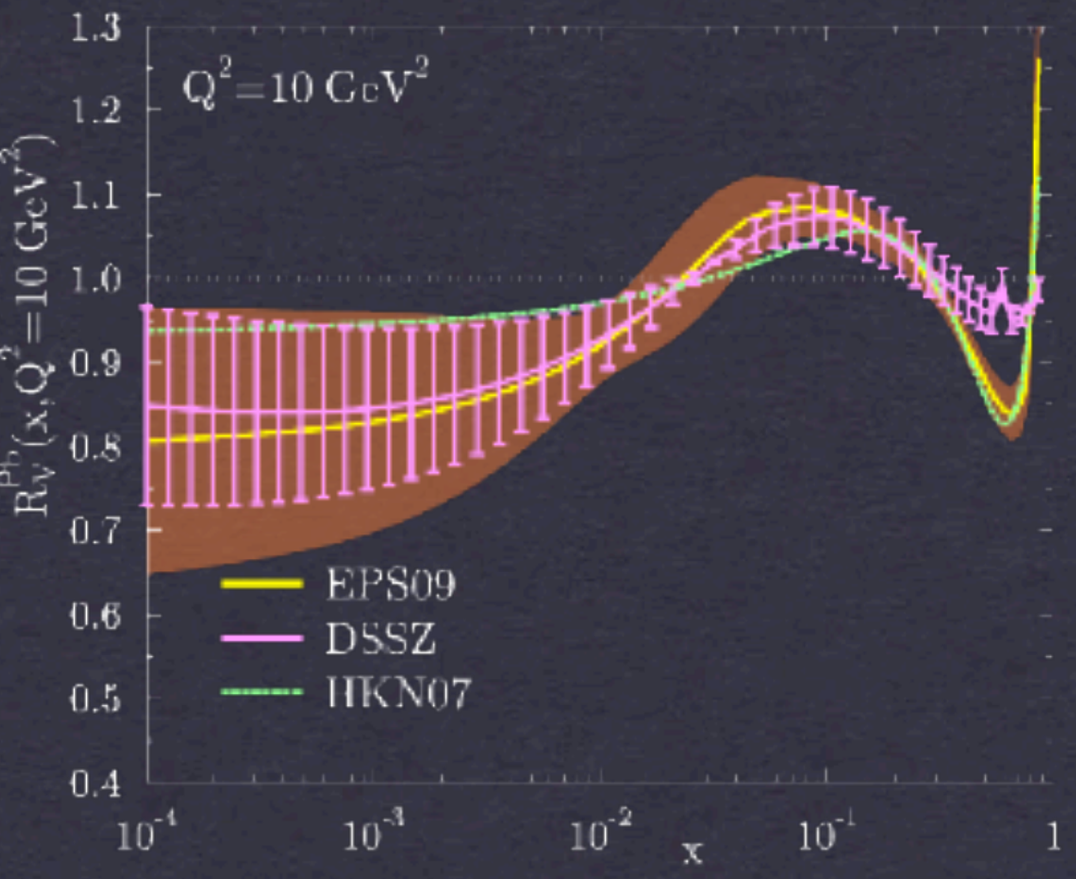
SETS OF NUCLEAR PDFS IN THE MARKET

SET	**HKN07**	**EPS09**	**DSSZ**	**nCTEQ**
reference	PRC76 (2007) 065207	JHEP 0904 (2009) 065	PRD85 (2012) 074028	arXiv: 1307.3454
data type	e-DIS D-Y	e-DIS D-Y **hadro production**	e-DIS D-Y **hadro production** **v-DIS**	e-DIS D-Y
# data points	1241	929	1579	708
proton PDF	MRST98	CTEQ6.1	MSTW2008	CTEQ6M
scheme	ZM-VFNS	ZM-VFNS	GM-VFNS	GM-VFNS
comments	first uncertainty set	**huge shadowing & anti-shadowing for gluons**	**medium modified FFs**	**ongoing**

AND IF WE

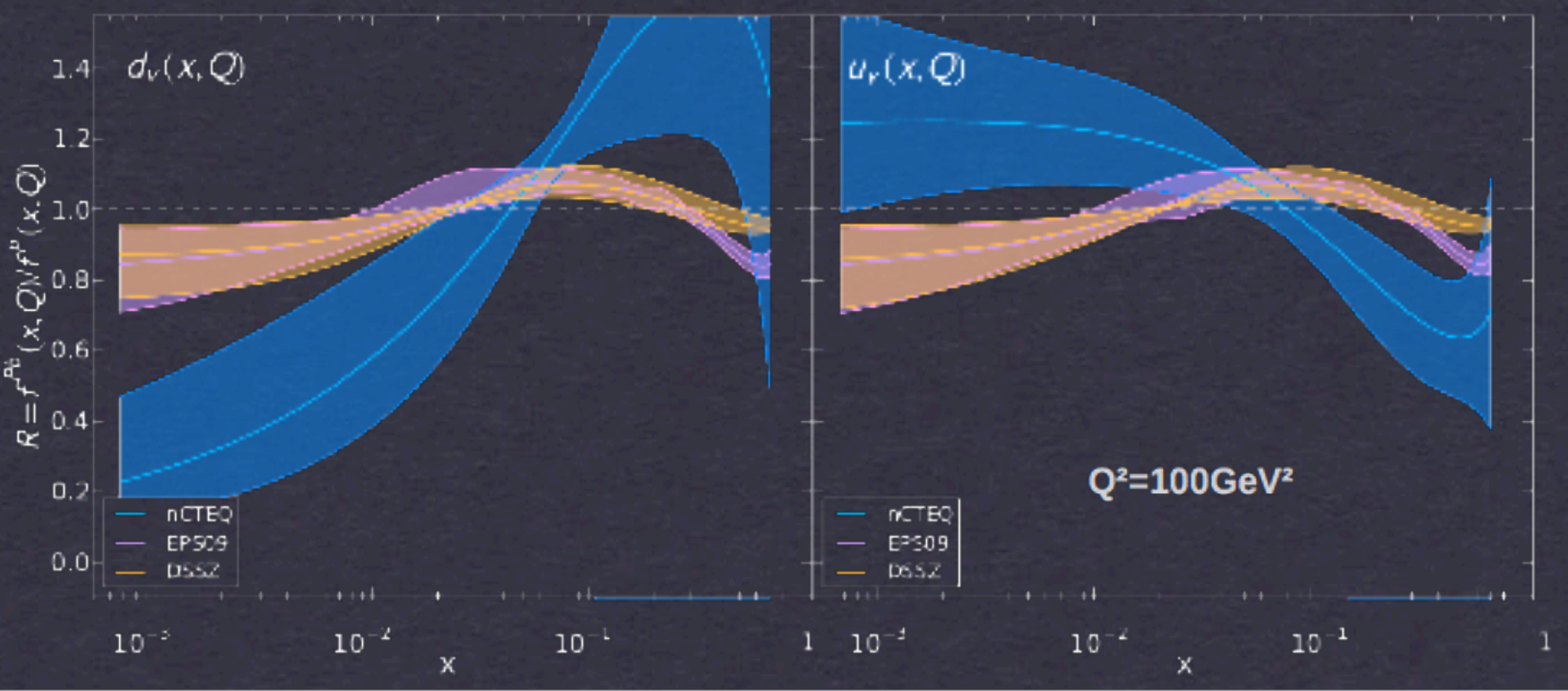
COMPARE

THEM ...

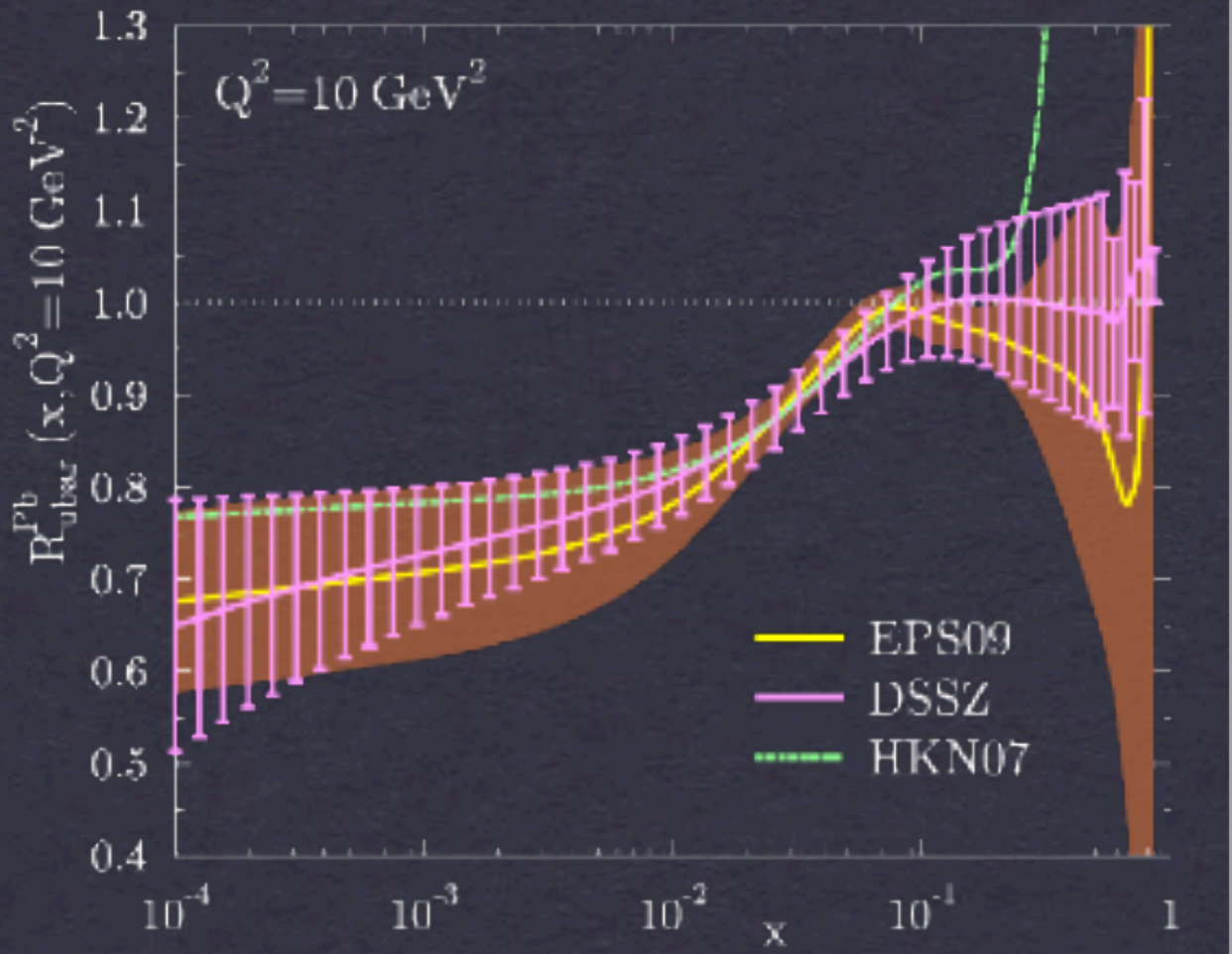


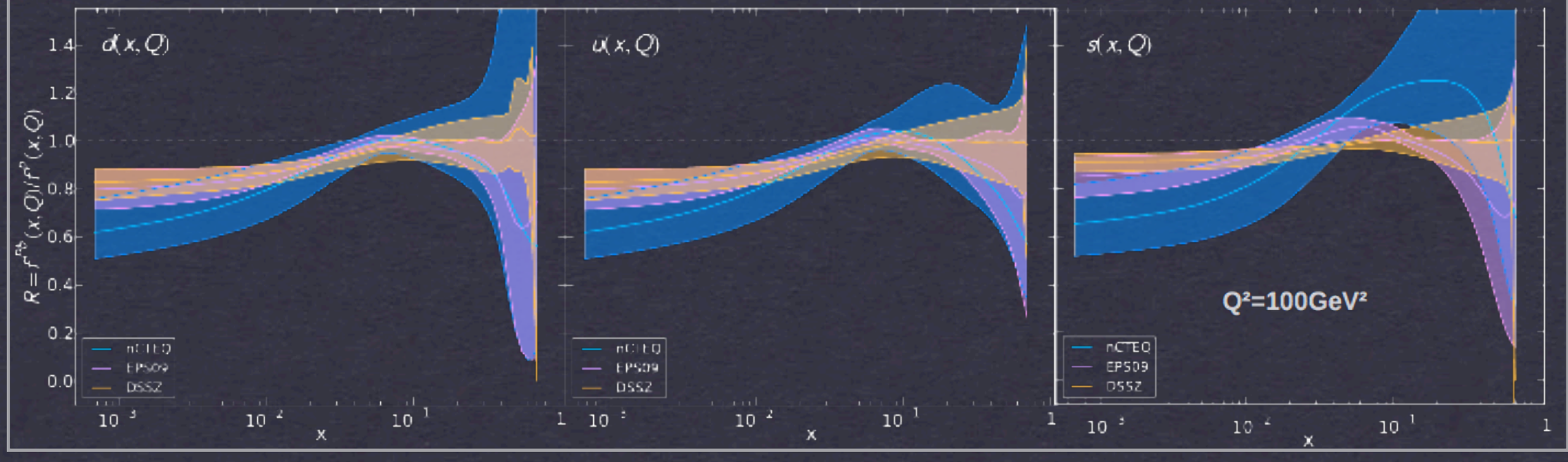
VALENCE COMPATIBLE
HIGH X DISCREPANCY

FROM
ELECTRON
DIS

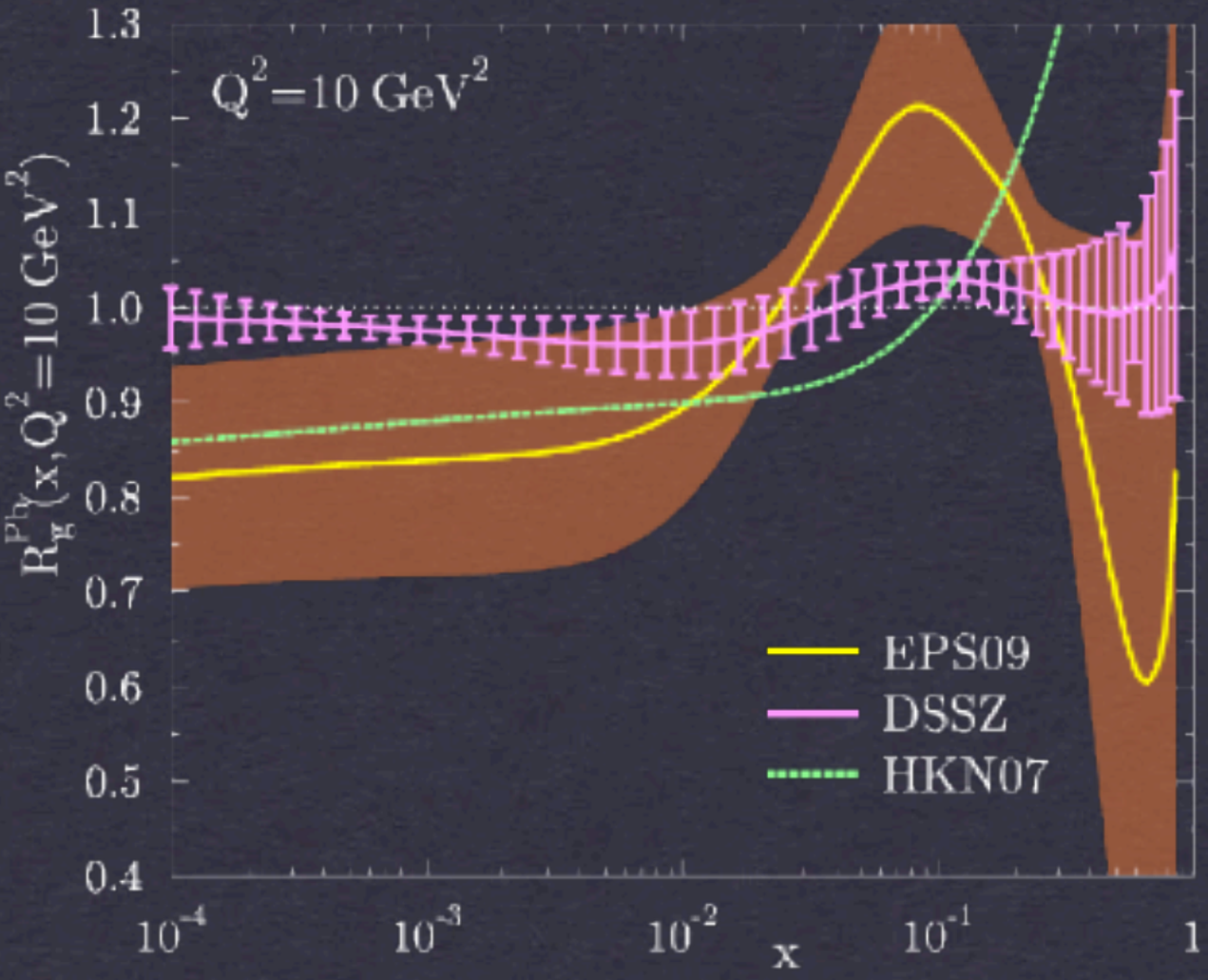


SEA COMPATIBLE





GLUONS



DIFFERENT TREATMENT OF HADRO-PRODUCTION

EPS09: ANTI-SHADOWING

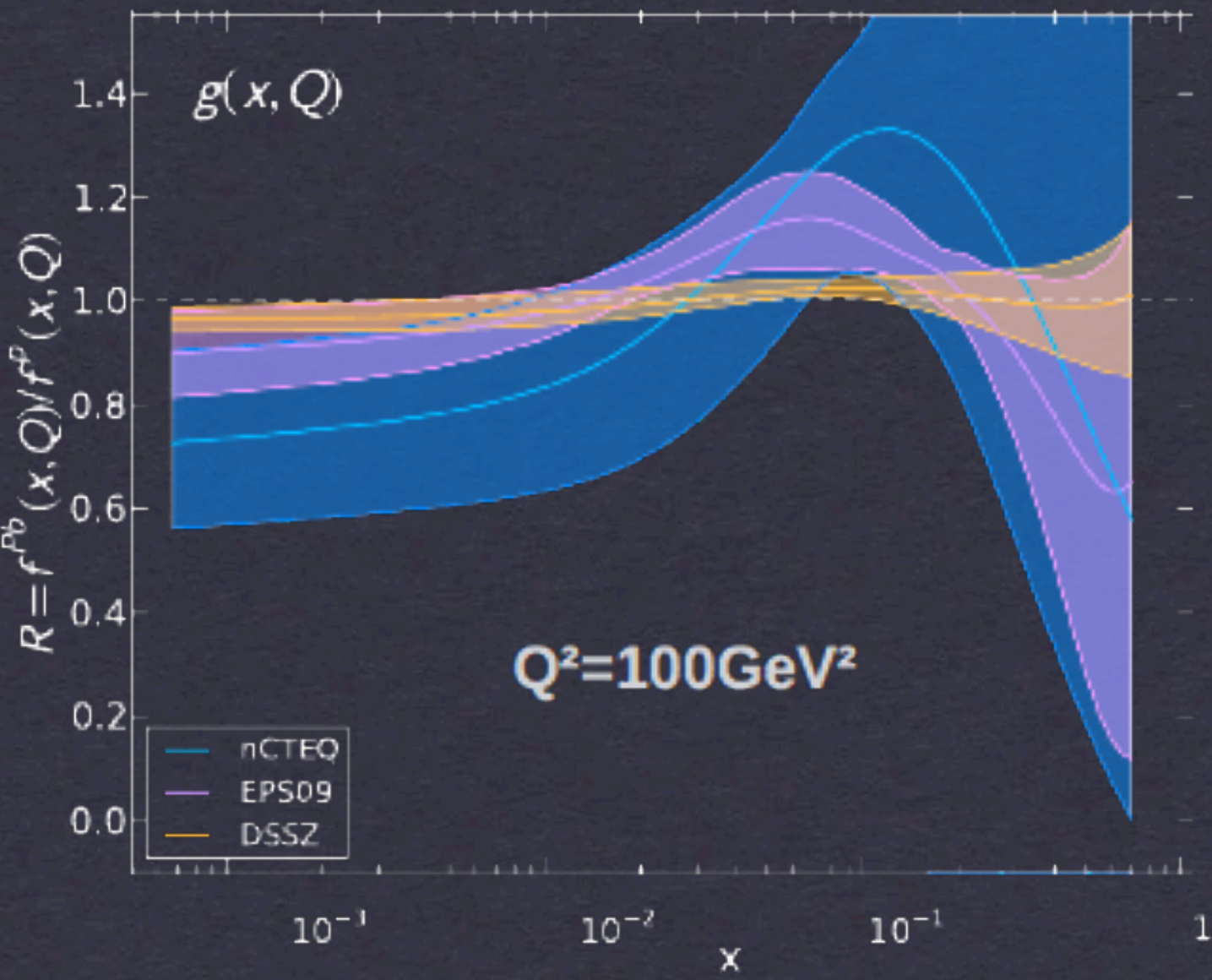
DSSZ: nFFs

GLUONS

nCTEQ

STRONGER EFFECT

ONGOING WORK



NEUTRINO-NUCLEUS DIS

SEA-VALENCE DISENTANGLEMENT

NEUTRINO-NUCLEUS DIS

SEA-VALENCE DISENTANGLEMENT

CLAIM FROM A PREVIOUS nCTEQ WORK:

PRESENCE OF NON-UNIVERSAL EFFECTS

HINT OF FACTORIZATION BREAKING

NEUTRINO-NUCLEUS DIS

SEA-VALENCE DISENTANGLEMENT

CLAIM FROM A PREVIOUS NCTEQ WORK:

PRESENCE OF NON-UNIVERSAL EFFECTS

HINT OF FACTORIZATION BREAKING

EPS09: INCLUSION VIA A RE-WEIGHTING METHOD

DSSZ: INCLUSION IN THE FIT

NCTEQ: ONGOING WORK

SOME REMARKS:

DIFFERENT NPDFS ≠ **DIFFERENT QUALITY OF DATA DESCRIPTION**

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WHICH NPDF SET SHOULD BE USED?

Hadro-production (FFs): HKN07 or EPS09

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Hadro-production (nFFs): DSSZ

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Hadro-production (nFFS): DSSZ

Other: HKN07, EPS09 or DSSZ

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Hadro-production (nFFs): DSSZ

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neutrino data: EPS09 or DSSZ

Hadro-production (FFs): HKN07 or EPS09

Hadro-production (nFFs): DSSZ

Other: HKN07, EPS09 or DSSZ

neutrino data: EPS09 or DSSZ

Outside the kinematical region

included in the fits:

NONE 100% reliable

- NUCLEAR EFFECTS TRULY UNIVERSAL?
- CORRELATED ERRORS?
- MORE DATA IN D-Y AND HADRO-PRODUCTION?
- CROSS-SECTIONS OR STRUCTURE FUNCTIONS?
- NUCLEAR EFFECTS FOR DEUTERON?
- MORE FLEXIBLE PARAMETERIZATIONS?
- HIGHER FIXED-ORDER ANALYSES WORTHWHILE?
- A-A COLLISIONS?
- FINAL STATE NUCLEAR EFFECTS?
- ...???

BAYESIAN

RE-WEIGHTING

& THE LHC

N. Armesto, J. Rojo, C. A. Salgado, P.Z.,
JHEP 1311 (2013) 015

Fitting is:

TIME CONSUMING (months/years)

CUMBERSOME

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TIME CONSUMING (months/years)

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Re-weighting:

methods to quickly assess the impact of new data on PDFs

The re-weighting method

Developed:

W. T. Giele and S. Keller, Phys. Rev. D58 (1998) 094923.

R. D. Ball et al. [NNPDF Collaboration], Nucl. Phys. B 849 (2011) 112 [Erratum-ibid. B 854 (2012) 926] [Erratum-ibid. B 855 (2012) 927].

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G. Watt and R. S. Thorne, JHEP (2012) 052.

Other:

H. Paukkunen and C. A. Salgado, Phys. Rev. Lett.110, 212301 (2013).

For any observable

$$\langle \mathcal{O} \rangle = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} \mathcal{O}[f_k]$$

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N new data points ⇒

$$\mathcal{P}_{new}(f) = \mathcal{N}_\chi \mathcal{P}(\chi|f)\mathcal{P}_{old}(f)$$

with

$$\mathcal{P}(\chi|f) \propto (\chi^2(y,f))^{\frac{1}{2}(n-1)} e^{-\frac{1}{2}\chi^2(y,f)}$$

After the re-weighting

$$\langle \mathcal{O} \rangle_{\rm new} = \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k \mathcal{O}[f_k]$$

where

$$w_k = \frac{(\chi^2_k)^{\frac{1}{2}(n-1)} e^{-\chi^2_k/2}}{\frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} (\chi^2_k)^{\frac{1}{2}(n-1)} e^{-\chi^2_k/2}}$$

RE-WEIGHTING ≠ NEW FIT

RE-WEIGHTING ≠ NEW FIT

To quantify the accuracy

$$N_{\rm eff} \equiv \exp\left\{ \frac{1}{N_{\rm rep}} \sum_{k=1}^{N_{\rm rep}} w_k \log(N_{\rm rep}/w_k) \right\}$$

Hadroproduction

1000 MC replicas

$pPb \rightarrow h+X$ + MSTW2008 + EPS09 + DSS

D. de Florian, R. Sassot and M. Stratmann, Phys. Rev. D76 (2007) 074033.
R. Sassot, M. Stratmann and P.Z., Phys. Rev. D82 (2010) 074011.

DGLAP & CGC pseudodata

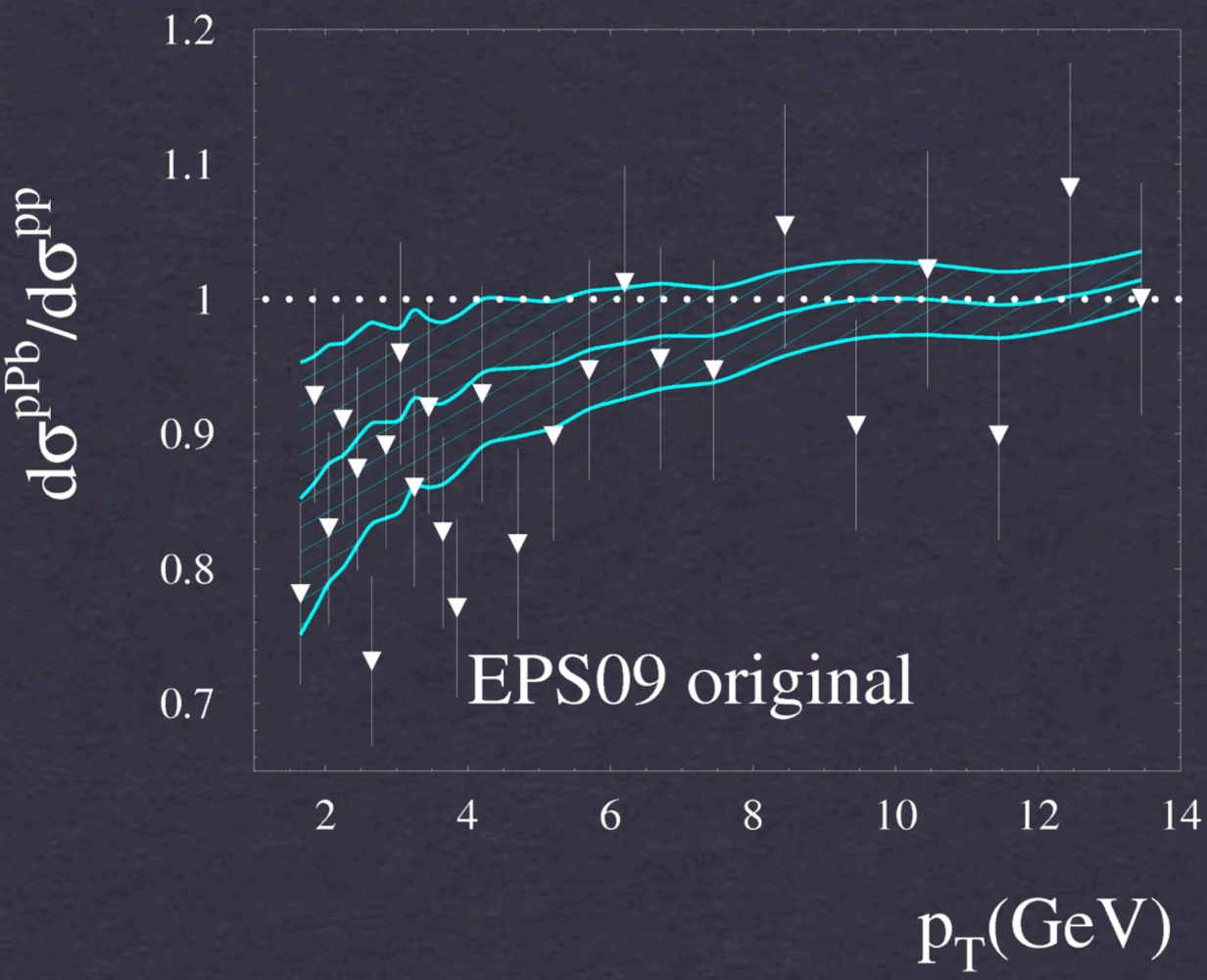
J. L. Albacete, A. Dumitru, H. Fujii and Y. Nara, Nucl. Phys. A 897 (2013) 1.

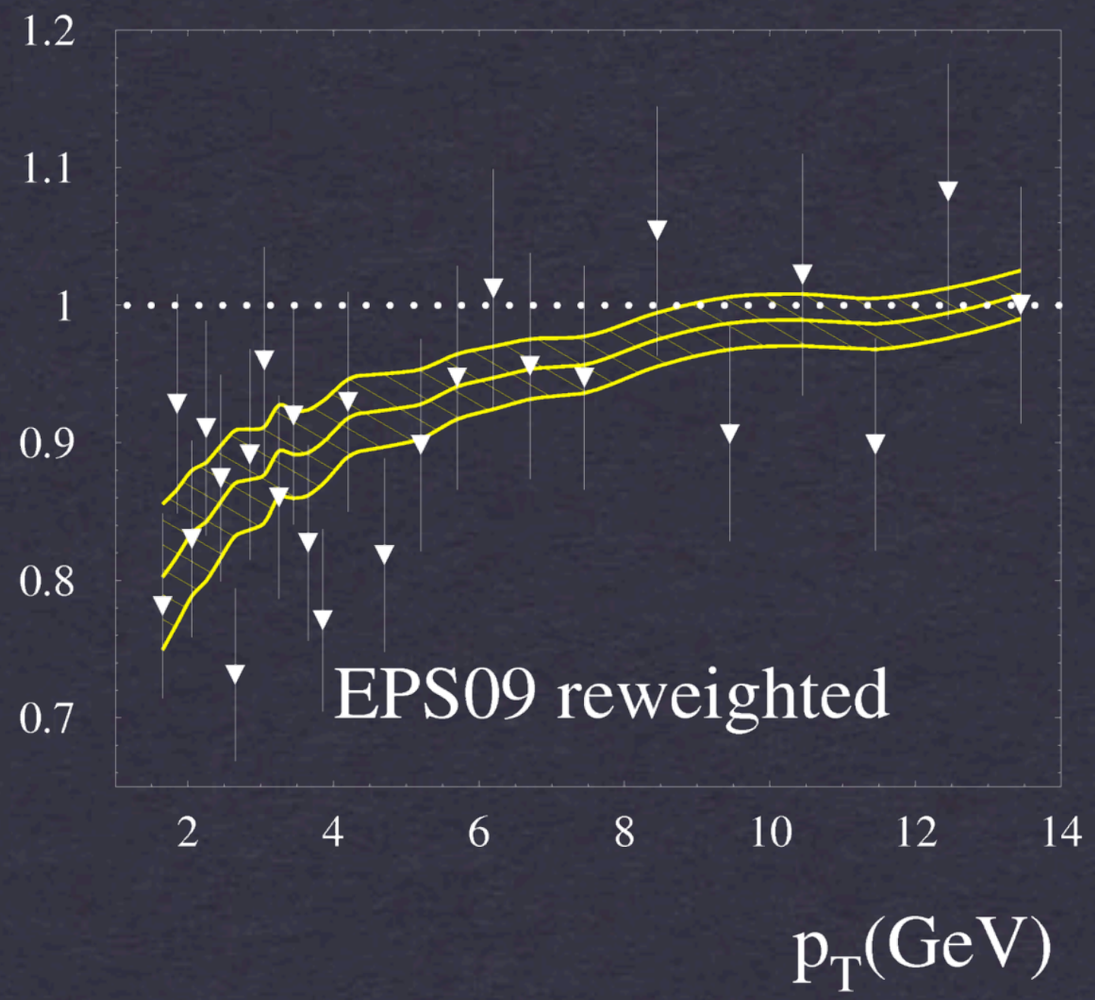
5% systematic & 7% normalization uncertainties

$L_{INT} = 30\ N_B^{-1}$

$\eta = 0$ & $\eta = 2$

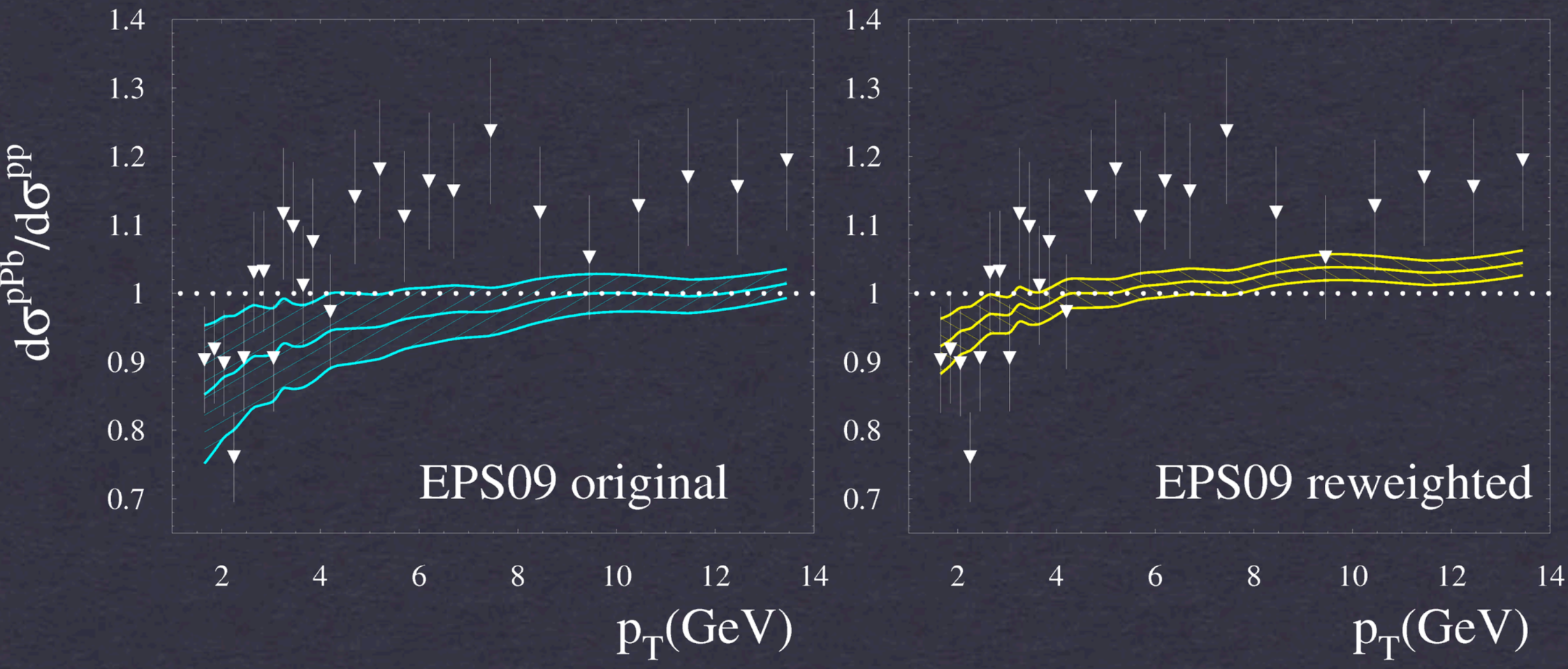
DGLAP for η=0





N=25	χ^2 / N	$\langle \chi^2 \rangle$ / N	N_{EFF}
Before	1.11	1.75	-
After	0.84	1.02	624

CGC for η=0



N=25	χ^2 / N	$< \chi^2 >$ / N	N_{EFF}
Before	2.25	2.76	-
After	1.50	1.58	229

$\eta = 0$

No change in the valence

Change in the sea

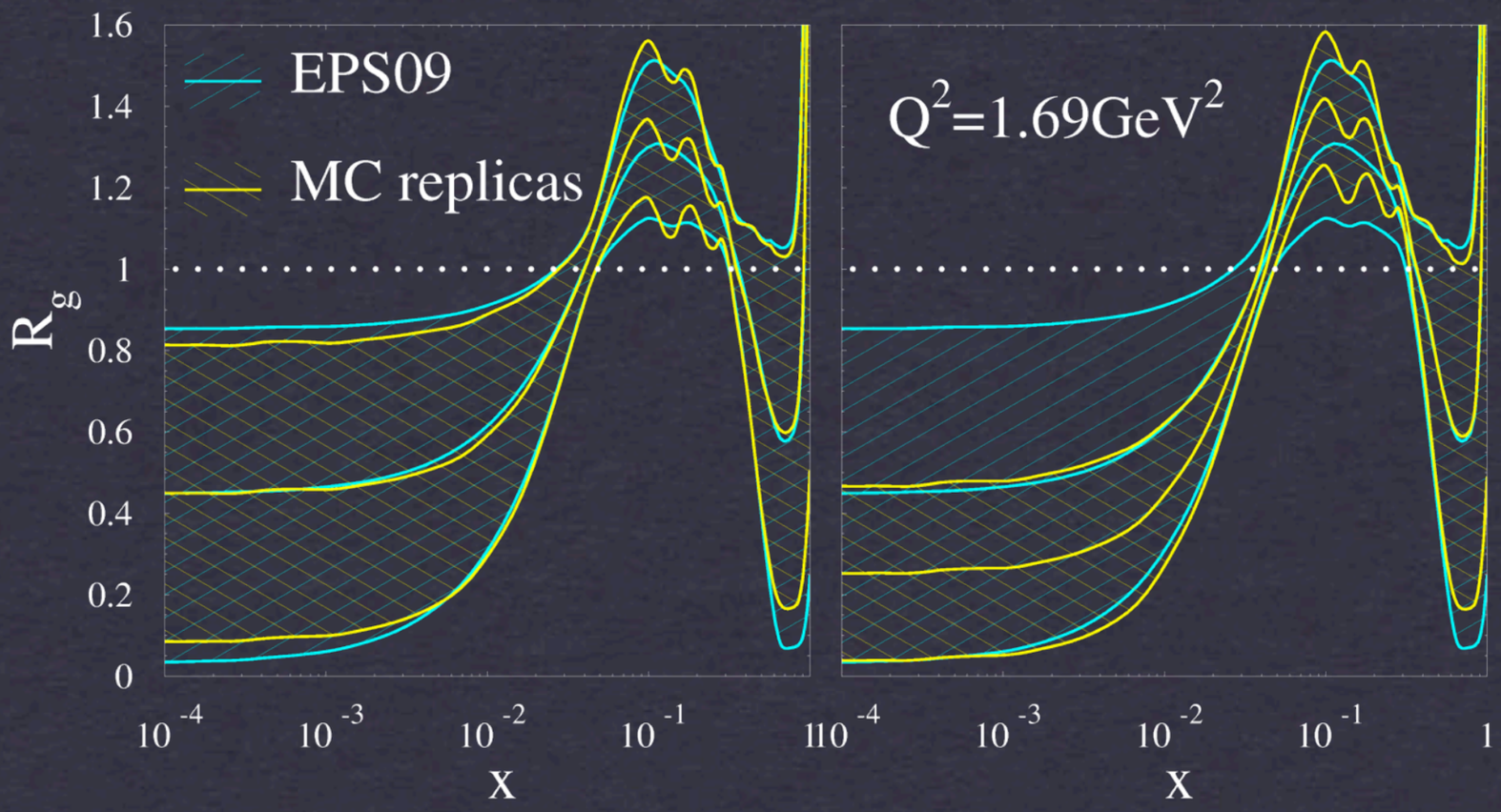
DGLAP

$\eta = 0$

No change in the valence

change in the sea

DGLAP

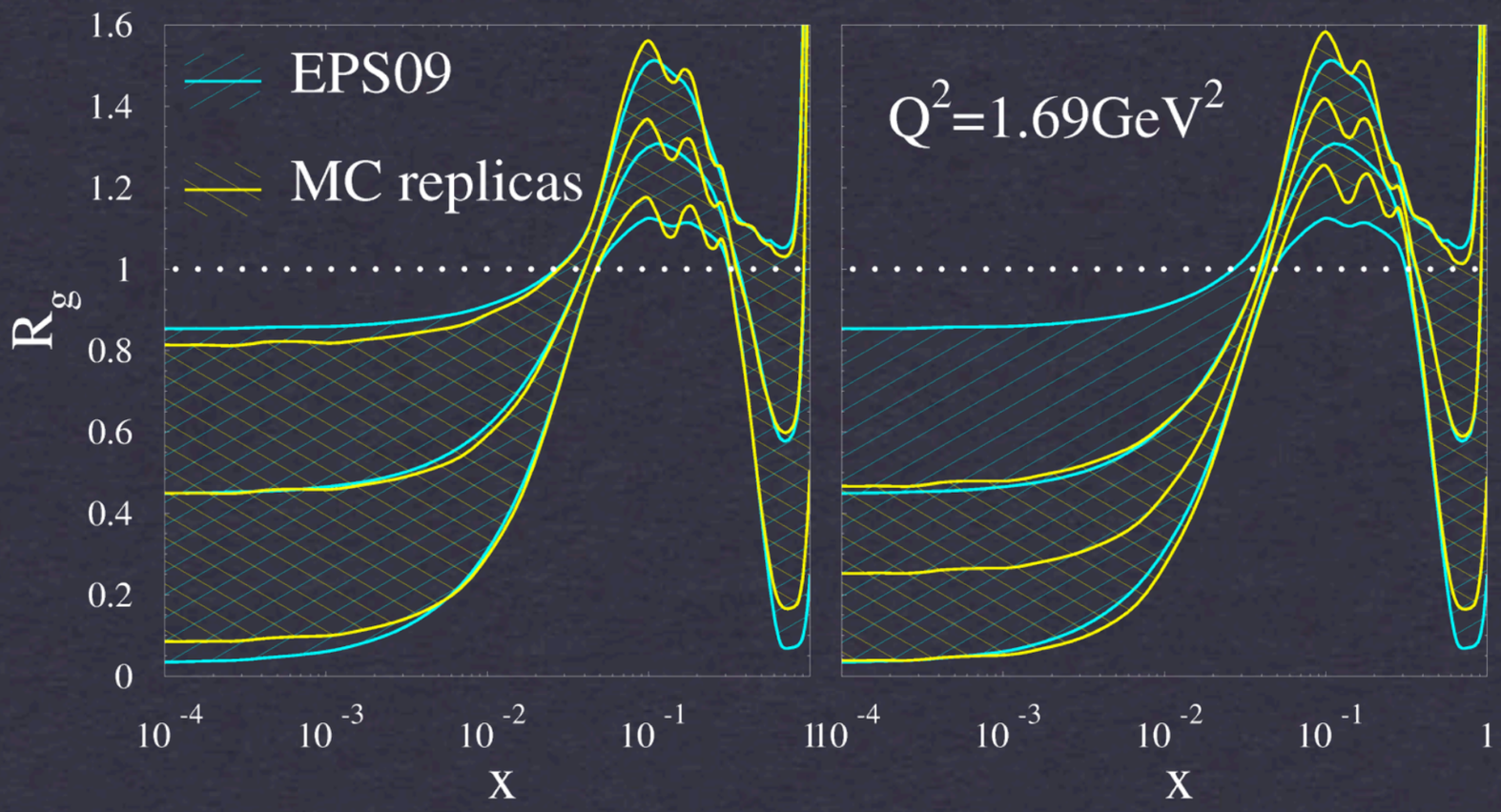


$\eta = 0$

NO CHANGE IN THE VALENCE

CHANGE IN THE SEA

DGLAP



CGC

CHANGE IN THE VALENCE

NO CHANGE IN THE SEA

$\eta = 0$

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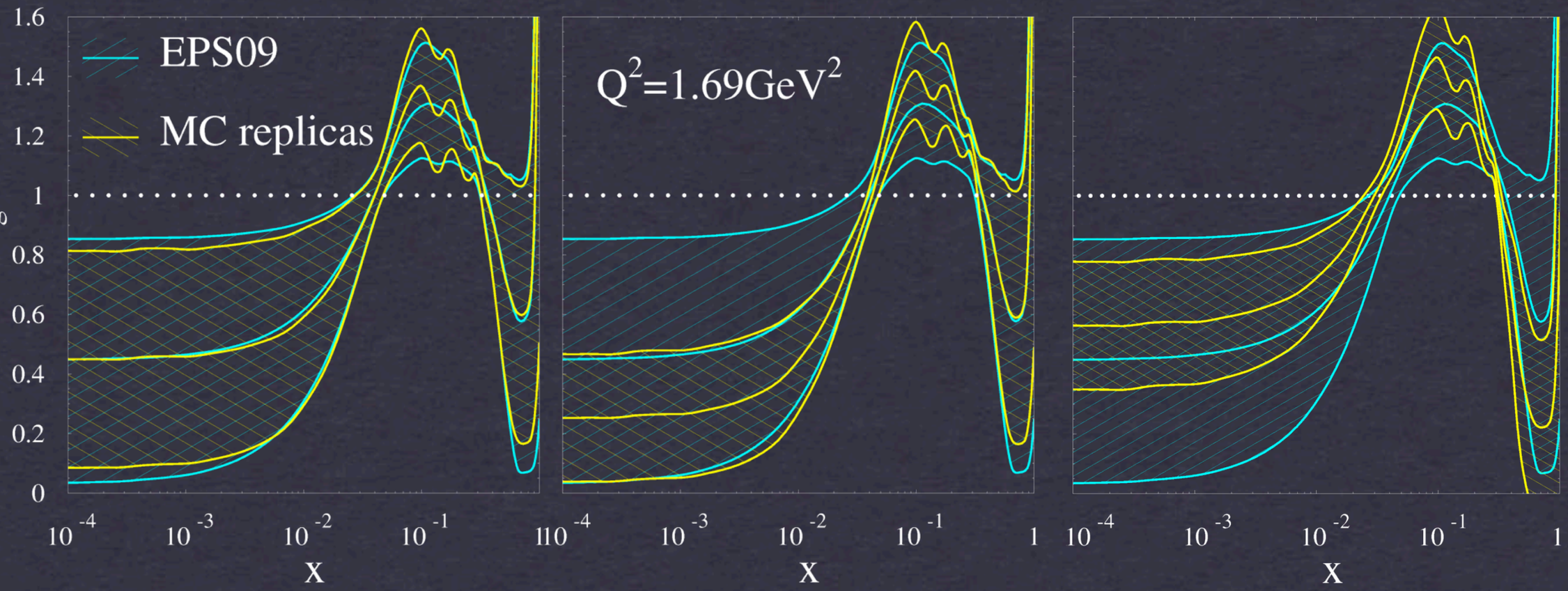
CHANGE IN THE SEA

DGLAP

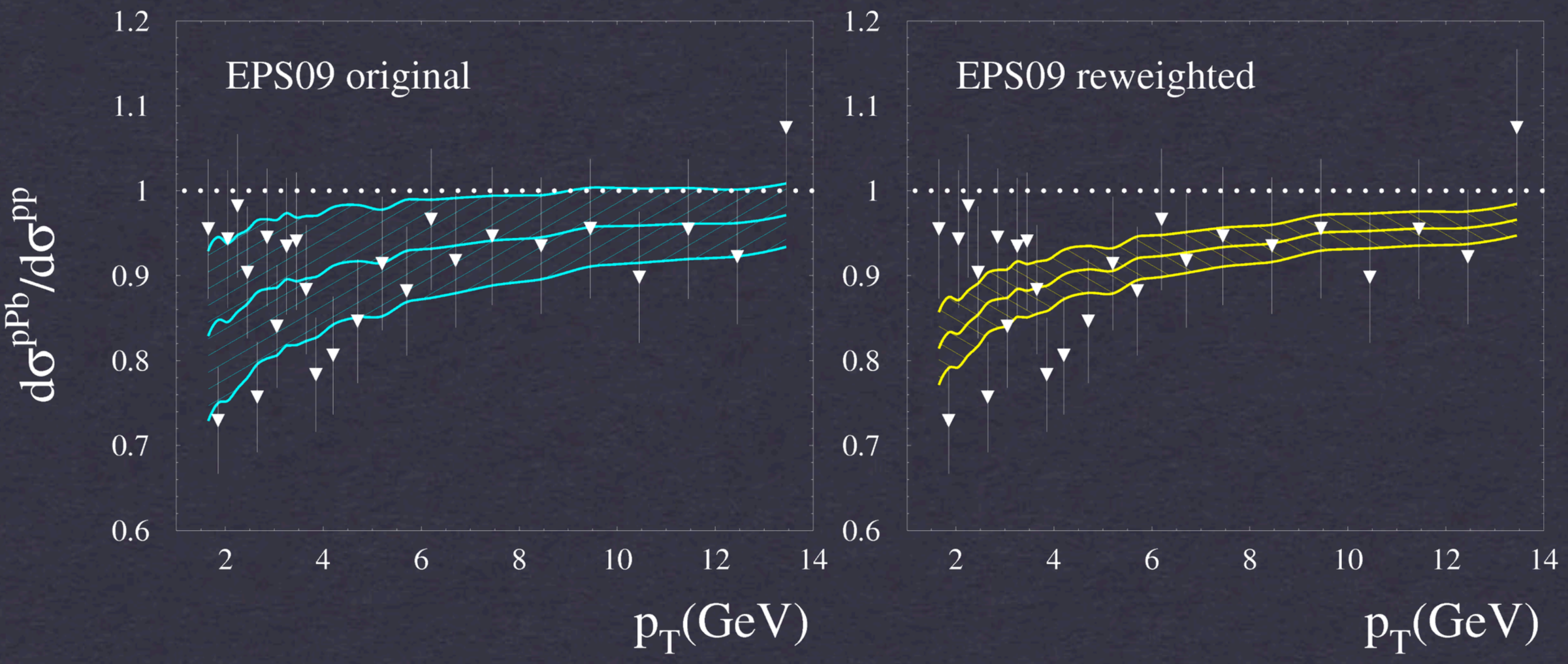


CGC

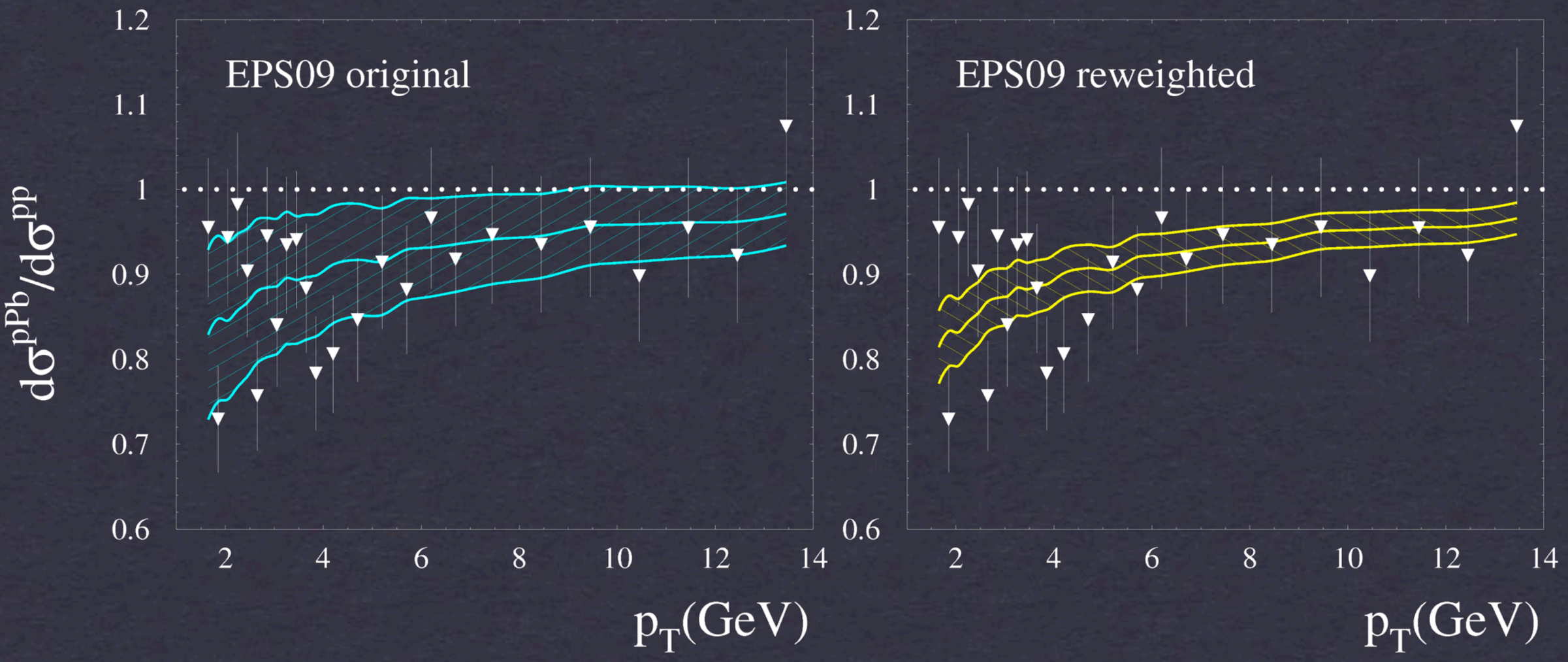
CHANGE IN THE VALENCE

NO CHANGE IN THE SEA

DGLAP for η=2


EPS09 original
EPS09 reweighted
$d\sigma^{pPb}/d\sigma^{pp}$
1.2
1.1
1
0.9
0.8
0.7
0.6
2
4
6
8
10
12
14
p_T(GeV)

DGLAP for η=2



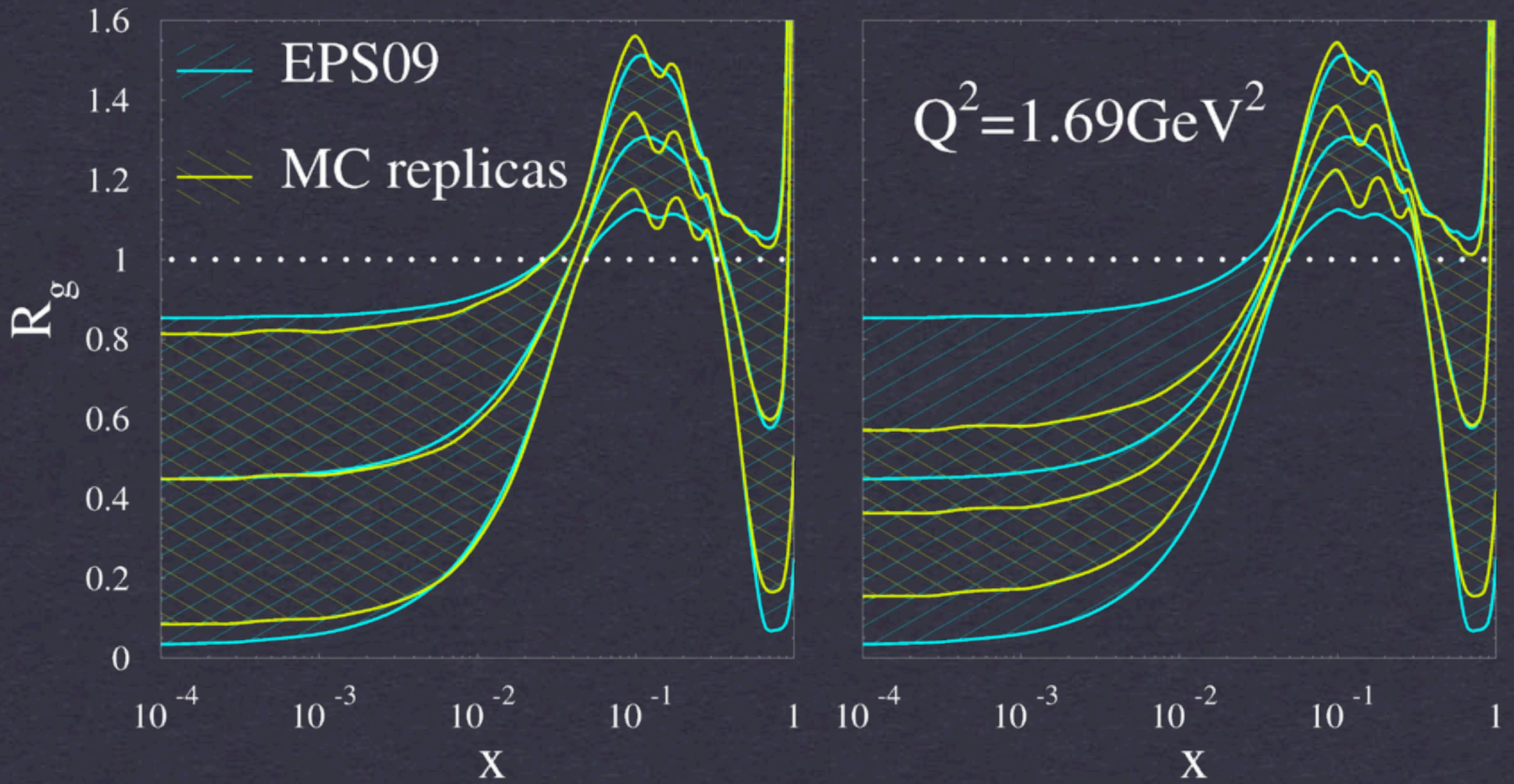
N=25	χ^2 / N	$<\chi^2>$ / N	N_{EFF}
Before	0.95	1.82	-
After	0.92	1.08	612

DGLAP for $\eta=2$

No change in the valence

Slight modification for the sea

DGLAP for η=2

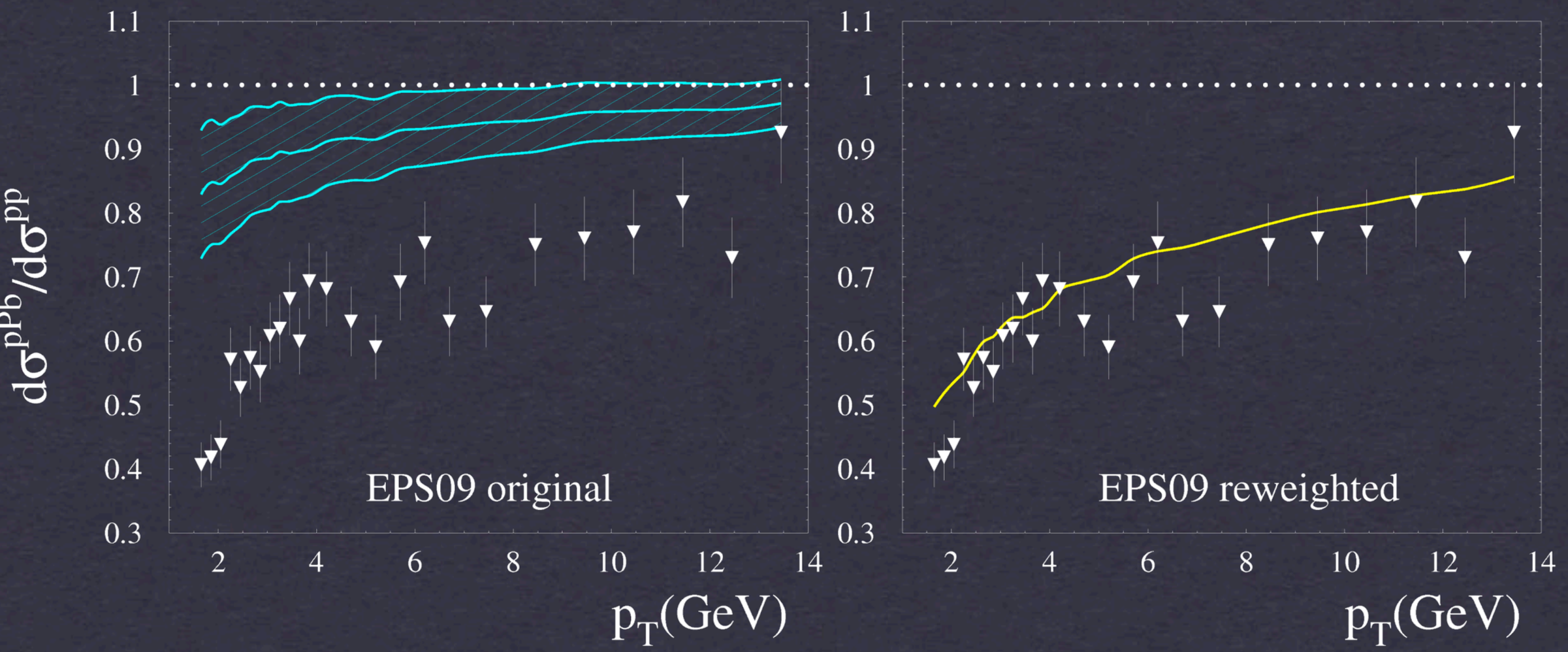


No change in the valence

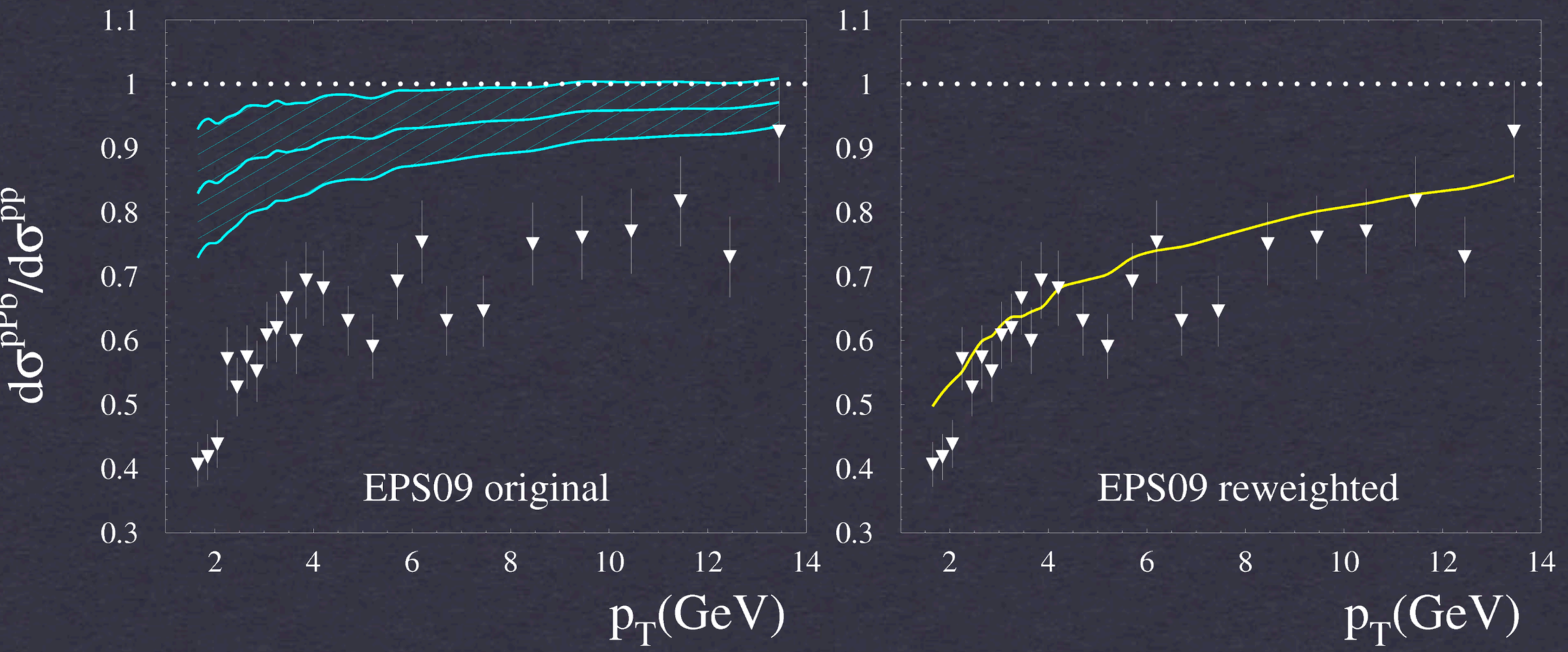
Slight modification for the sea

GLUON!

CGC for η=2


1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
$d\sigma^{pPb}/d\sigma^{pp}$
EPS09 original
EPS09 reweighted
2
4
6
8
10
12
14
p_T(GeV)

CGC FOR η=2



WE CAN FIT THIS, RIGHT?

CGC for $\eta=2$

Unfortunately, NO, because

CGC for $\eta=2$

Unfortunately, NO, because

N=25	χ^2 / N	$\langle \chi^2 \rangle$ / N	N_{EFF}
Before	36.43	38.62	-
After			

CGC for $\eta=2$

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Before	36.43	38.62	-
After	1.85	1.85	

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N=25	χ^2 / N	$\langle \chi^2 \rangle$ / N	N_{EFF}
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THE RE-WEIGHTING METHOD IS INVALIDATED

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So? What happens with the gluons?

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THE RE-WEIGHTING METHOD IS INVALIDATED

So? What happens with the gluons?

They are completely suppressed for $x < 10^{-2}$

SUMMARY

- SEVERAL SETS OF nPDFs AVAILABLE
- GLUON DISTRIBUTIONS NOT (YET) WELL CONSTRAINED BY DATA
- LHC DATA REQUIRED TO IMPROVE PROTON PDFs
- p-Pb @ LHC CRUCIAL TO STUDY THE LOW x REGION
- EIC & LHeC TO GO FURTHER

Re-weighting methods:

if data ~ predictions ⇒ time saving!

Otherwise, re-fitting required

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all DGLAP & $\eta = 0$ CGC pseudodata:

30-50% reduction of the gluon uncertainty

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if data ~ predictions ⇒ time saving!

Otherwise, re-fitting required

all DGLAP & $\eta = 0$ CGC pseudodata:

30-50% reduction of the gluon uncertainty

CGC pseudodata at $\eta = 2$: no conclusions

ONGOING COMPARISON WITH OTHER RE-WEIGHTING METHODS

SAME WITH DSSZ NUCLEAR PDFS COMING SOON

ONGOING COMPARISON WITH OTHER RE-WEIGHTING METHODS

SAME WITH DSSZ NUCLEAR PDFS COMING SOON

EPS09 MONTE CARLO REPLICAS AVAILABLE AT

HTTP://IGFAE.USC.ES/HOTLHC/

INDEX.PHP/SOFTWARE