Nuclear PDFs

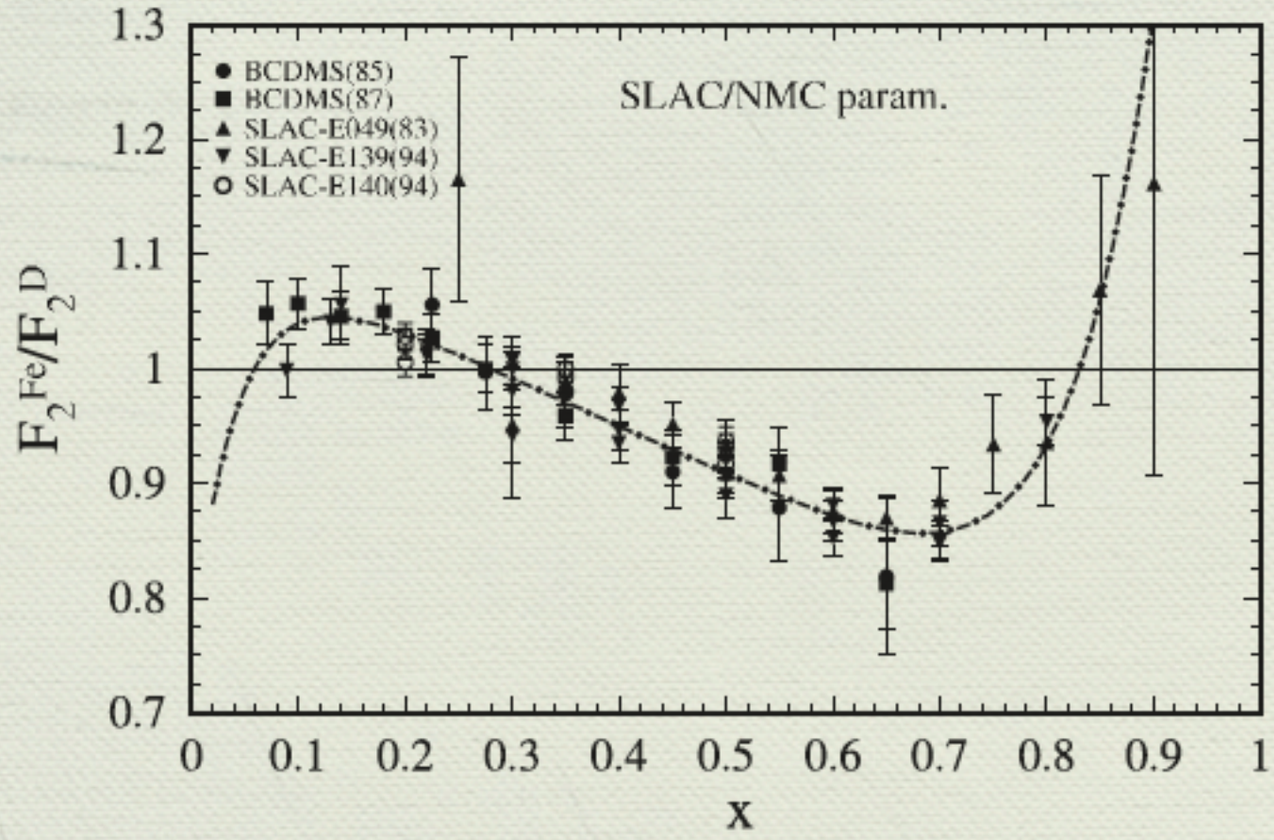
Pia Zurita

Universidad de Buenos Aires

CERN-ECFA-NuPECC Workshop on the LHeC, Chavannes-de-Bogis, June 2012

What are nuclear parton distributions?

effects in cross-sections = effect on the PDFs?



nuclear PDFs = parton densities in bound nucleons

What are nuclear parton distributions?

factorization for e-p DIS

$$\frac{d^2\sigma}{dxdQ^2} = \sum_a f_a \otimes d\hat{\sigma}_{al\to l'X} + \mathcal{O}\left(\frac{1}{Q^2}\right)$$

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e-A collisions

introduce universal nuclear PDF

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introduce universal nuclear PDF

- same DGLAP scale evolution
- same hard scattering cross sections

as for free proton PDFs

all nuclear effects are absorbed into non-perturbative nPDFs

How do we determine nPDFs? ⟶ QCD global analyses

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different strategies for parameterization

Convolute with a weight function

$$f_i^A(x_N, Q_0^2) = \int_{x_N}^{A} \frac{dy}{y} W_i(y, A, Z) f_i(x_N/y, Q_0^2)$$

de Florian, Sassot [PRD69(2004)074028]

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Find them from scratch

$$f_i^A(x_N, Q_0^2) = f_i(x_N, Q_0^2, A) \qquad f_i(x_N, Q_0^2) = f_i(x_N, Q_0^2, A = 1)$$

nCTEQ [PRD80(2009)094004]

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nCTEQ
[PRD80(2009)094004]

Relate to the proton PDFs by a multiplicative factor

$$f_i^A(x_N, Q_0^2) = R_i(x_N, Q_0^2, A) f_i(x_N, Q_0^2)$$

Hirai, Kumano, Nagai [PRC76(2007)065207]
Eskola, Paukkunen, Salgado [JHEP0904(2009)065]
de Florian, Sassot, Stratmann, Z. [PRD85(**2012**)074028]

How do these different choices compare?

convolution (nDS)	multiplicative factor (EPS)	from scratch (nCTEQ)
first NLO analysis	**first dAu**	**first neutrino DIS**

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Our analysis

D. de Florian, R. Sassot,
M. Stratmann, P. Z.
[PRD85(2012)074028]

DSSZ

electron DIS x~[0.01-1] (valence at higher x, sea at x~0.01)

Drell-Yan x~[0.01-0.2] (valence/sea but large errors)

hadroproduction dAu

neutrino DIS (valence/sea)

global

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same conventions for evolution, alphas , F2 coeff.

massive coeff. for neutrino F2 and F3 J. Bluemlein et al. 2011

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up-to-date

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up-to-date

improved hessian approach: eigenvector representation
J. Pumplin et al. 2001

"error sets"

uncertainties

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DSSZ

parameterization

$$f_i^A(x_N, Q_0) = R_i^A(x_N, Q_0)\, f_i^p(x_N, Q_0)$$

$$R_v^A(x, Q_0^2) = \varepsilon_1 x^{\alpha_v}(1-x)^{\beta_1} \times (1+\varepsilon_2(1-x)^{\beta_2})(1+a_v(1-x)^{\beta_3})$$

$$R_s^A(x, Q_0^2) = R_v^A(x, Q_0^2)\,\frac{\varepsilon_s}{\varepsilon_1}\frac{1+a_s x^{\alpha_s}}{a_s+1}$$

$$R_g^A(x, Q_0^2) = R_v^A(x, Q_0^2)\,\frac{\varepsilon_g}{\varepsilon_1}\frac{1+a_g x^{\alpha_g}}{a_g+1}$$

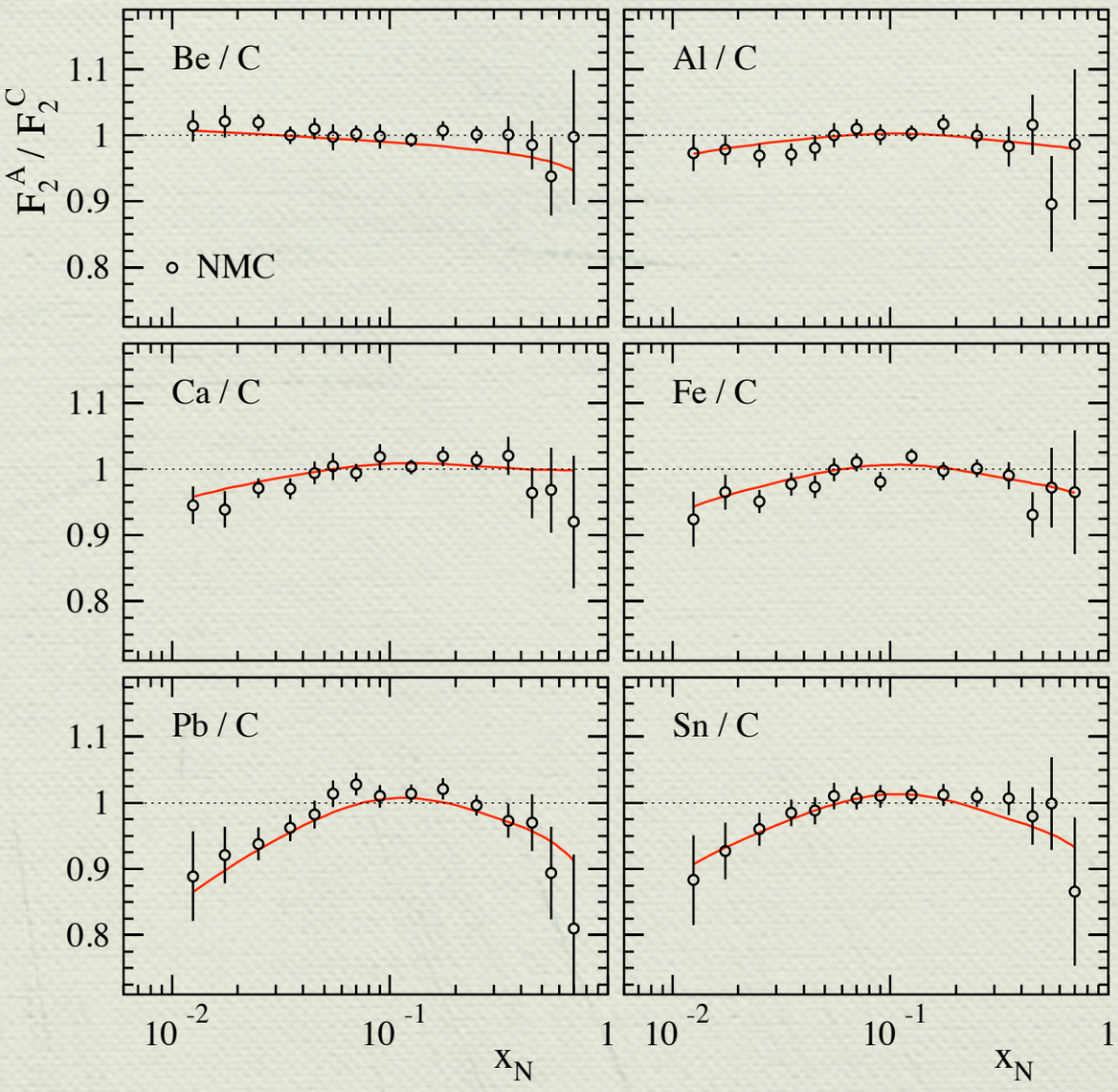
$\alpha_v, \alpha_s, \alpha_g, \beta_1, \beta_2, \beta_3, a_v, a_s, a_g$

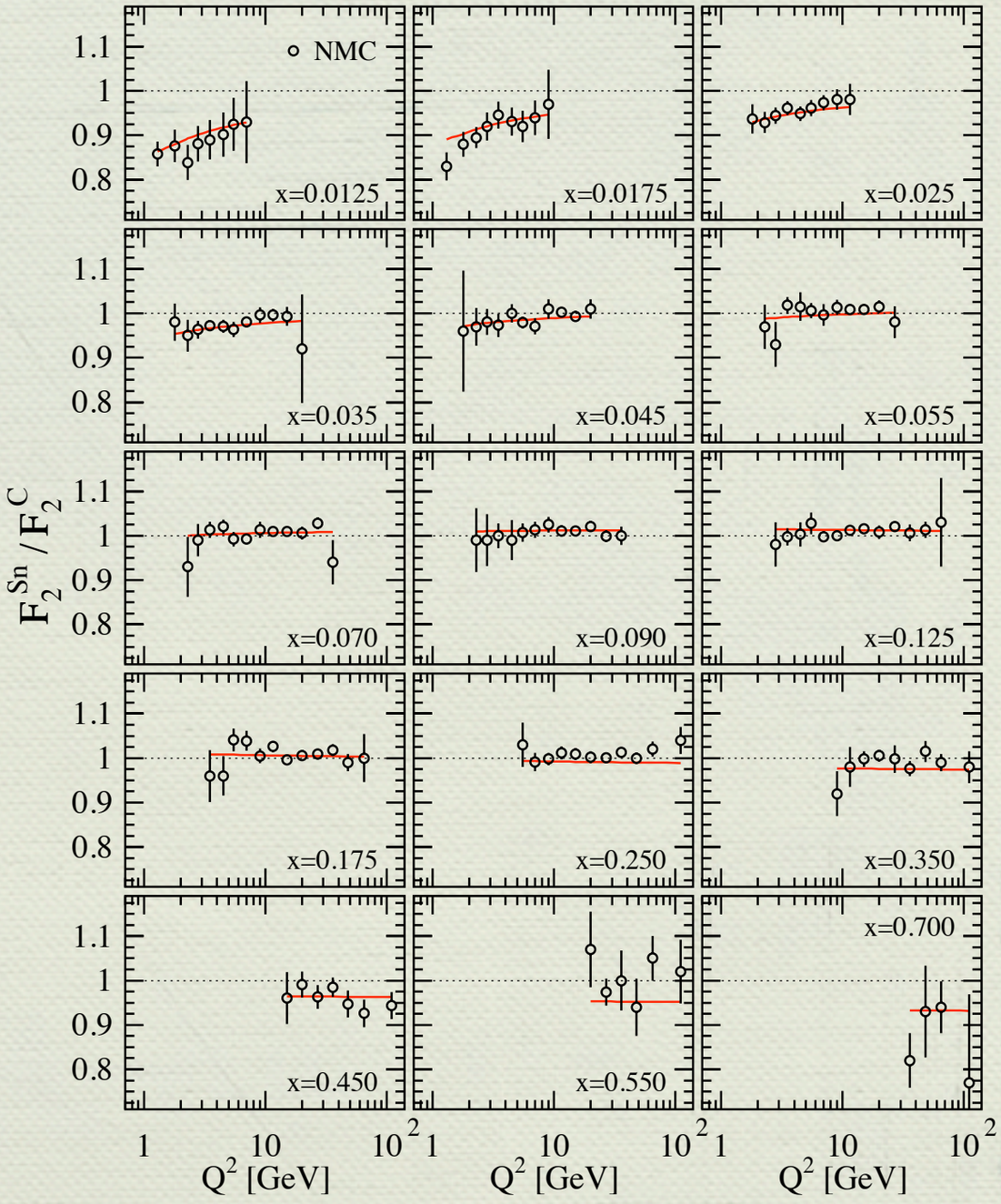
$\xi = \gamma_\xi + \lambda_\xi A^{\delta_\xi}$

25 free parameters

What does DSSZ look like?

NC-DIS





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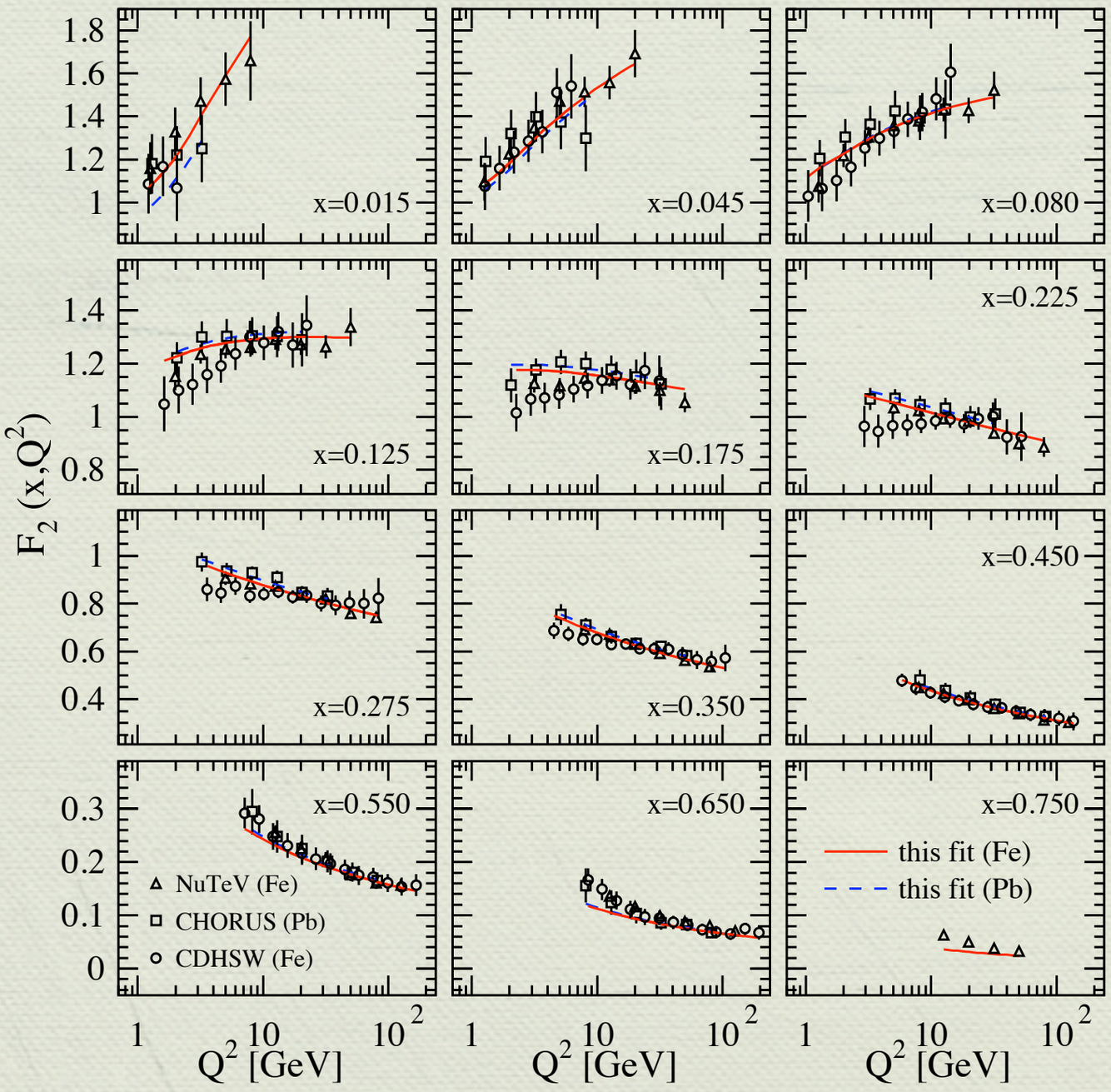
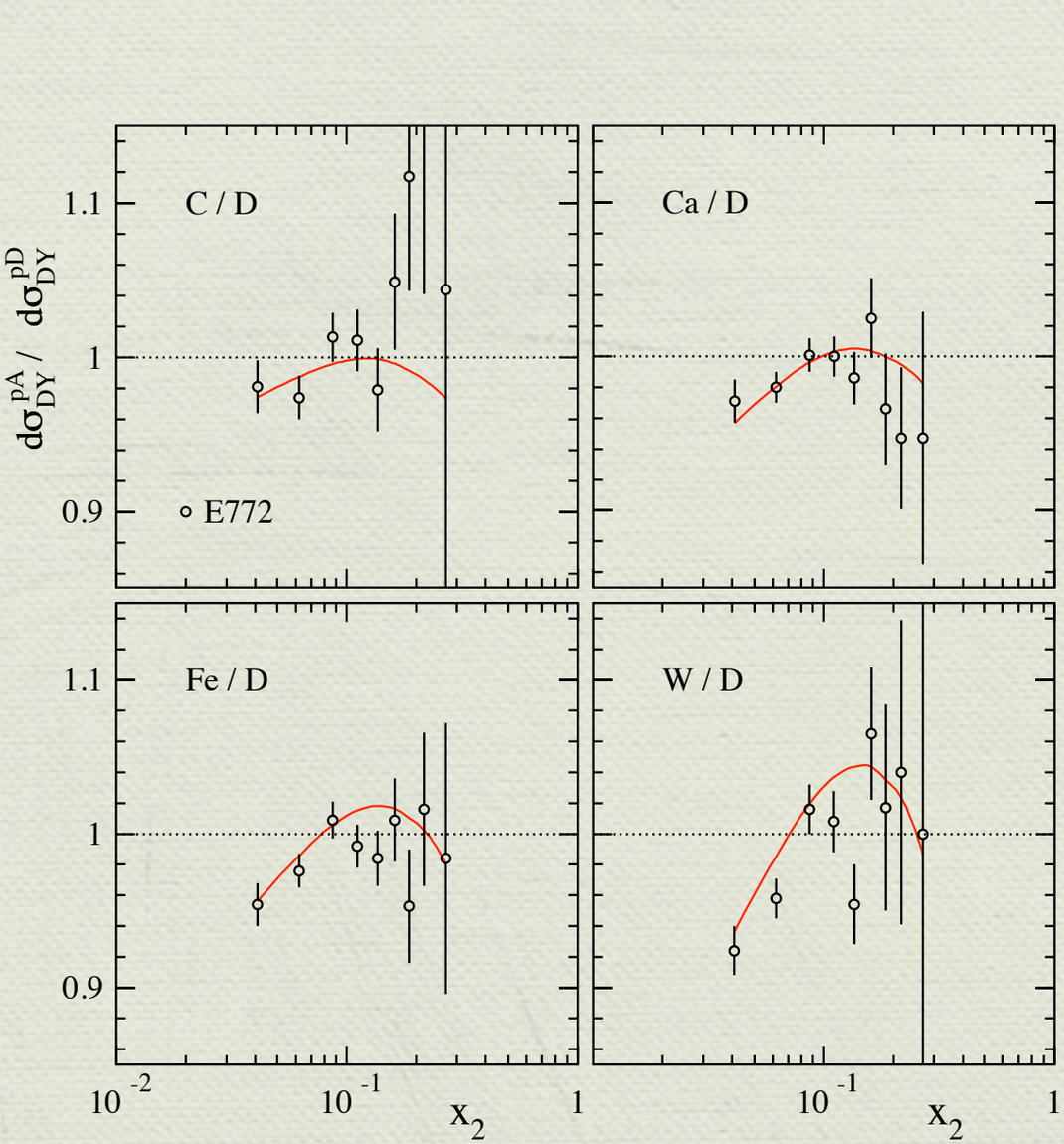
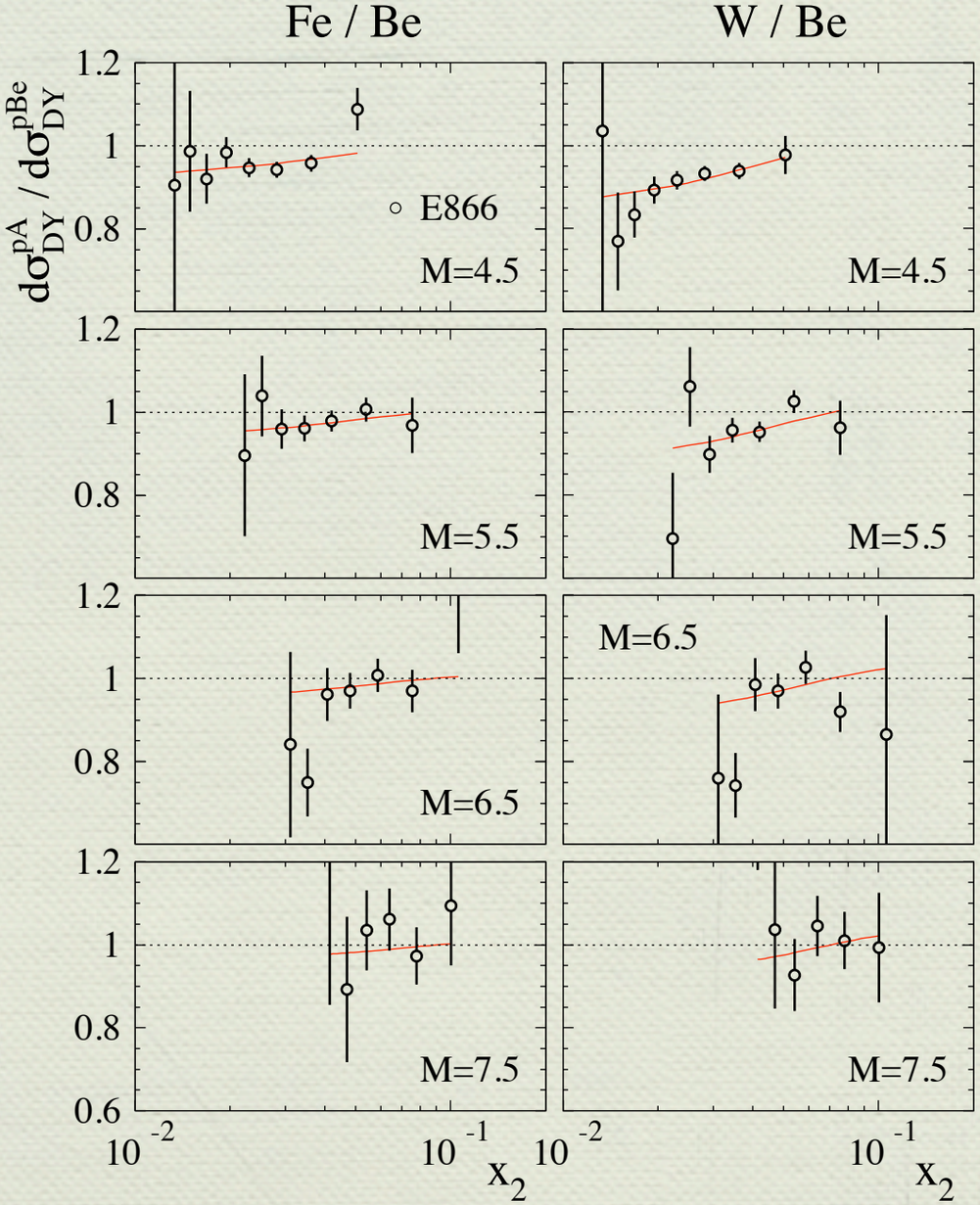
CC-DIS



What does DSSZ look like?

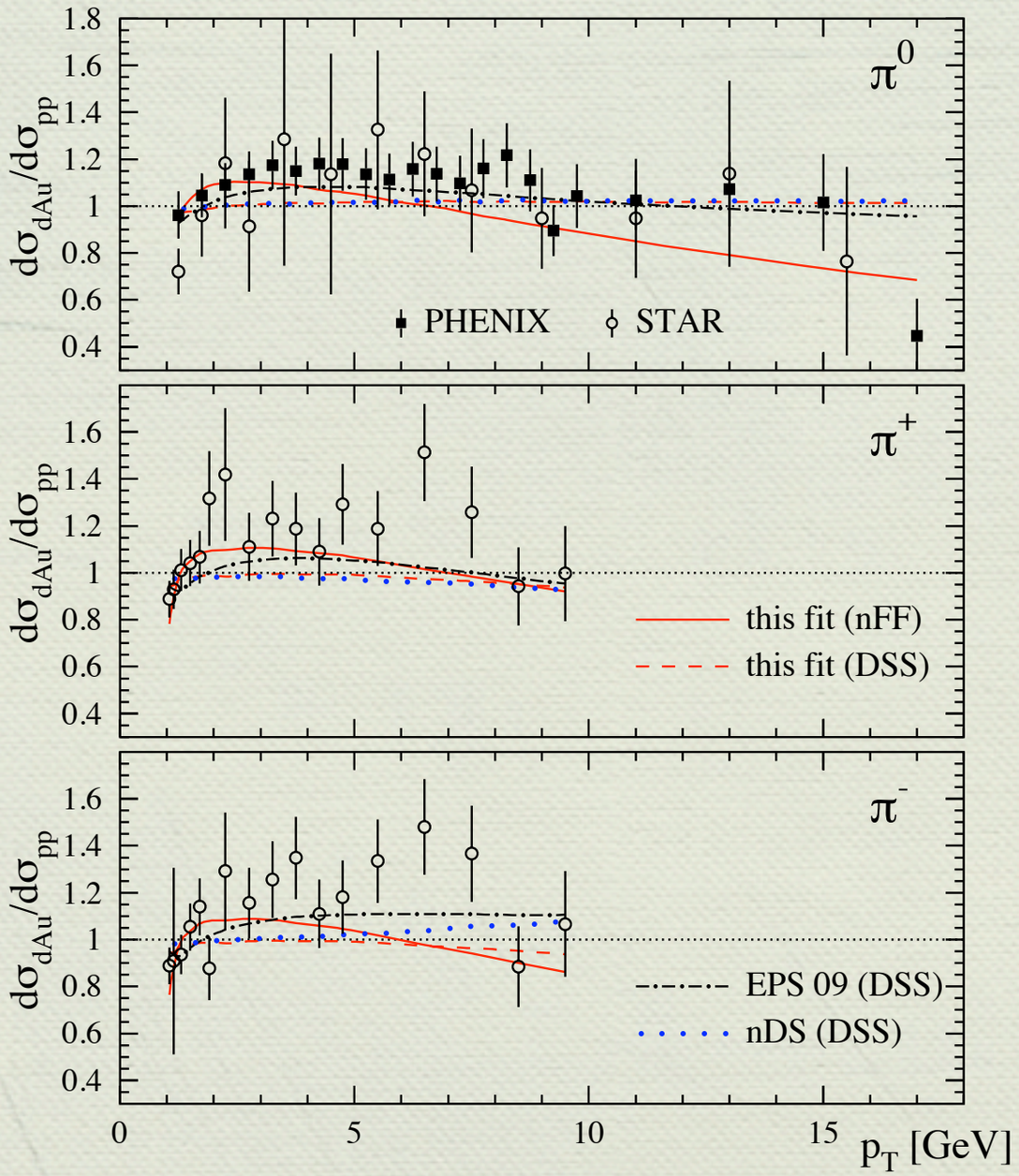
Drell-Yan





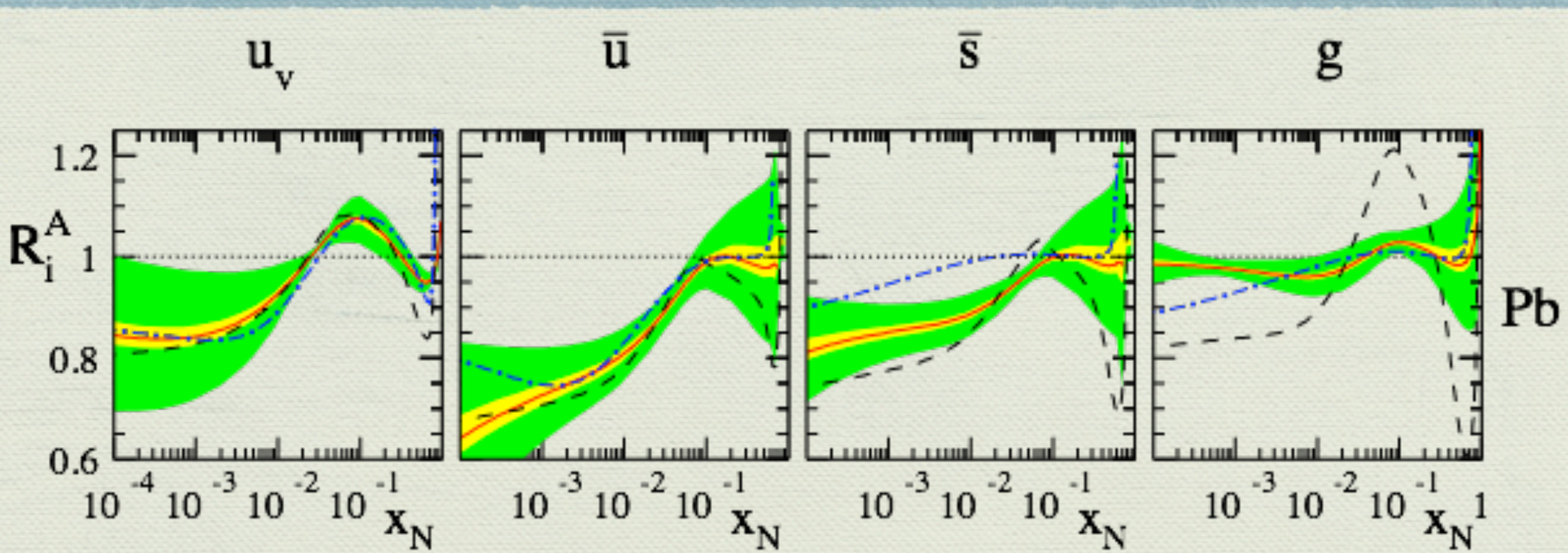
What does DSSZ look like?

single-inclusive hadroproduction



When we compare

with the convolutional approach (nDS)



nDS

DSSZ

strange sea → GRV98 vs. MSTW

different

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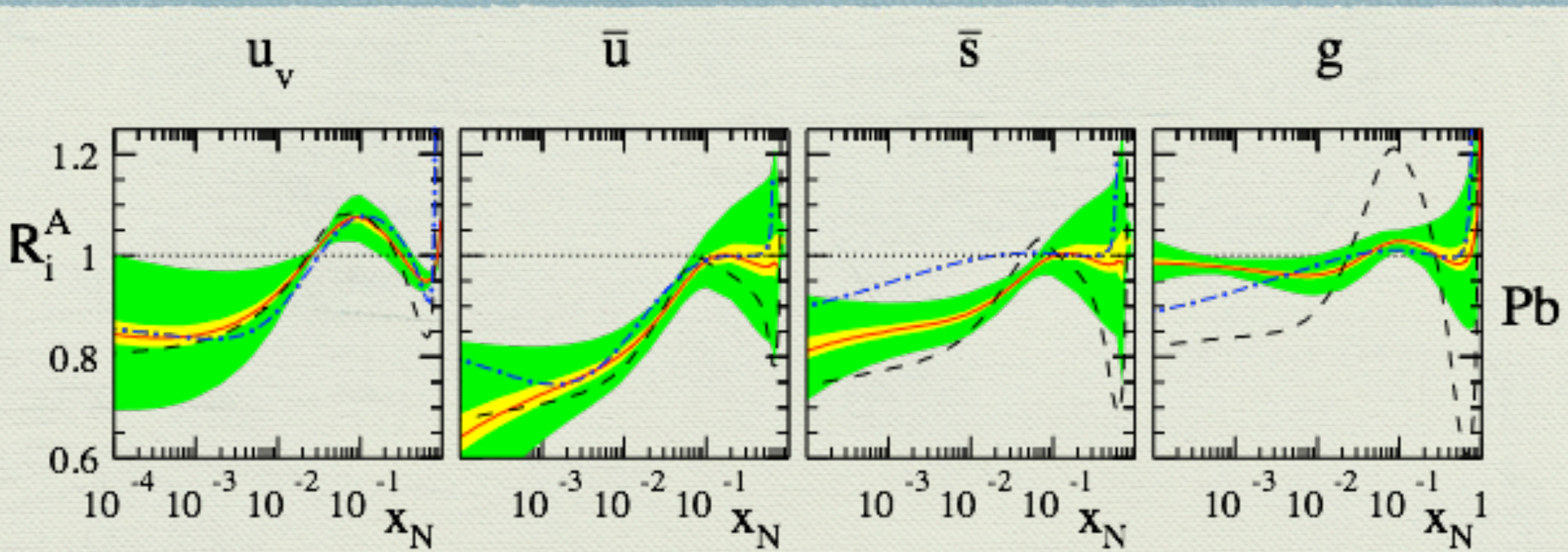

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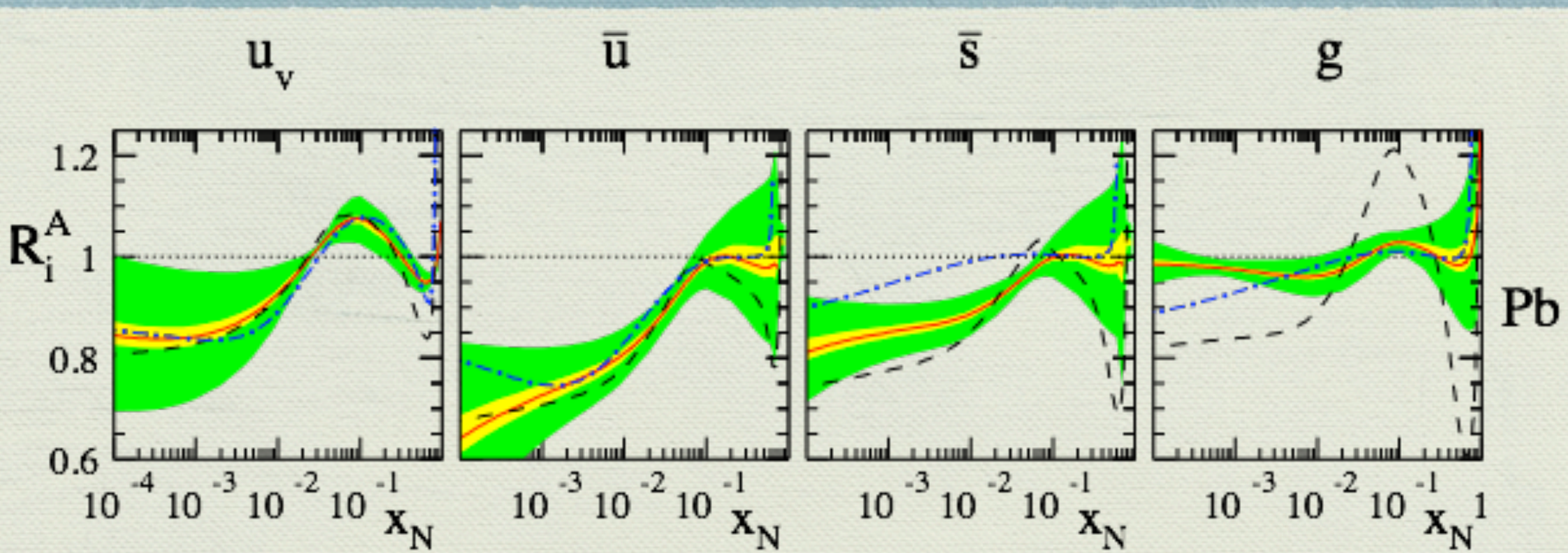
strange sea → GRV98 vs. MSTW

different

gluon
in the low x region → GRV98 vs. MSTW & **dAu data**

When we compare

with other multiplicative ansatz (EPS)



EPS

DSSZ

strange sea ⟶ CTEQ6M vs. MSTW

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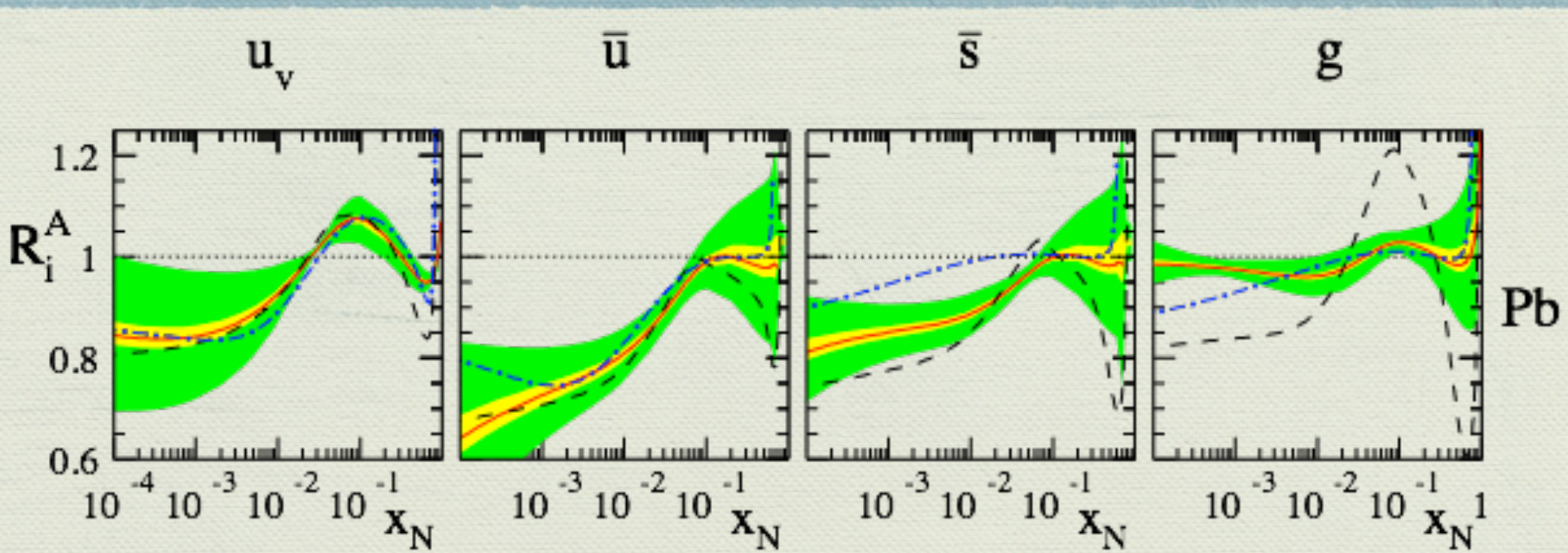

EPS

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strange sea → CTEQ6M vs. MSTW

different

gluon → **dAu data**

why, if both analyses use similar strategies?

EPS	compatible valence and u-sea distributions	**DSSZ**
ZM-VFNS		GM-VFNS
CTEQ		MSTW
no neutrino DIS data		neutrino DIS data
parameterization in sectors		continuous parameterization

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no effect for fragmentation in Au

medium-modified fragmentation functions

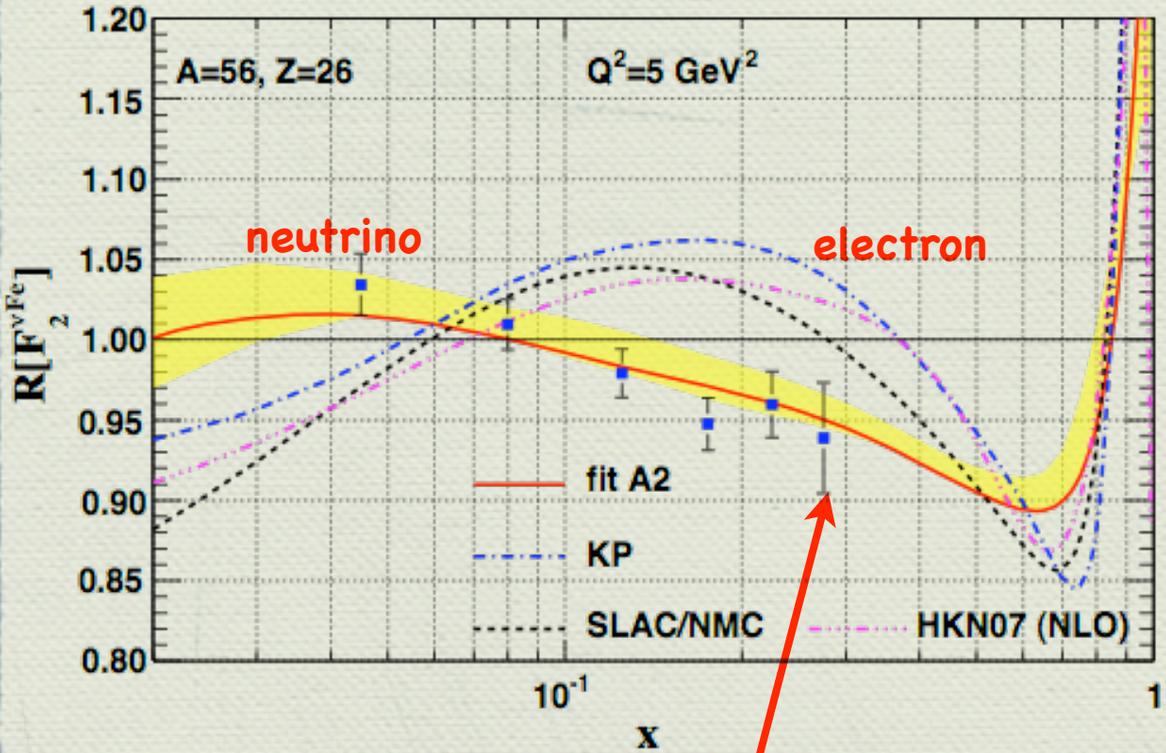
R.Sassot, M.Stratmann, P. Z. 2010

When we compare

with the direct parameterization (nCTEQ)

nCTEQ

tension between electron and neutrino DIS data



breakdown of factorization

When we compare

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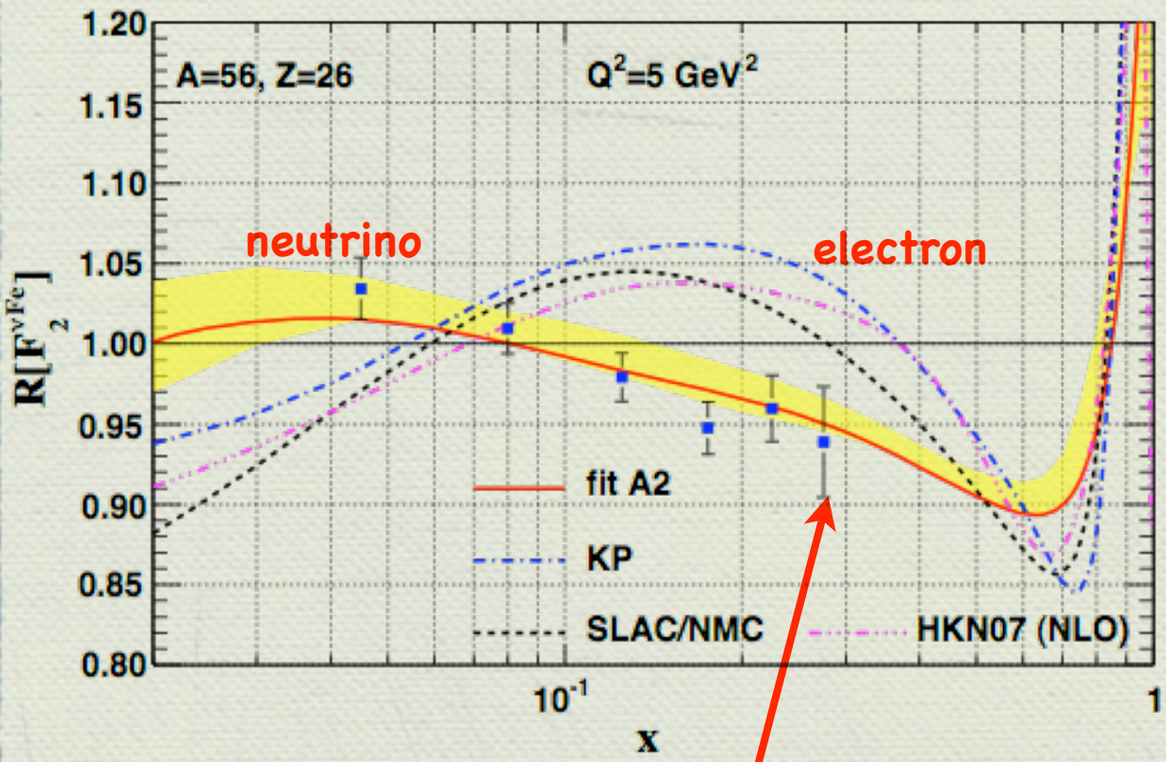
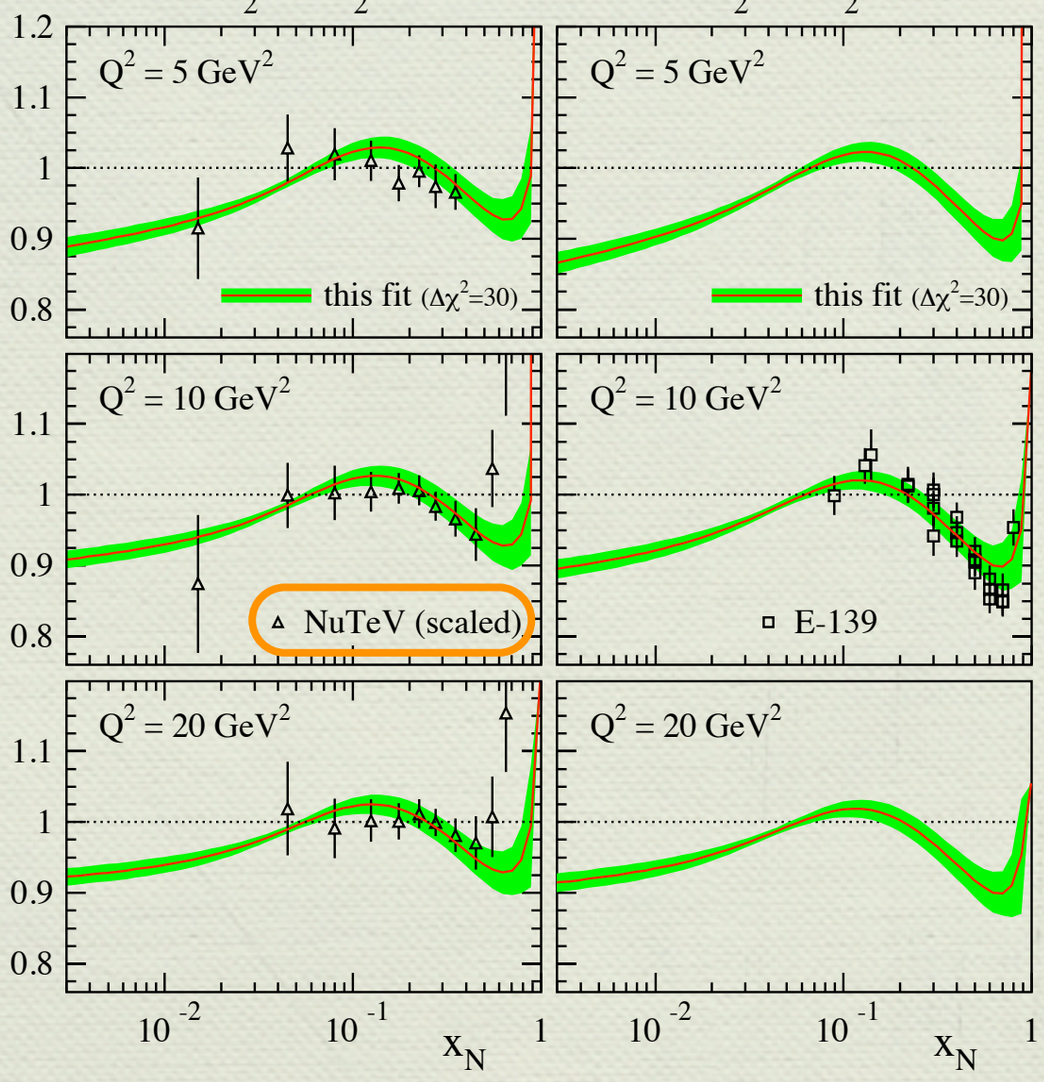


breakdown of factorization

DSSZ

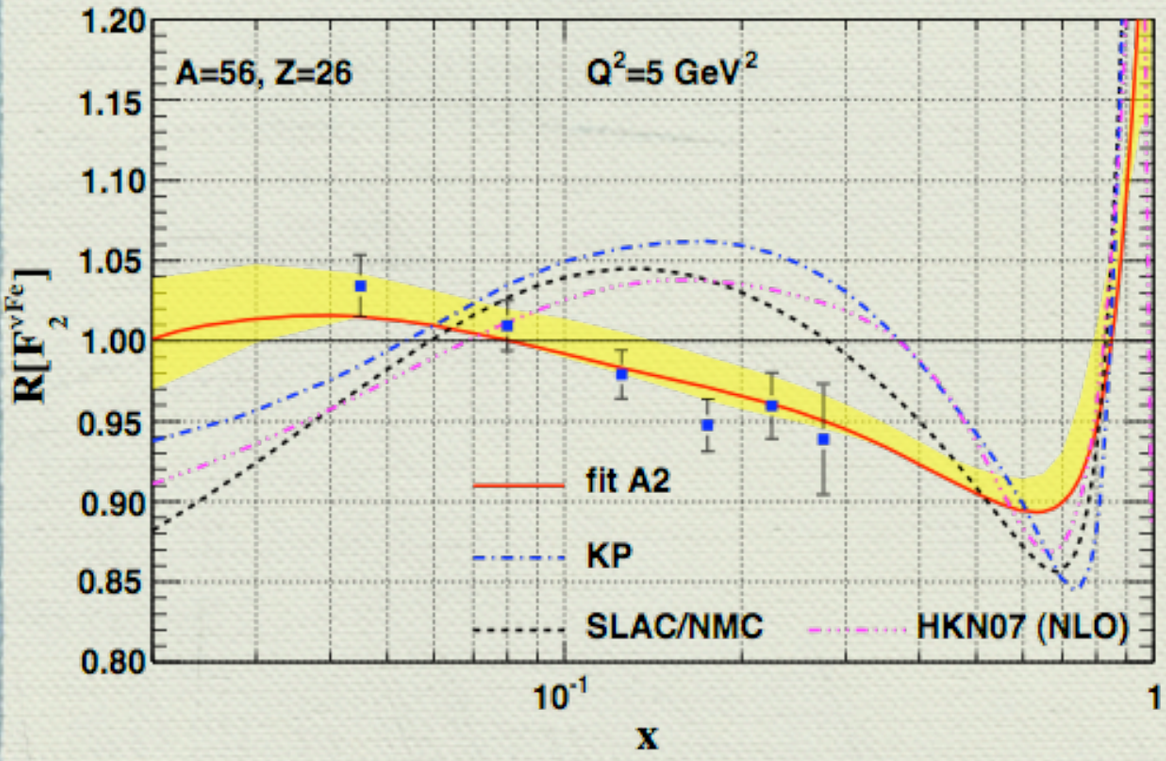
same pattern of nuclear effects for neutrino and electron DIS



what is different?

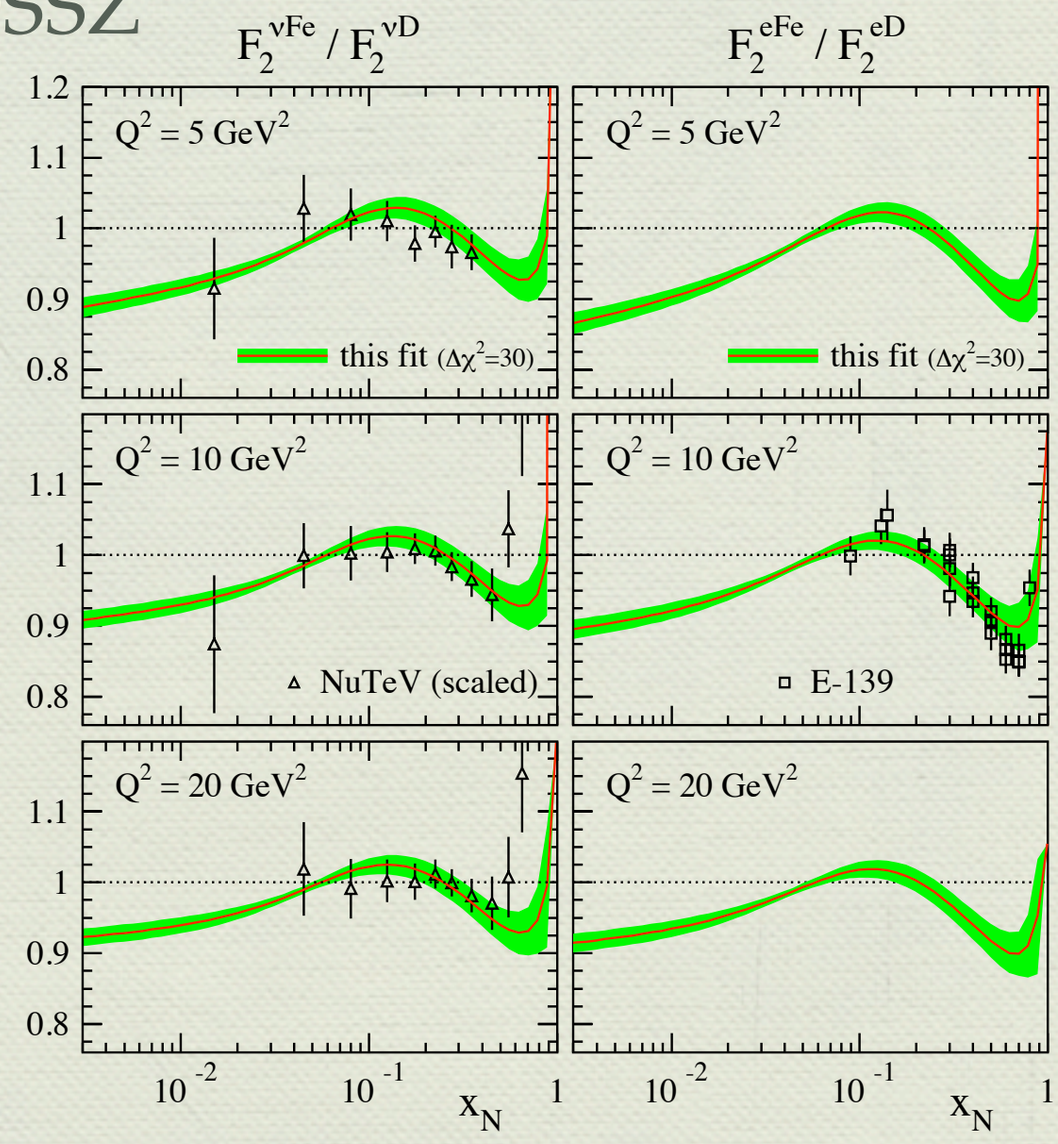
"theoretical data": $\mathbf{F_2^{\nu D}}$ not measured → must be computed

nCTEQ



$\mathbf{F_2^{\nu D}}$ $\quad \frac{Z}{A}F_2^p + \frac{A-Z}{A}F_2^n$

DSSZ



$\mathbf{F_2^{\nu D}}$ $\quad \frac{F_2^p + F_2^n}{2}$

Summing up...

support of factorization & universality

different nPDFs sets lead to fairly similar distributions

gluons not well determined: very different shapes for R_g

more precise gluon-dependent observables needed

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What's next?

p-Pb @ LHC

what can we look?

for initial state effects → Drell-Yan & prompt photons

p-Pb @ LHC

what can we look?

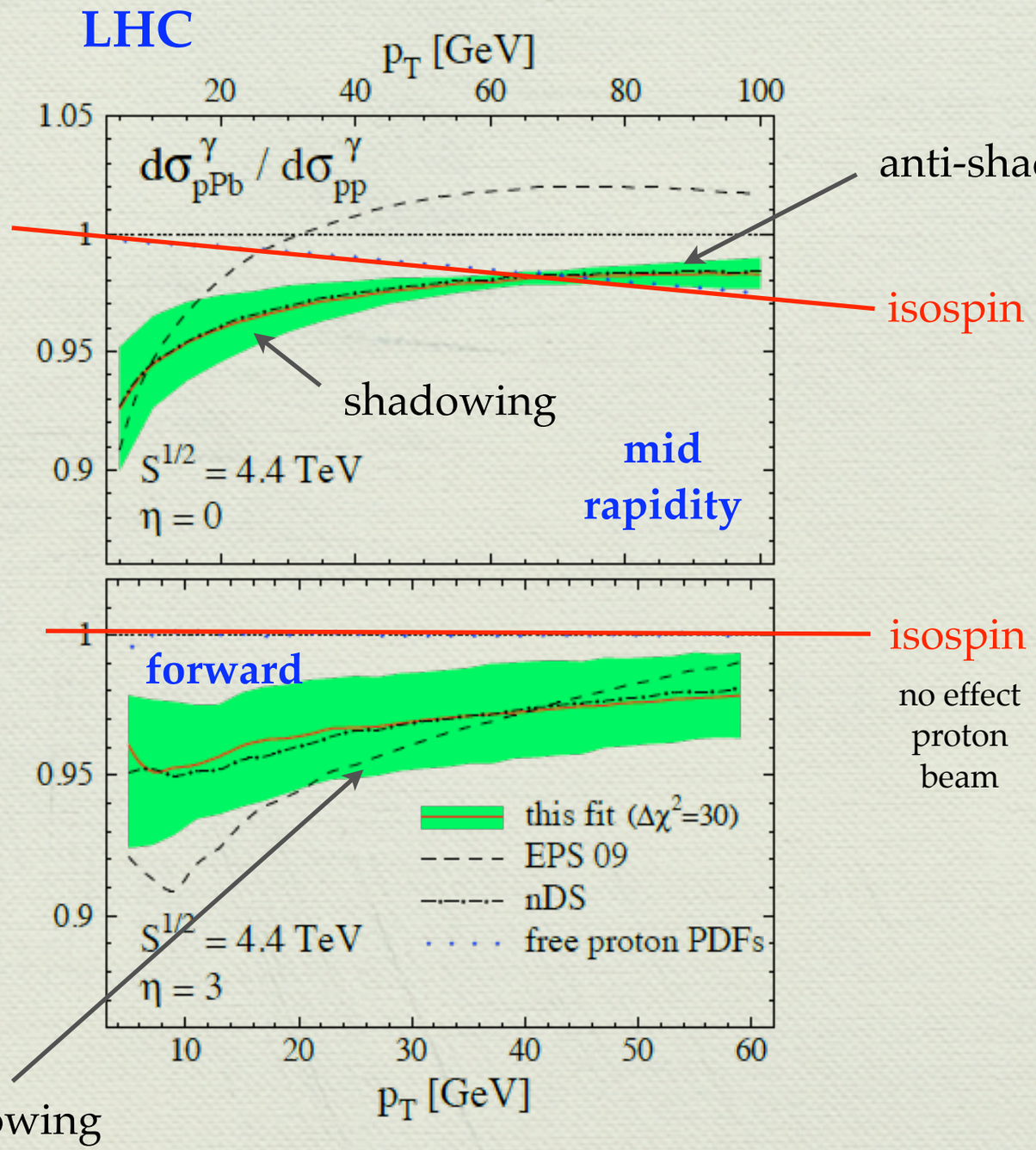
for initial state effects → Drell-Yan & prompt photons

to check for final state effects → single-inclusive hadroproduction

Prompt-photons

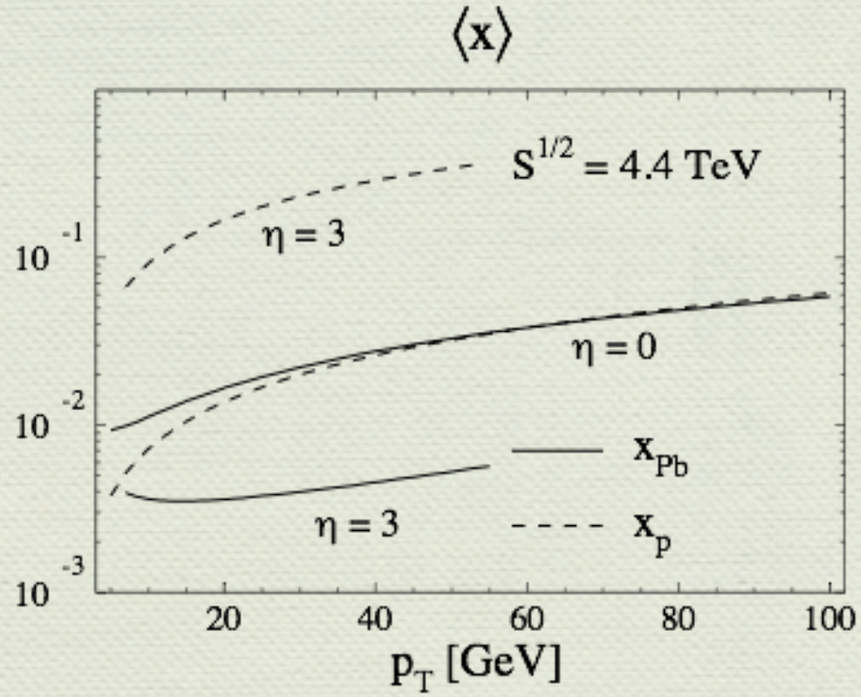
"isospin effects" = dilution of u-quark density from neutrons $\mathbf{u^A(x) < u^p(x)}$

ratio pPb/pp not unity even without nuclear modifications



isospin

no effect proton beam



would study shadowing and anti-shadowing regions

Drell-Yan

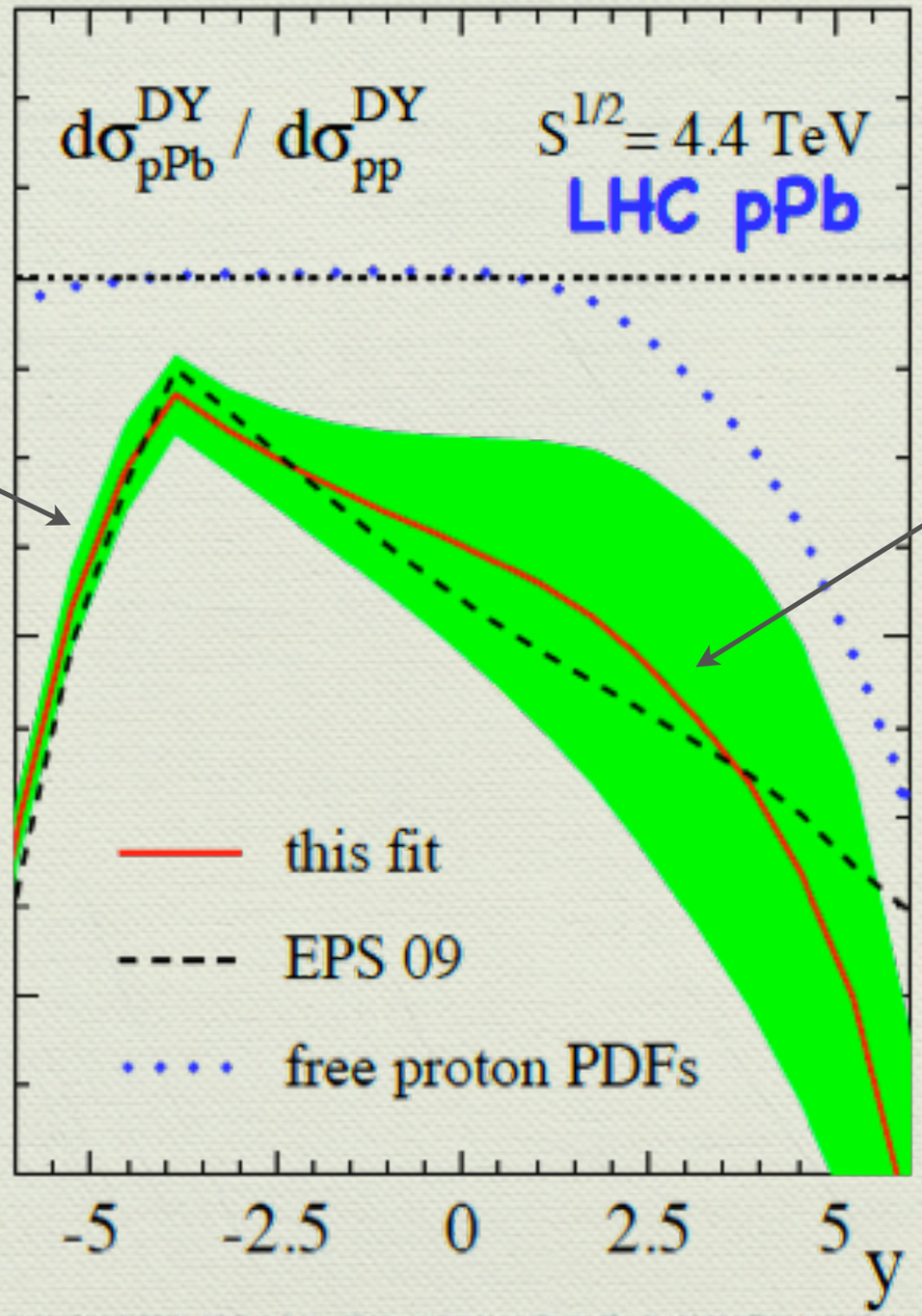
LO

$$d\sigma_{DY}^{pA} \propto e_u^2 \left[u(x_1)\bar{u}^A(x_2) + \bar{u}(x_1)u^A(x_2) \right] + e_d^2 \left[d(x_1)\bar{d}^A(x_2) + \bar{d}(x_1)d^A(x_2) \right]$$

large positive y

large negative y

$$x_{1,2} = \sqrt{M^2/s}\, e^{\pm y}$$



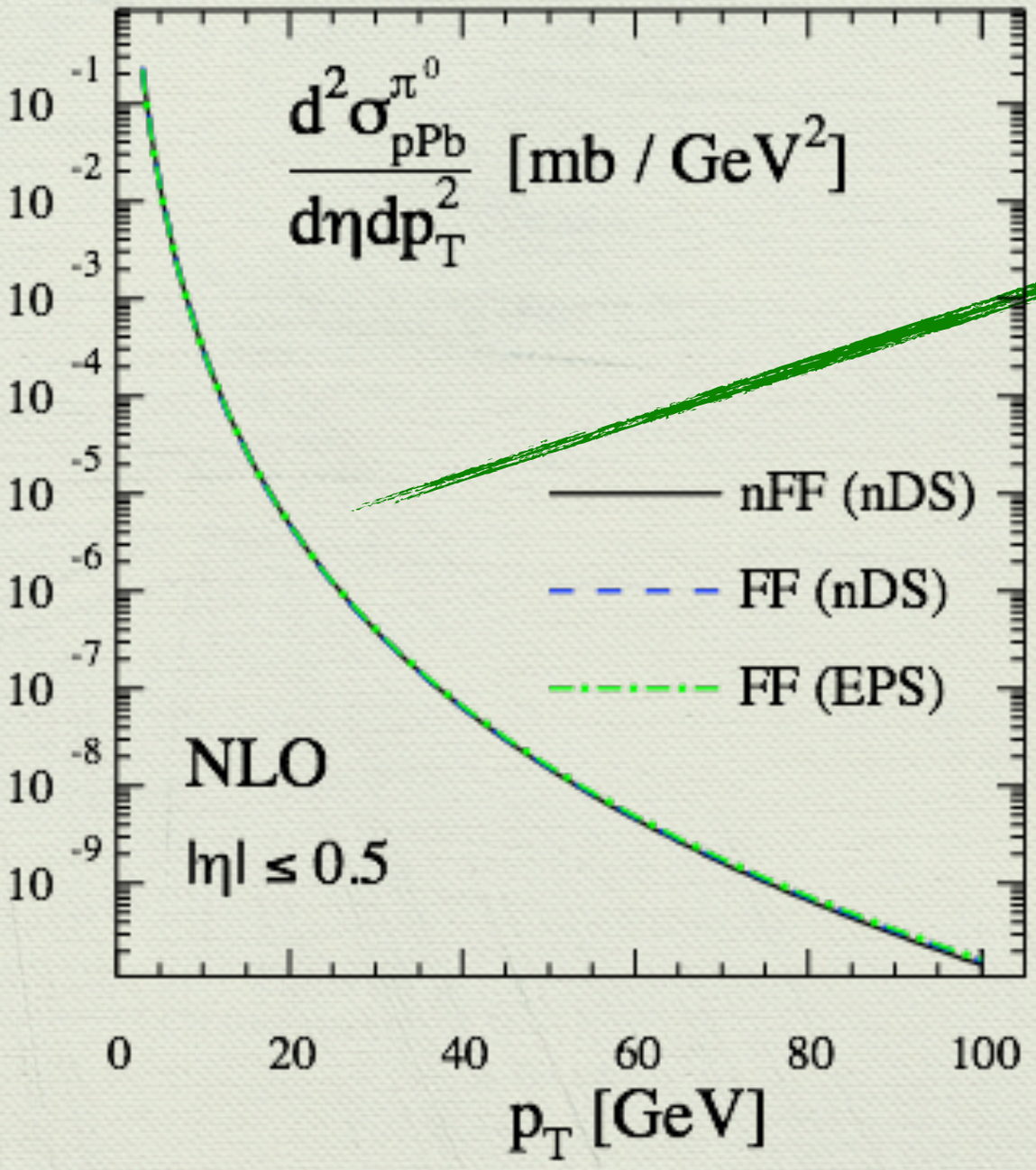
EMC effect
valence

shadowing
sea quarks

x reach at y=3

$$x_2 \simeq 5 \times 10^{-5}$$

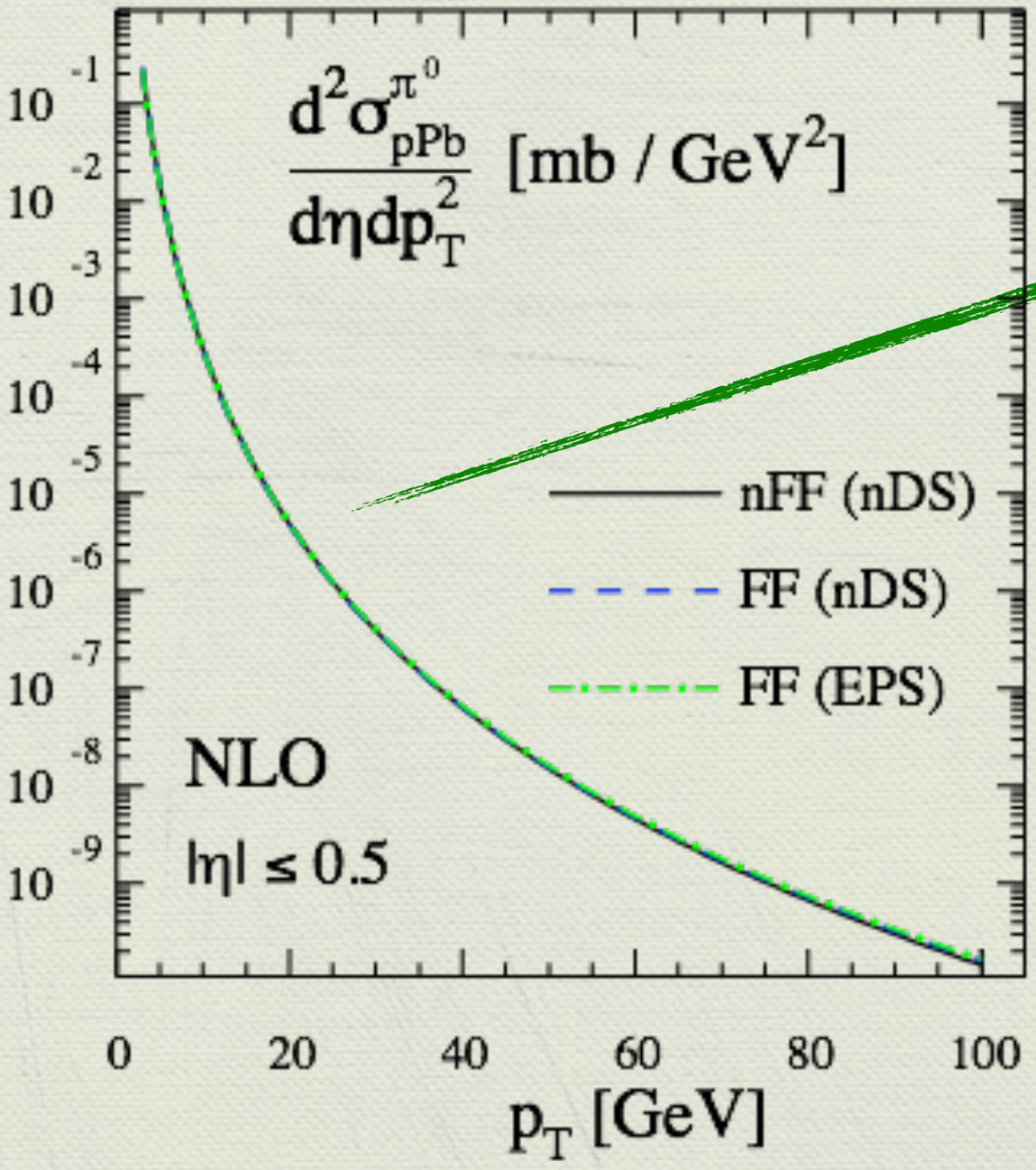
Single-inclusive hadroproduction



very different predictions for different nPDF sets

(sometimes not so easy to see)

Single-inclusive hadroproduction



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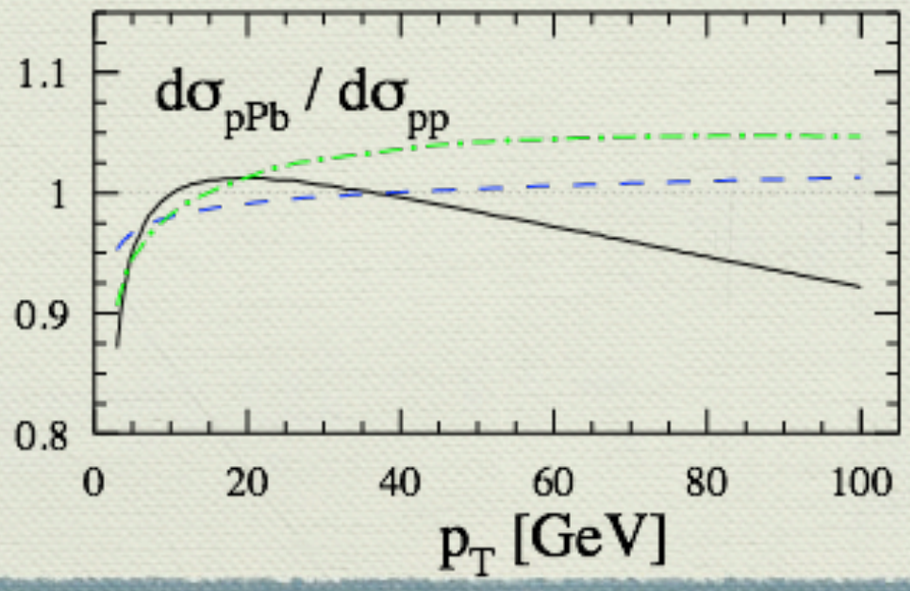
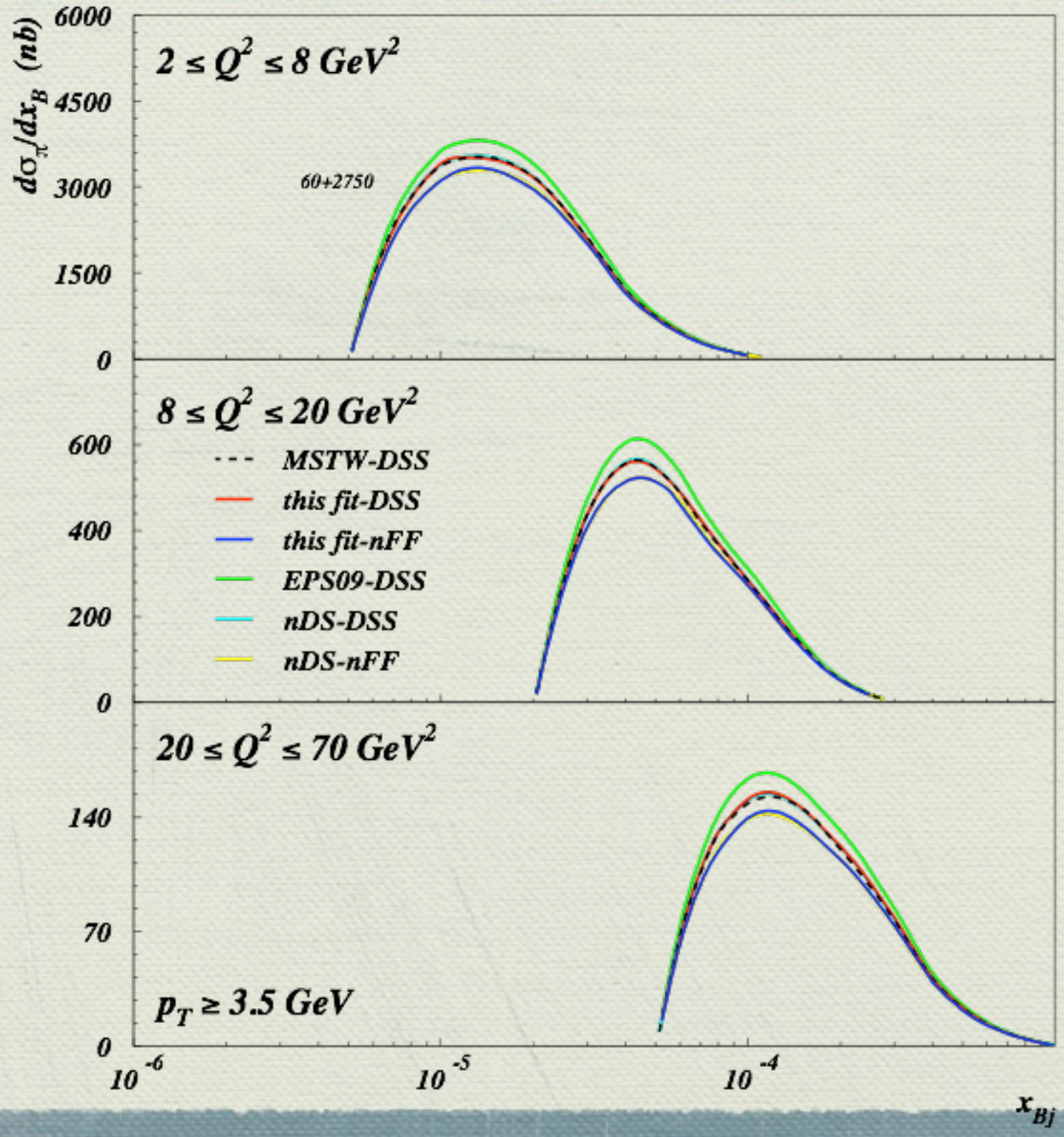


What about LHeC?



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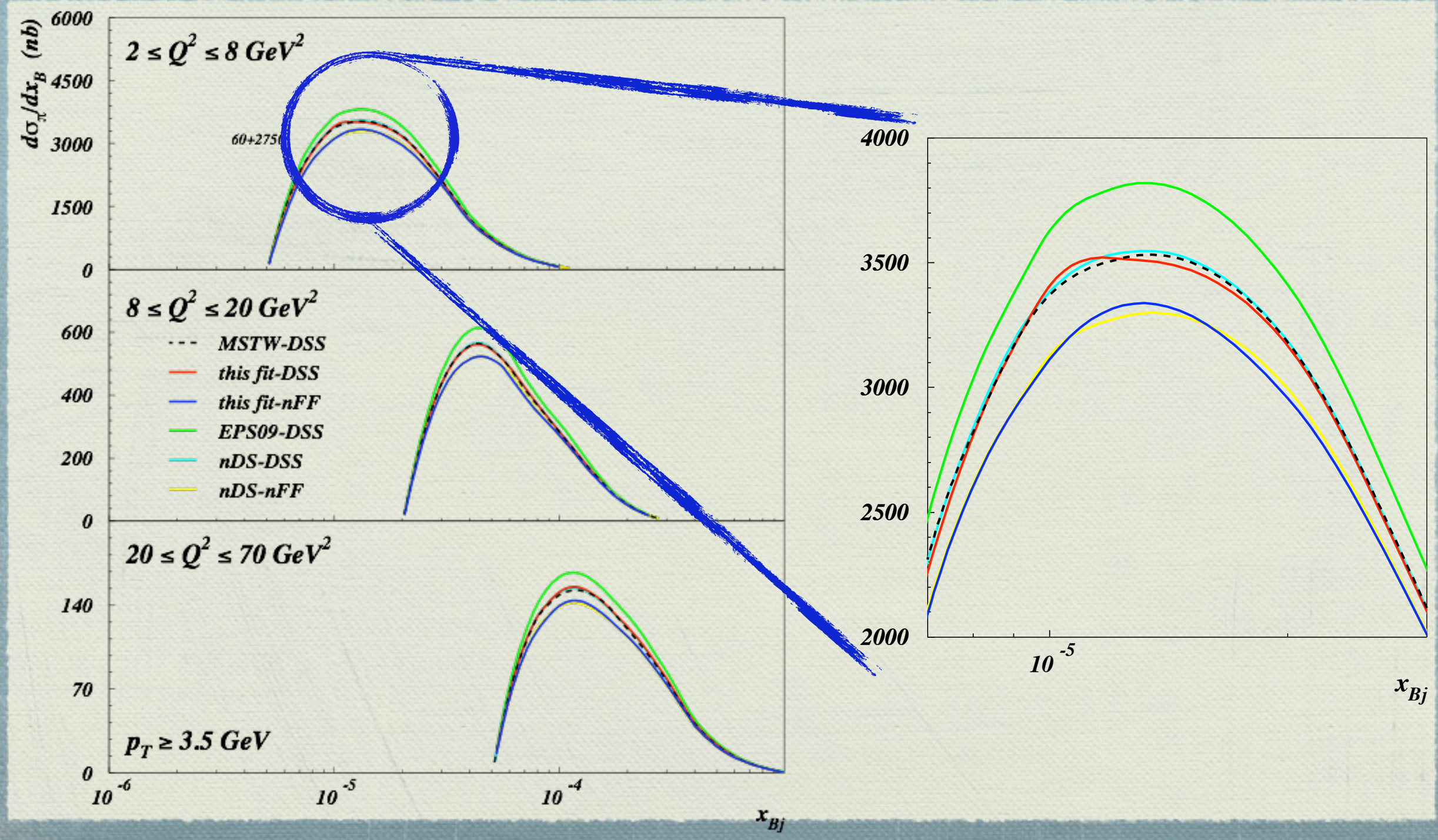


Summary

several sets of nPDFs available, all (but one) agree on factorization

strange and gluon distributions not yet fully constrained by data

p-Pb @LHC will be crucial to study the low x region

LHeC to cross check results

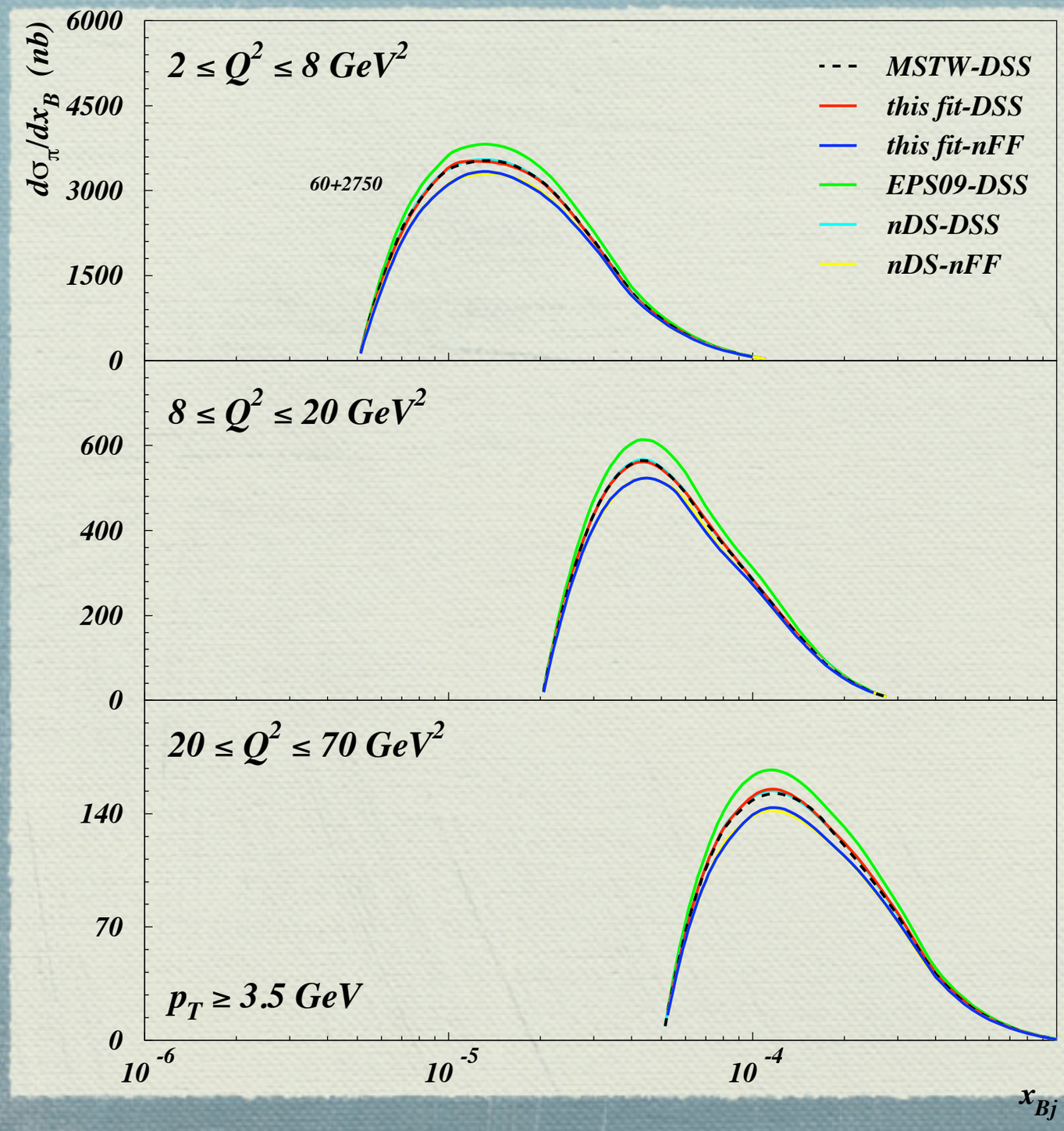
Back-up slides

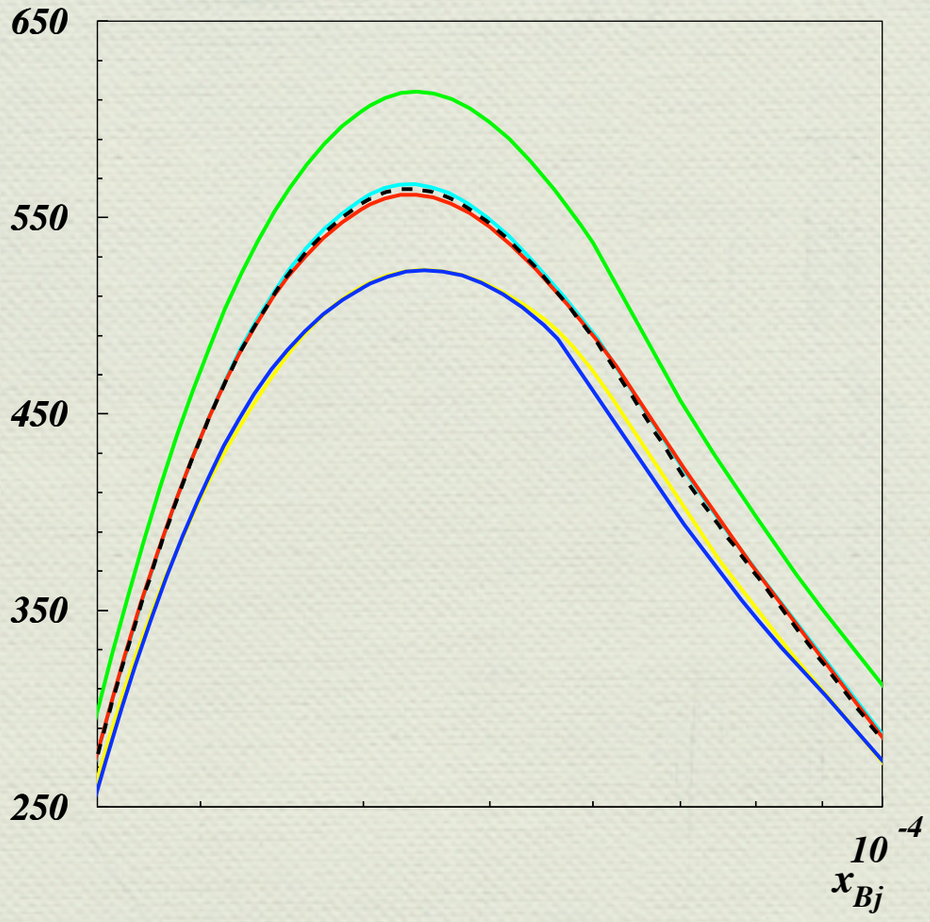
Why do we need nuclear parton distributions?

crucial ingredient for perturbative description of

- neutrino DIS with heavy targets (NuTeV, CHORUS, CDHSW)
- proton(deuteron)-heavy ion collision (dAu @ RHIC, pPb @LHC)
- electron DIS with nuclei (LHeC, EIC)

What about LHeC?





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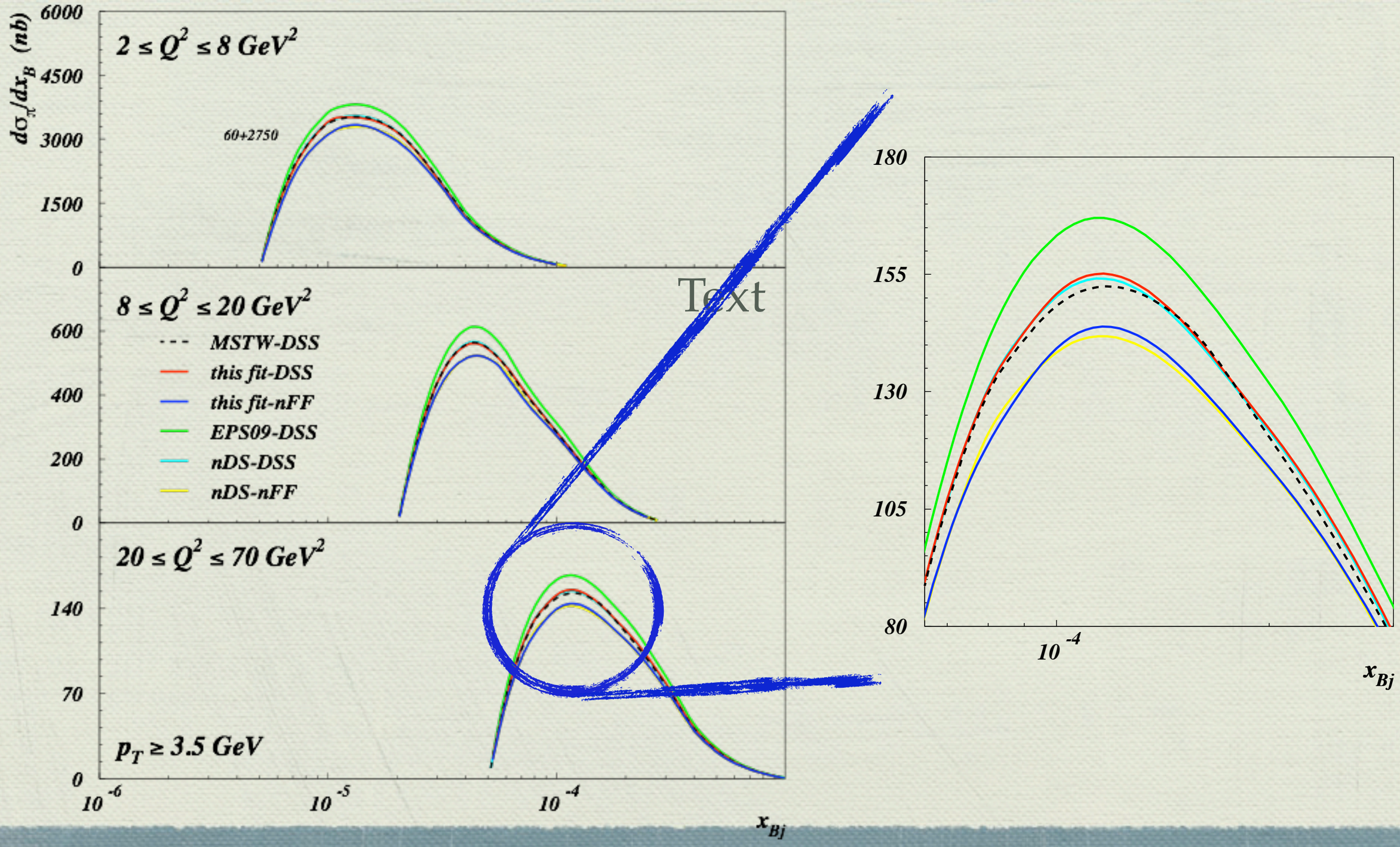
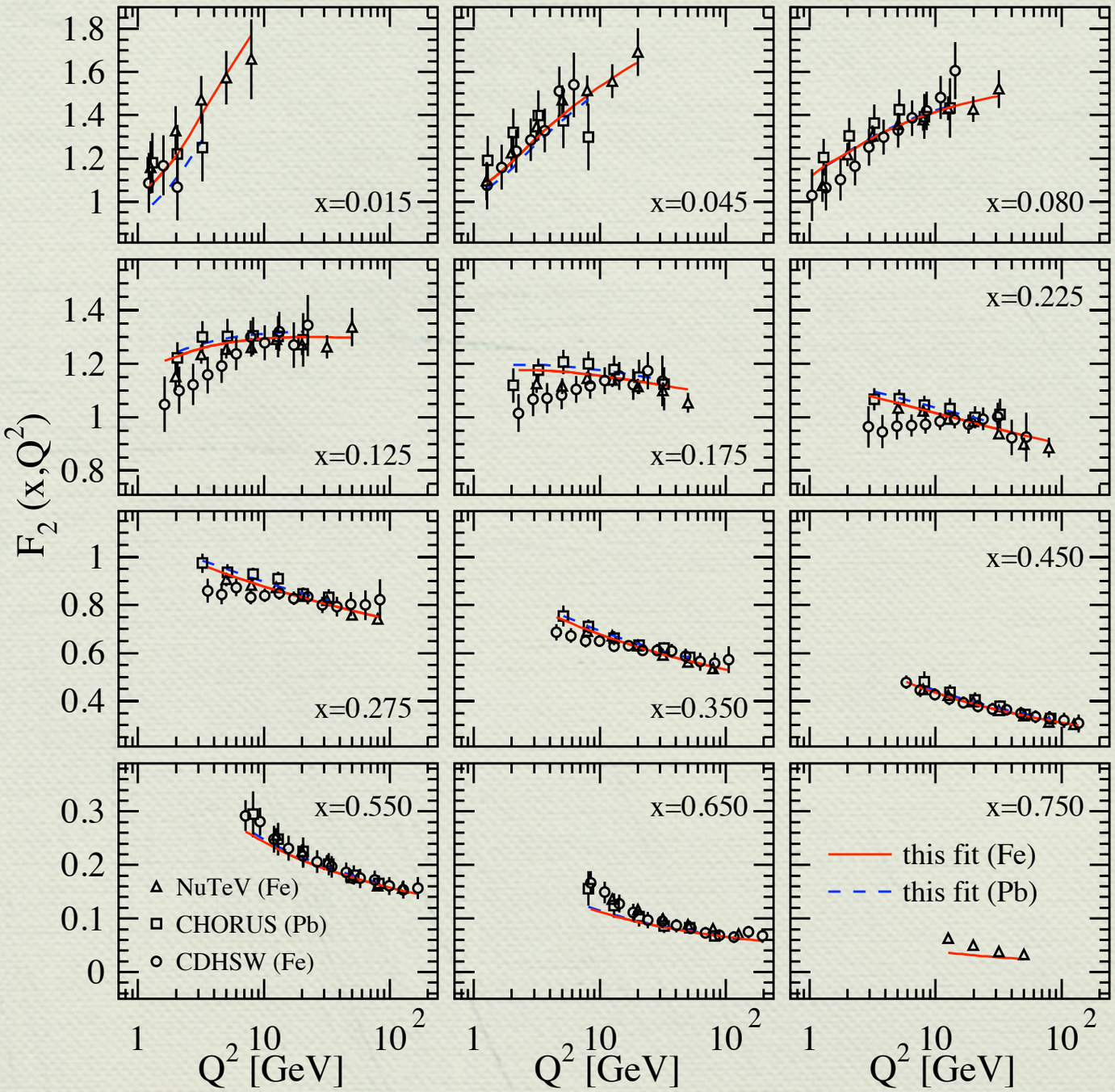


DSSZ gives a good description of CC-DIS



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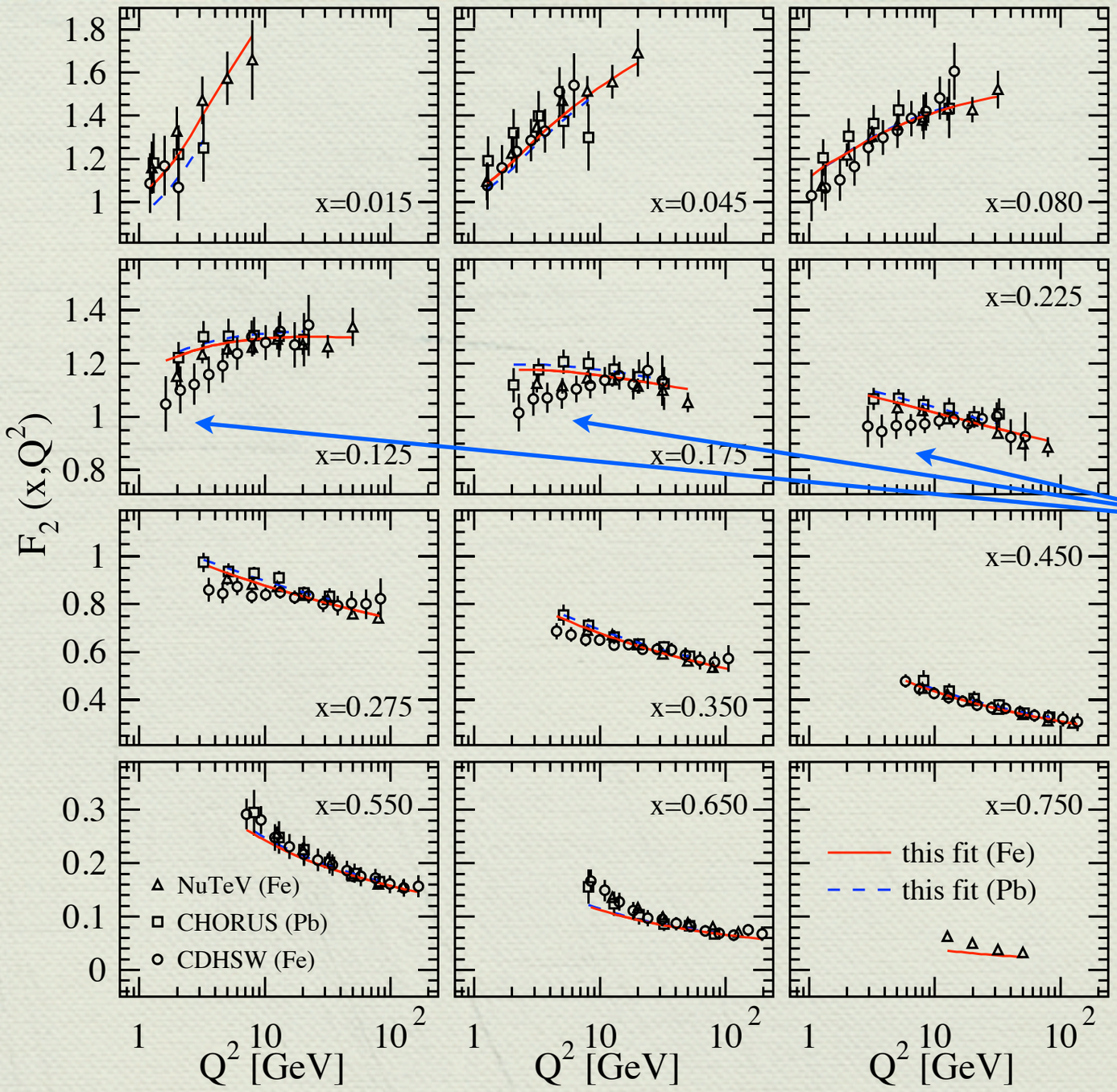
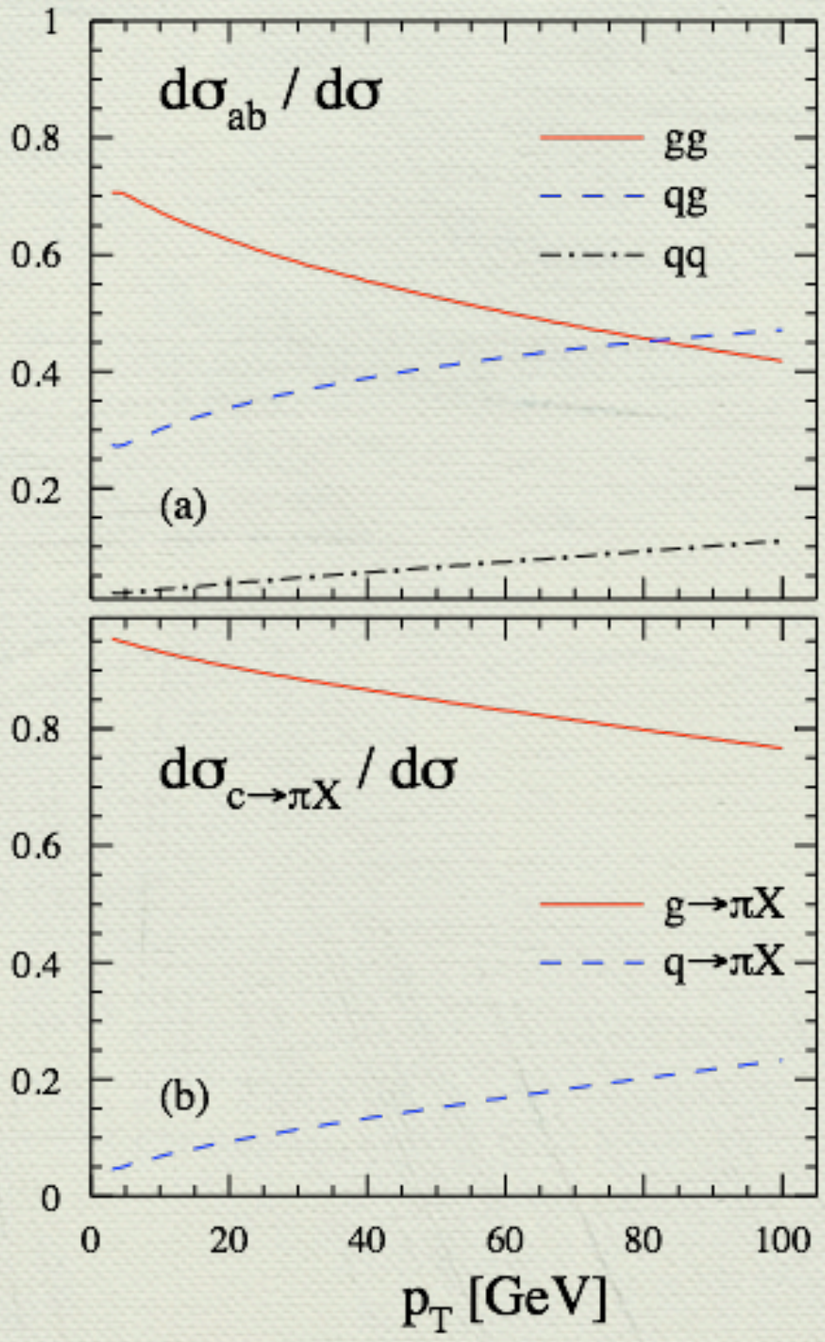


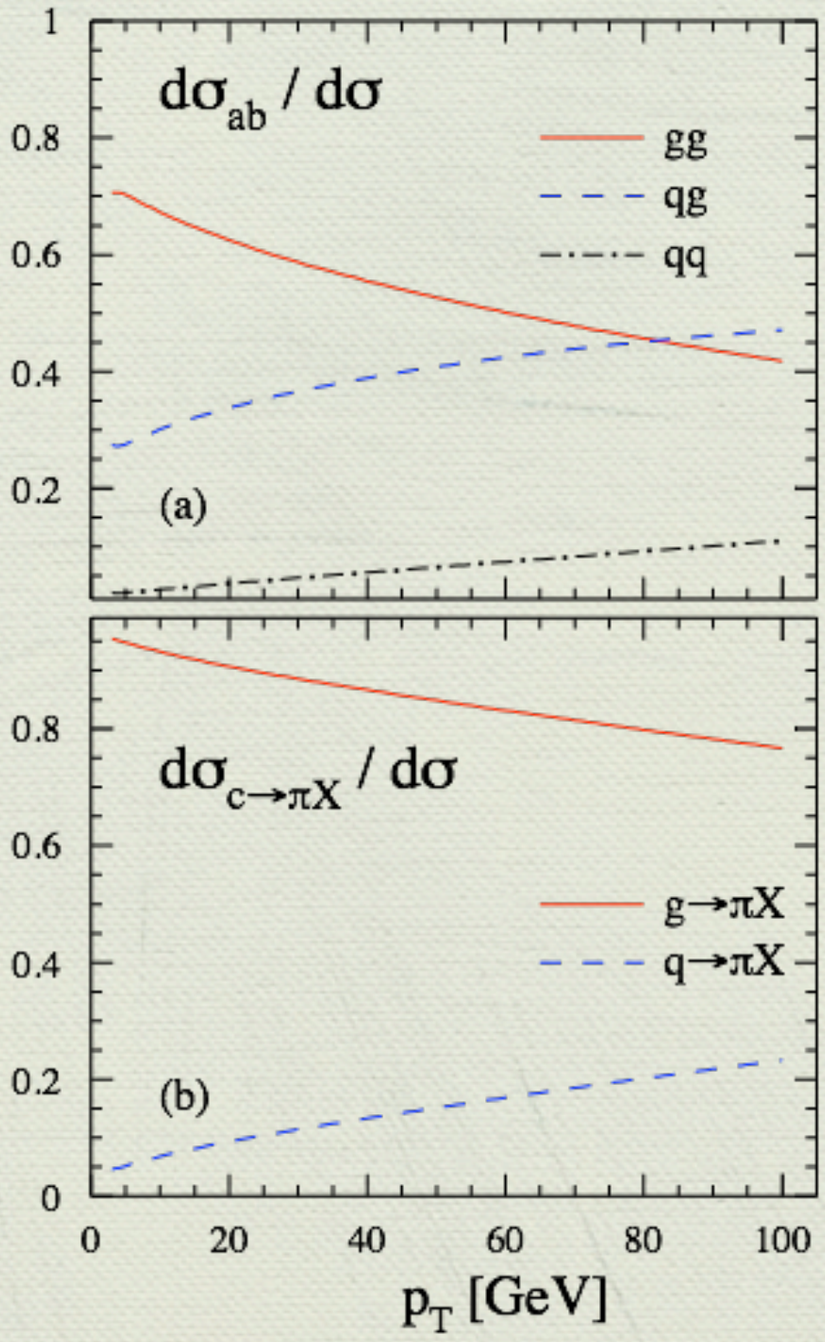
some tension between NuTeV and CDHSW (Fe) for specific x bins

Single-inclusive hadroproduction



main contribution from gluon-gluon and quark-gluon initiated processes

Single-inclusive hadroproduction

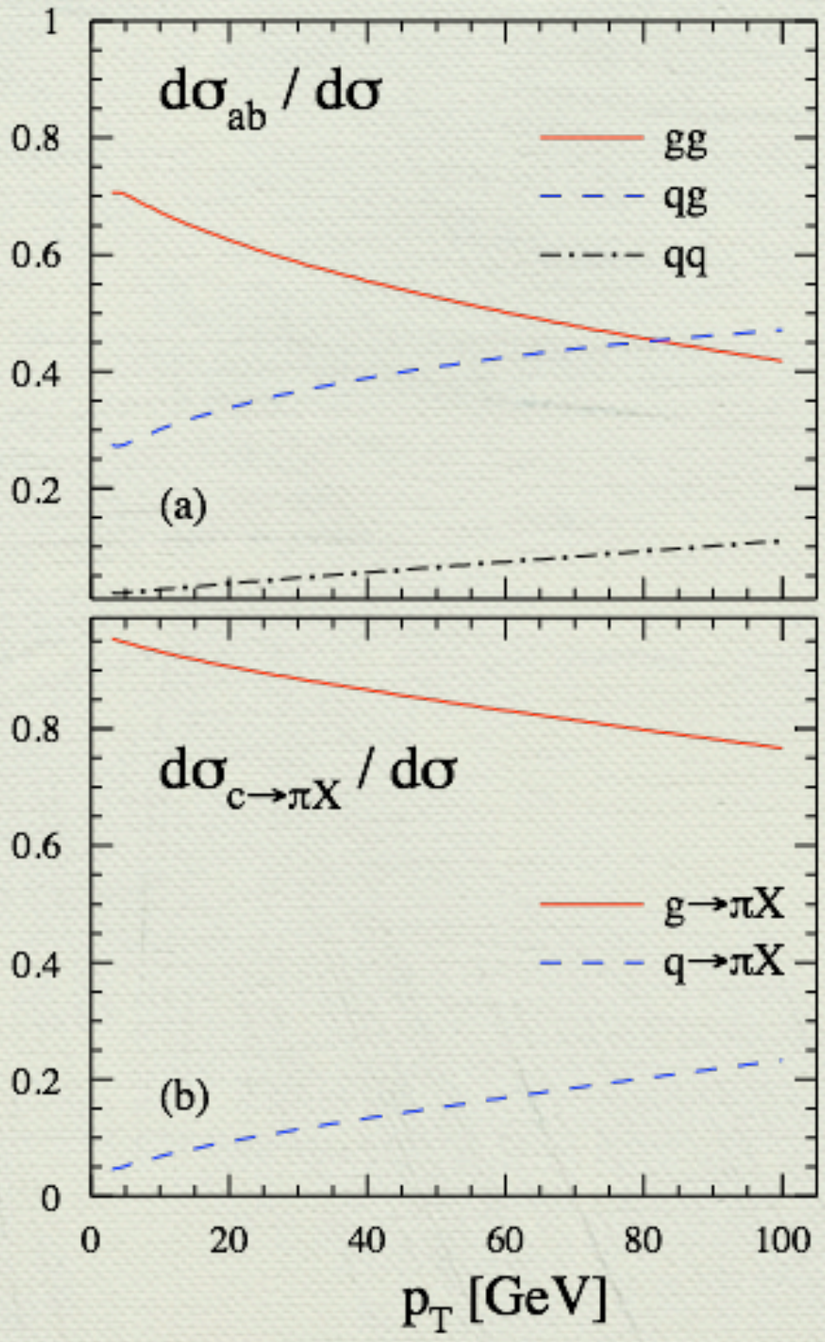


main contribution from gluon-gluon and quark-gluon initiated processes

and

from gluon fragmentation

Single-inclusive hadroproduction



main contribution from gluon-gluon and quark-gluon initiated processes

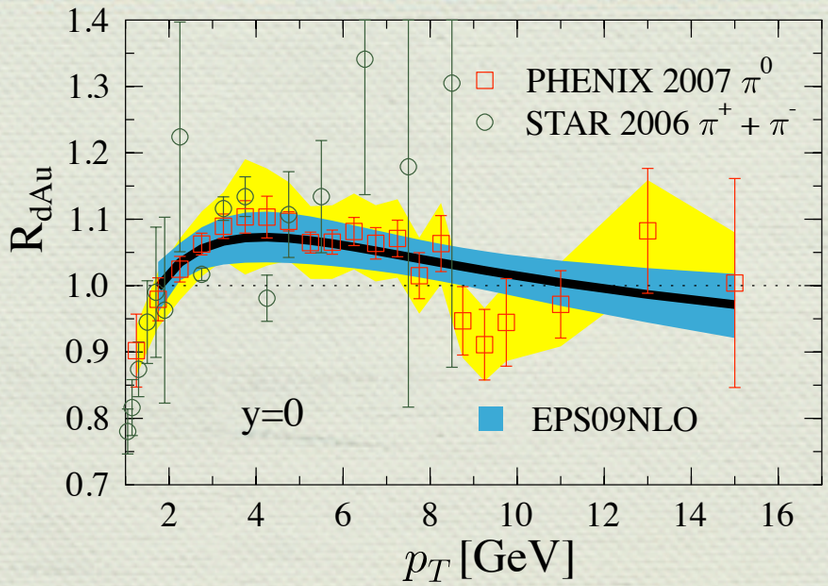
and

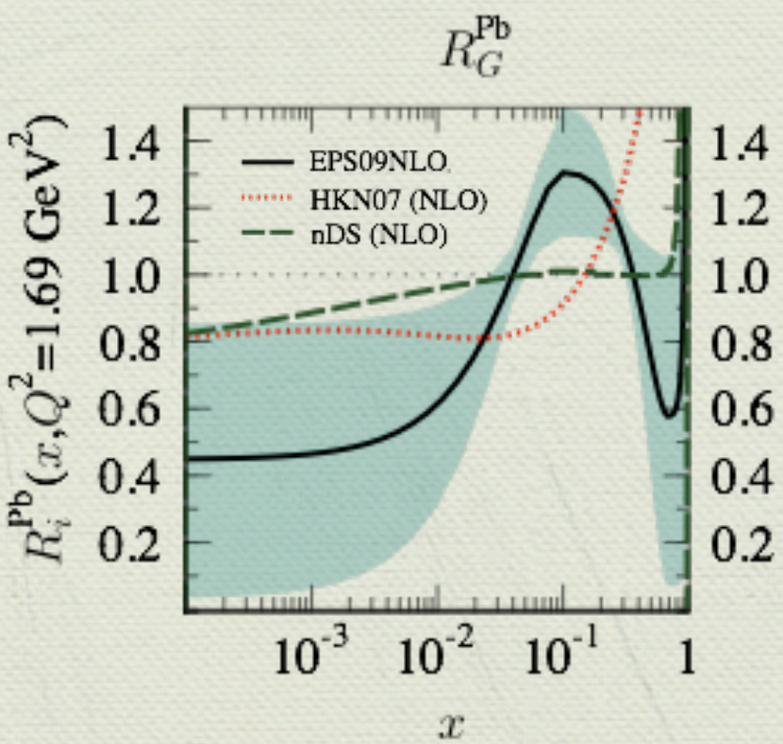
from gluon fragmentation

so pPb@LHC = great to study gluons!

Both analysis include data from hadroproduction in dAu collisions (highly sensitive to gluon distribution)

EPS

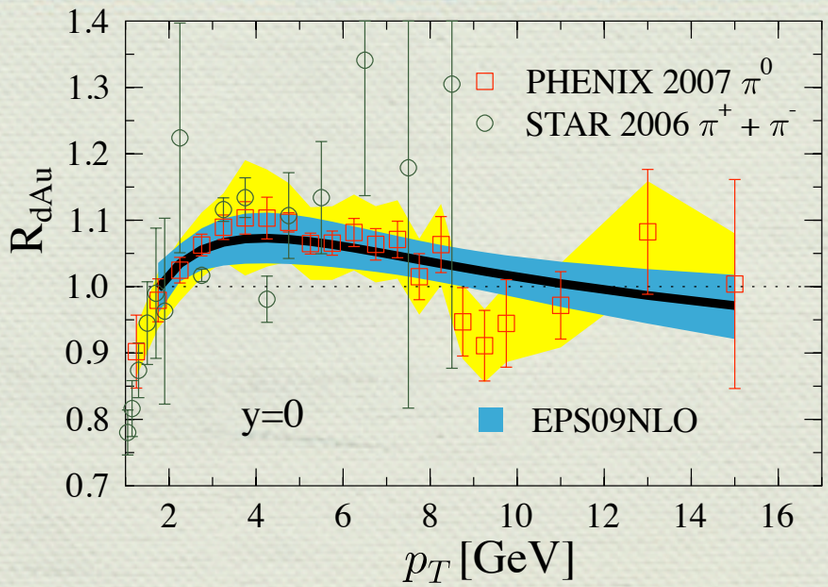


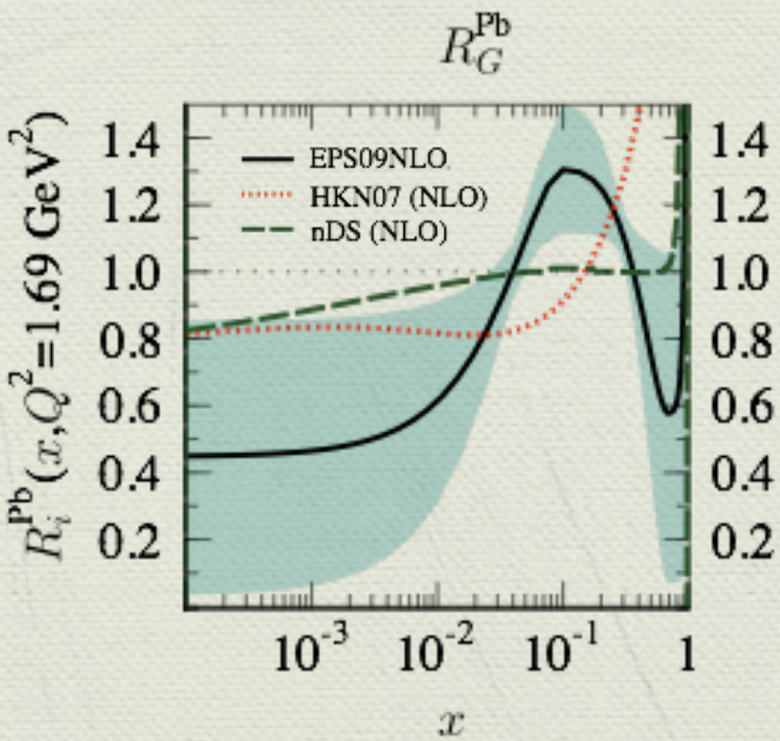


huge impact on gluons

Both analysis include data from hadroproduction in dAu collisions (highly sensitive to gluon distribution)

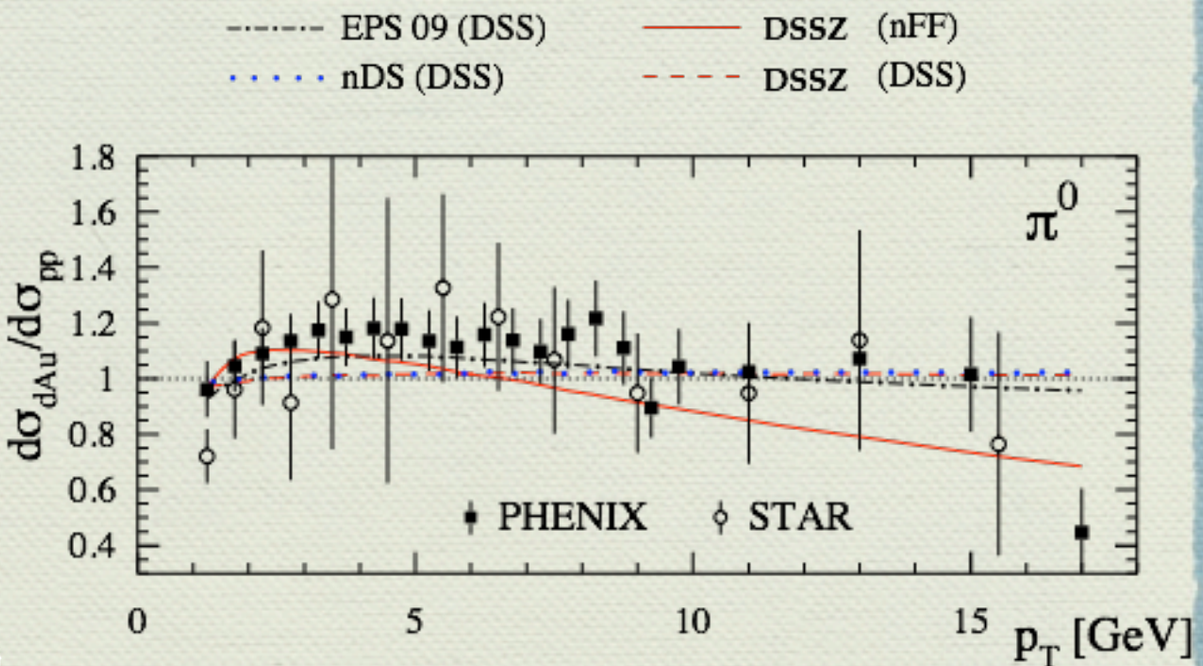
EPS



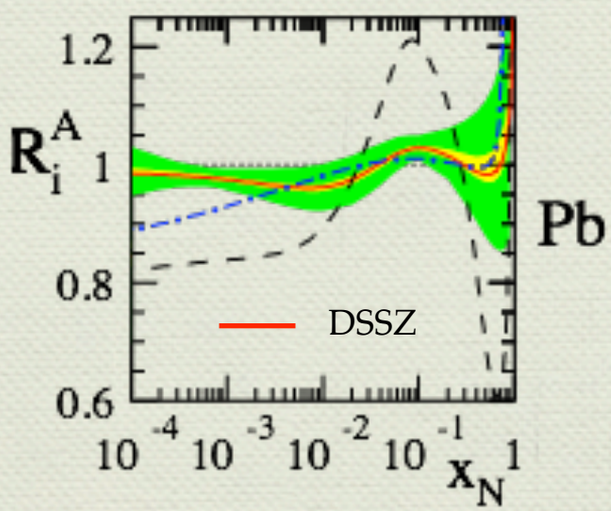


huge impact on gluons

DSSZ



small effect in gluons



How do these different choices compare?

<u>convolution</u> (nDS)	<u>multiplicative factor</u> (EPS)	<u>from scratch</u> (nCTEQ)
first NLO analysis	**first dAu**	**first neutrino DIS**
DIS & DY	DIS & DY	DIS & DY
	RHIC dAu pion production	**neutrino DIS**
convolutional ansatz in Mellin space	piecewise multiplicative ansatz	direct ansatz (recovering proton for A=1)
small effect on gluons	**huge anti-shadowing/ EMC effect for gluon**	**tension electron DIS/ neutrino DIS**
factorization and universality ✓	factorization and universality ✓	**factorization and universality ?**