Medium-modified fragmentation functions and nPDFs

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Universidad de Buenos Aires

in collaboration with M. Stratmann and P. Zurita

Phys.Rev.D81 054001 (2010)

UFRGS, Porto Alegre March 2010

Motivation

- ➡ high pT hadroproduction in pA and AA: RHIC, LHC
- ➡ study hadronization in different environments
- ➡ factorization & universality in a nucleus?
- ➡ relevant for the extraction of nPDFs

Phenomenology:

Early evidence:

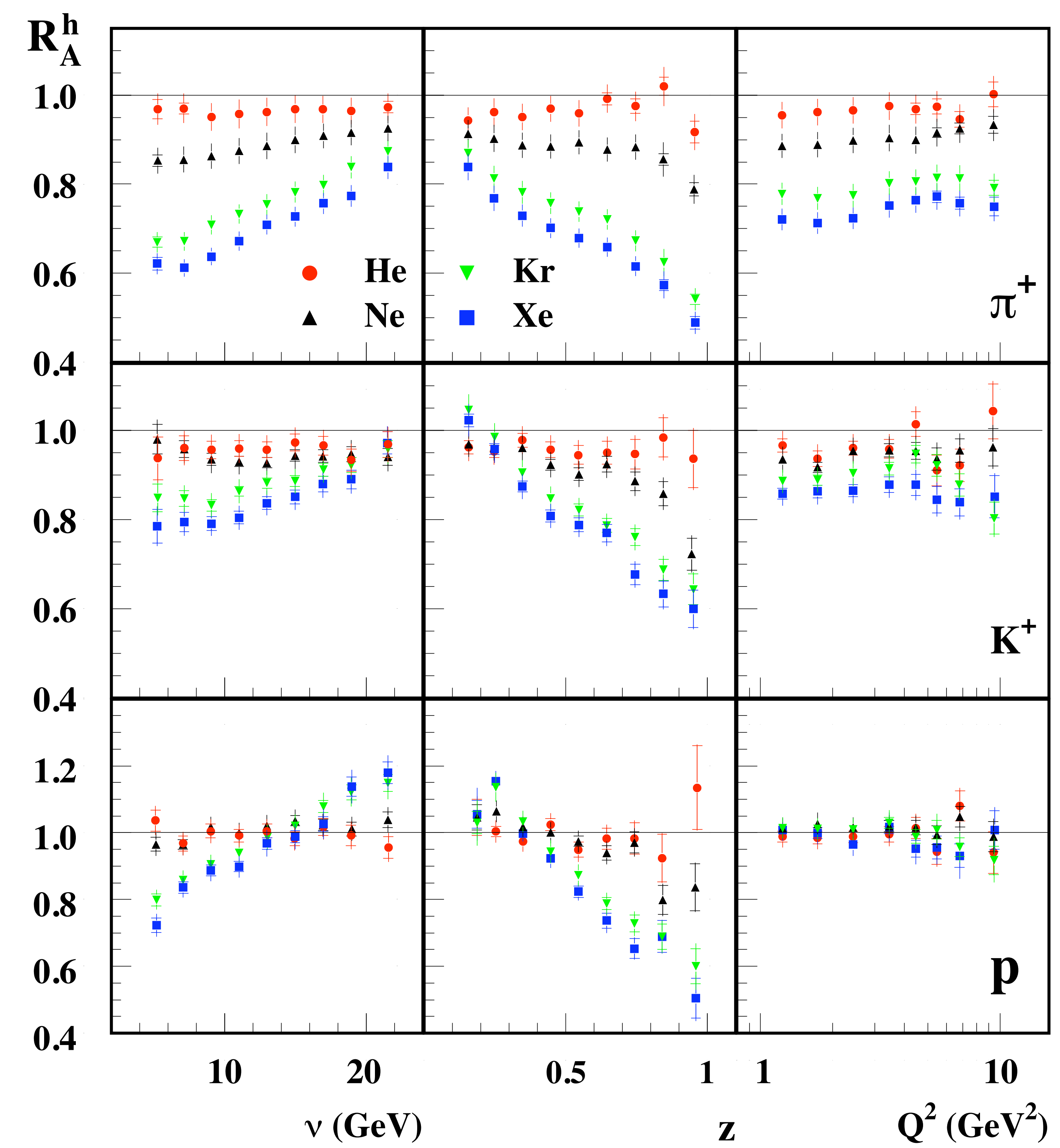
SLAC Phys.Rev.Lett. 40, 1624 (1978)
EMC Z.Phys. C52, 1 (1991)
E665 Phys.Rev. D50, 1836 (1994)

Precise SIDIS:

HERMES Nucl. Phys.B 780 1 (2007);

Precise dAu:

PHENIX Phys.Rev.Lett.98 172302 (2007)
STAR Phys.Lett.B616, 8 (2005)
B637, 161 (2006)

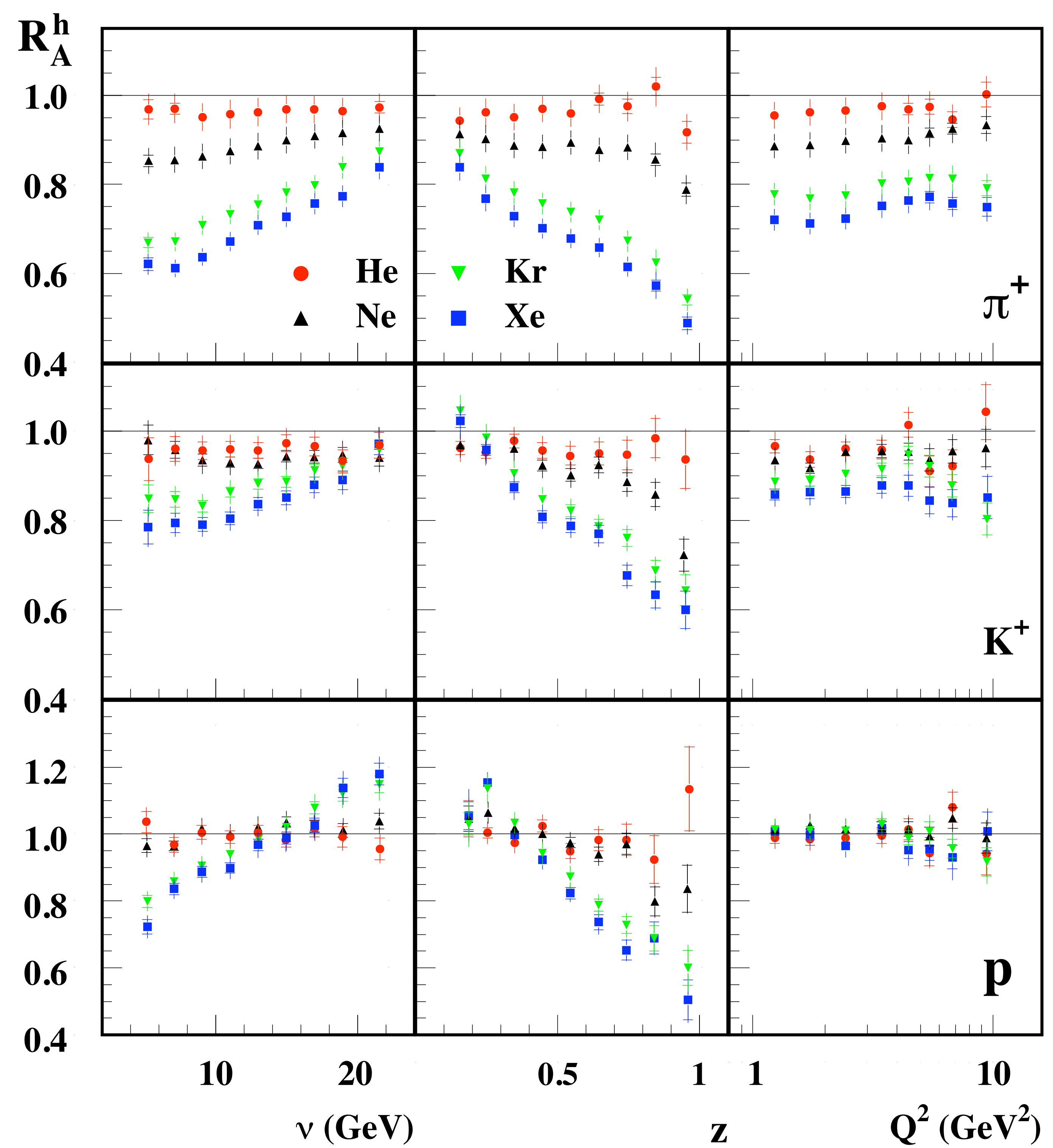


Phenomenology:

Precise SIDIS:

HERMES Nucl. Phys.B 780 1 (2007);

$$R(z,Q^2,\nu) = \frac{\left(\frac{N^{sidis}}{N^{inc}}\right)_A}{\left(\frac{N^{sidis}}{N^{inc}}\right)_D}$$



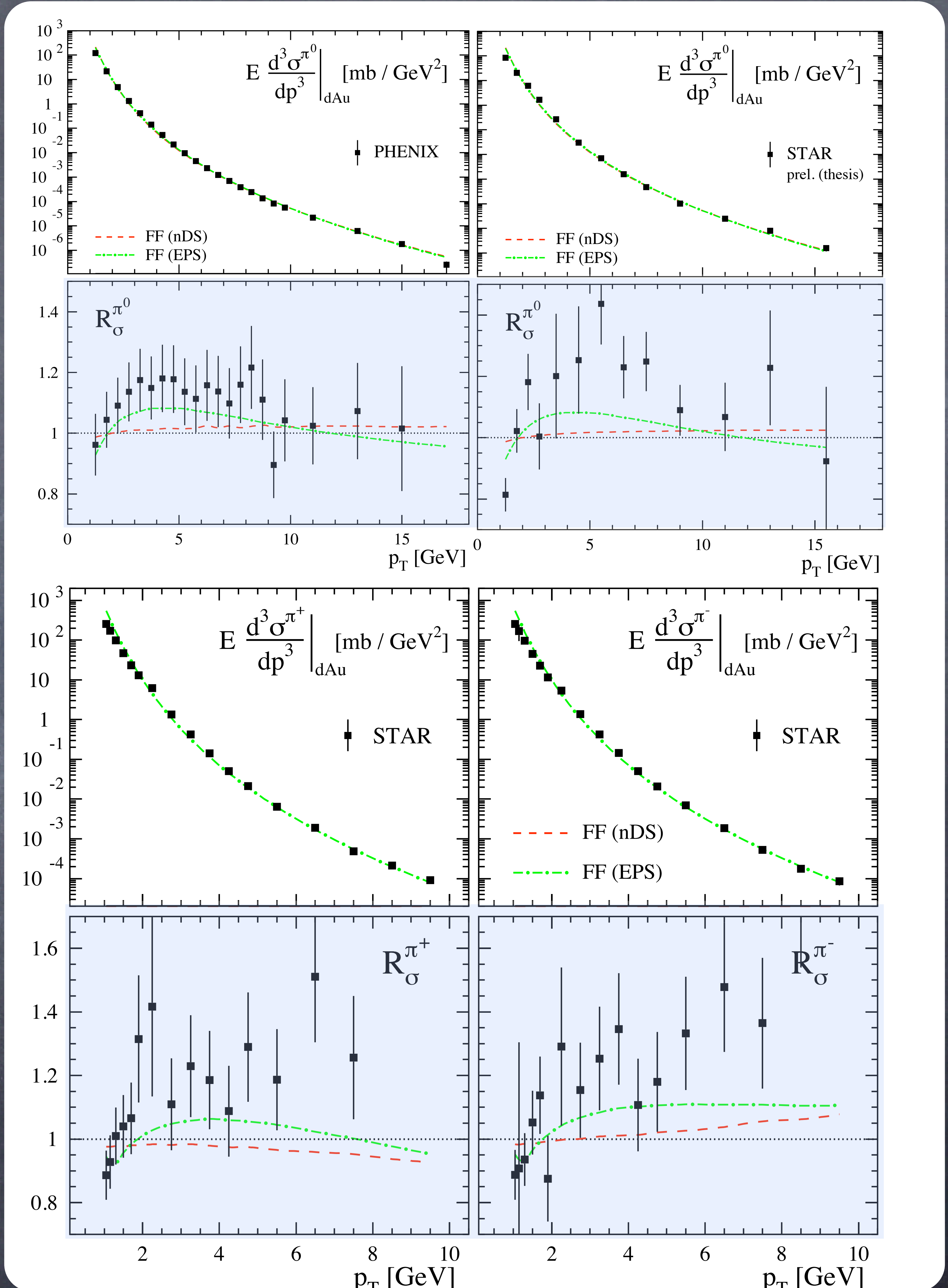
Phenomenology:

PHENIX Phys.Rev.Lett.98 172302 (2007).

STAR Phys.Lett.B616, 8 (2005) B637, 161 (2006)

O.Grebenyuk, Ph.D.Thesis, arXiv:0909.3006.

$$R_\sigma^H(A, p_T) \equiv \frac{1}{2\,A}\,\frac{E\,d^3\sigma^H/dp^3\big|_{dA}}{E\,d^3\sigma^h/dp^3\big|_{pp}}$$



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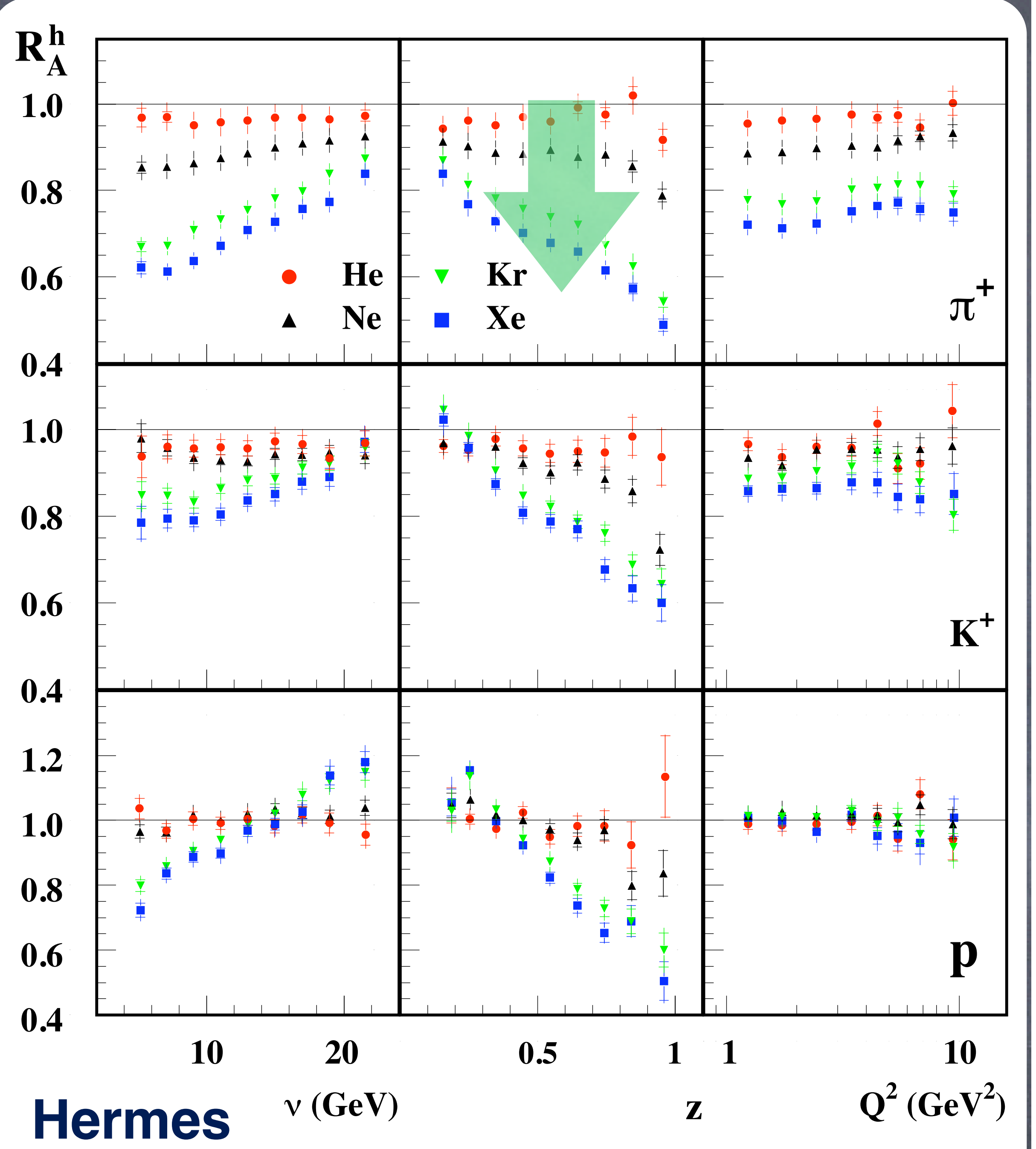
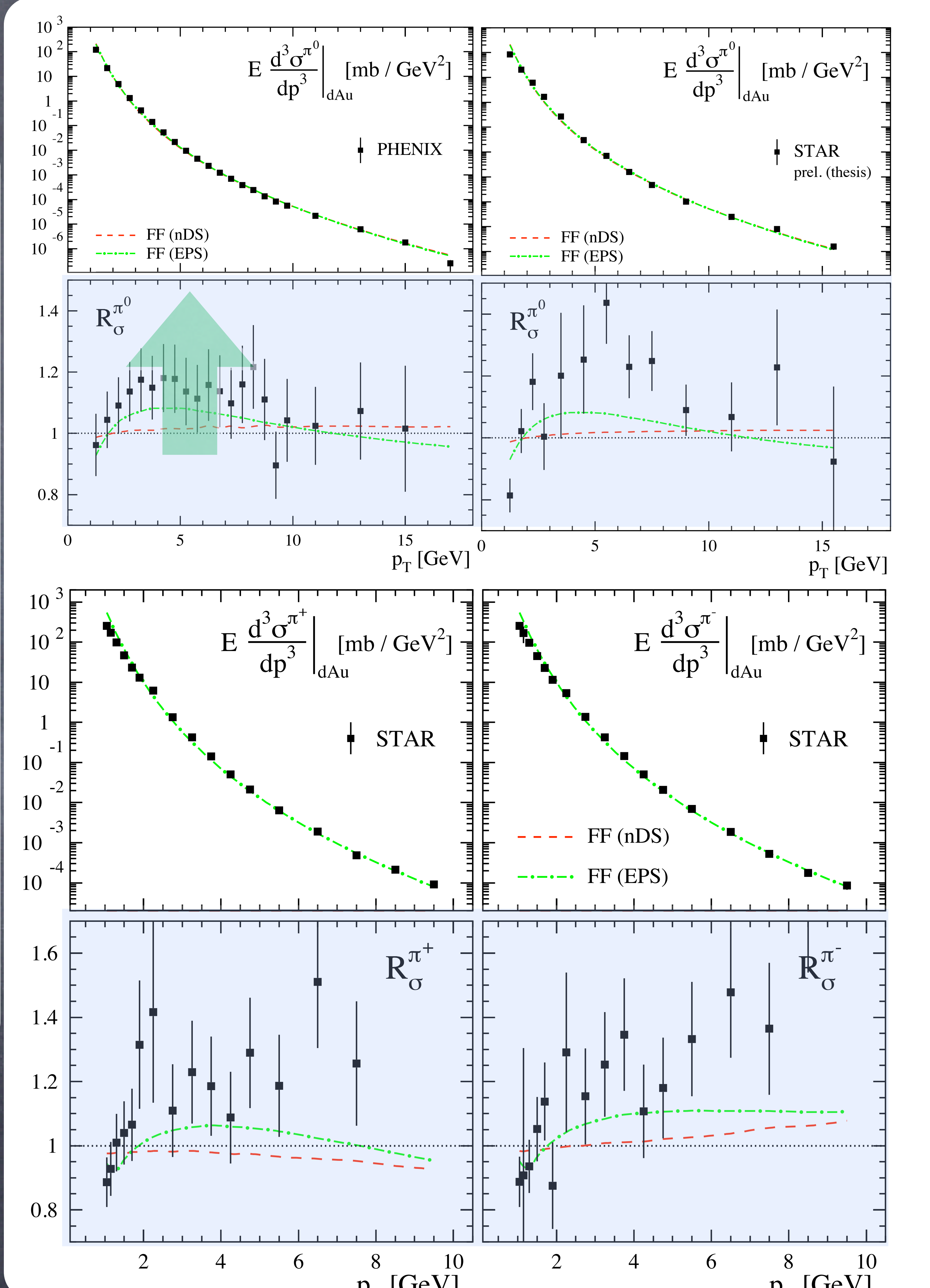
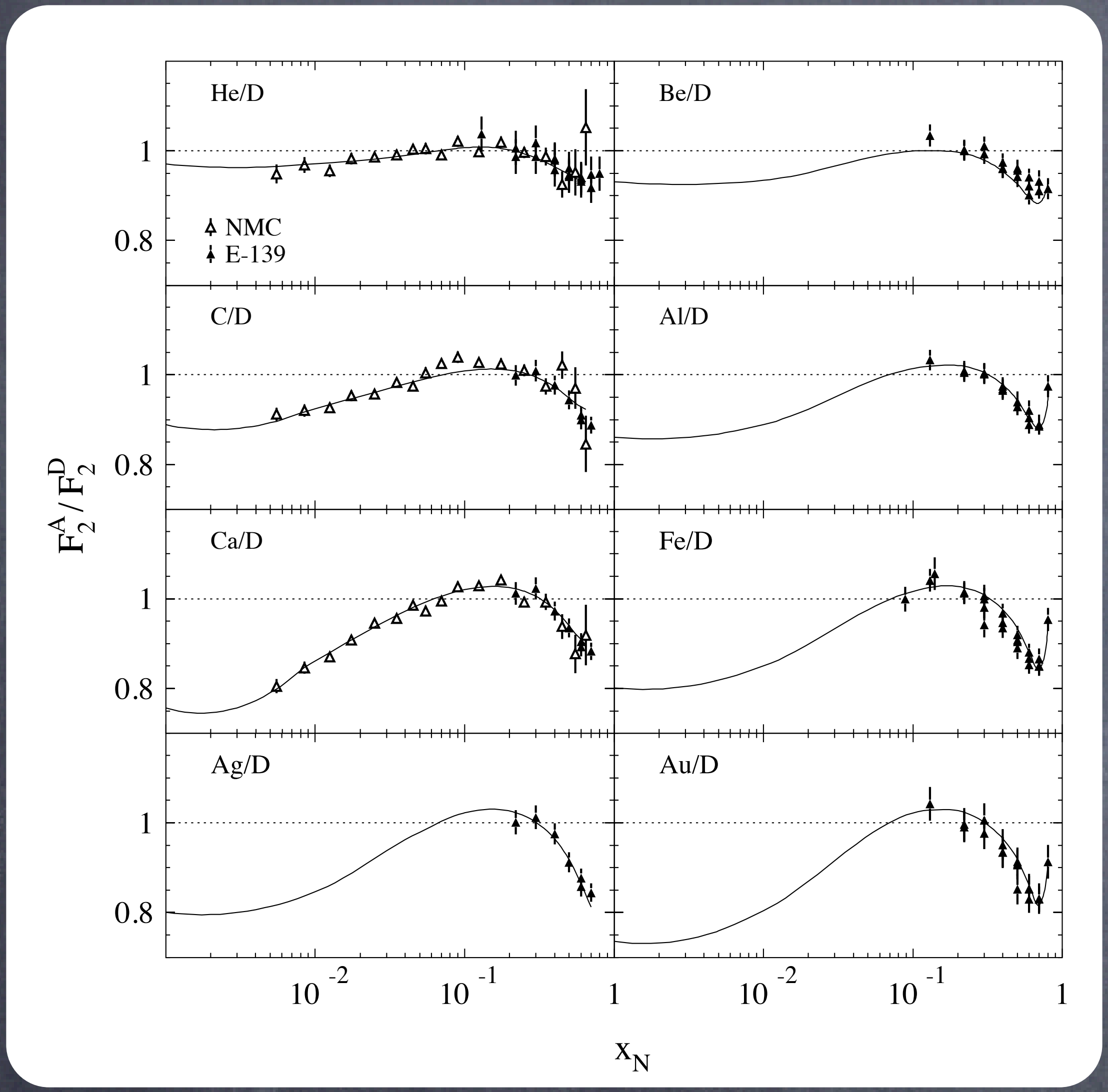


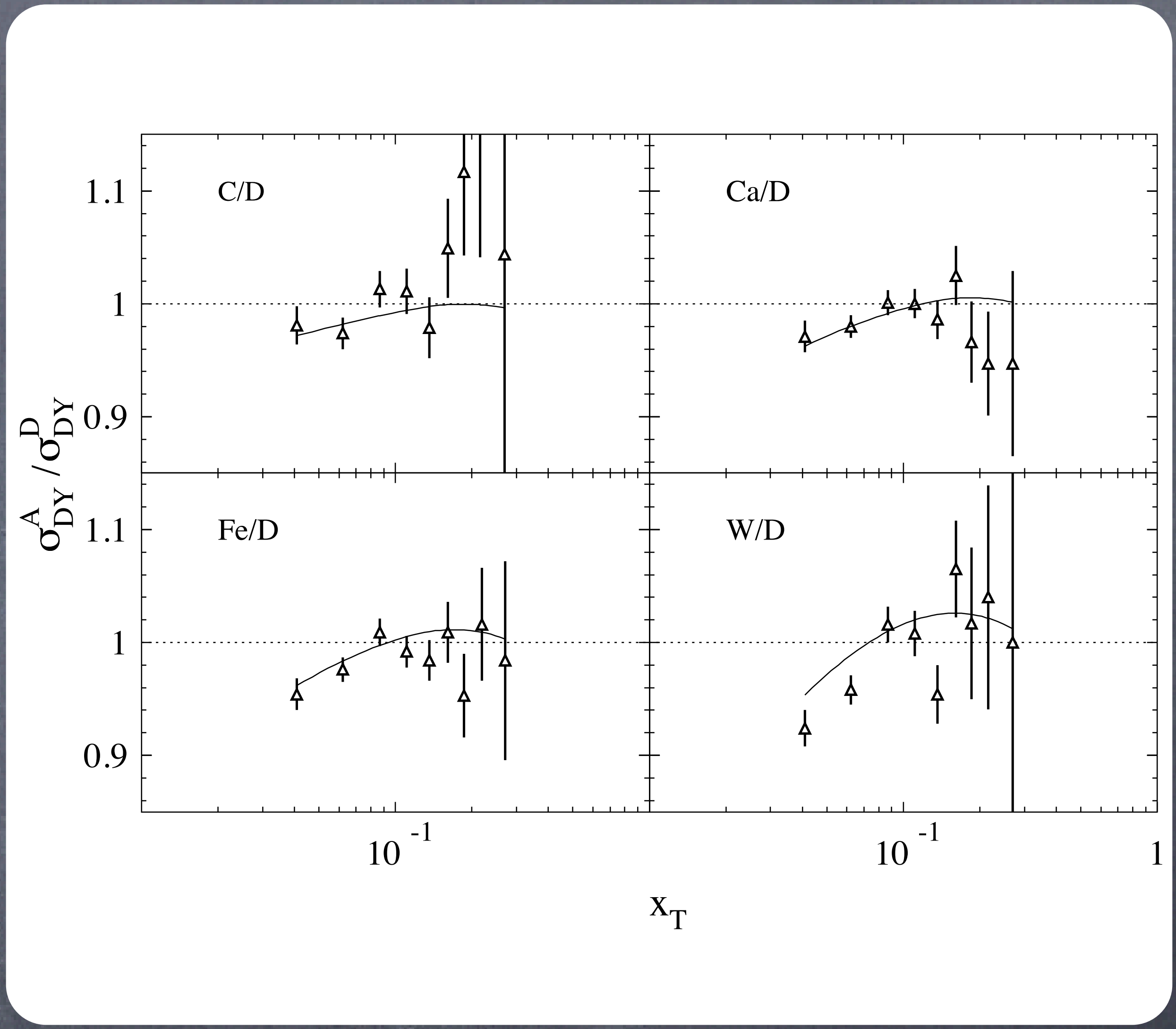


$$R_\sigma^H(A, p_T) \equiv \frac{1}{2\,A} \frac{E\, d^3\sigma^H/dp^3\big|_{dA}}{E\, d^3\sigma^h/dp^3\big|_{pp}}$$

Do nuclear effects factorize into PDFs and FFs?



DIS rates to D



Drell Yan rates to D

$$f_{i/p}(x,Q^2) \longrightarrow f_{i/A}(x,Q^2)$$

D.de Florian R.Sassot Phys.Rev.D69 074028 (2004)
M.Hirai, S.Kumano, T.H.Nagai Phys.Rev.C76 065207 (2007)
K.Eskola, H.Paukkunen, C.A.Salgado, JHEP0904, 065 (2009)

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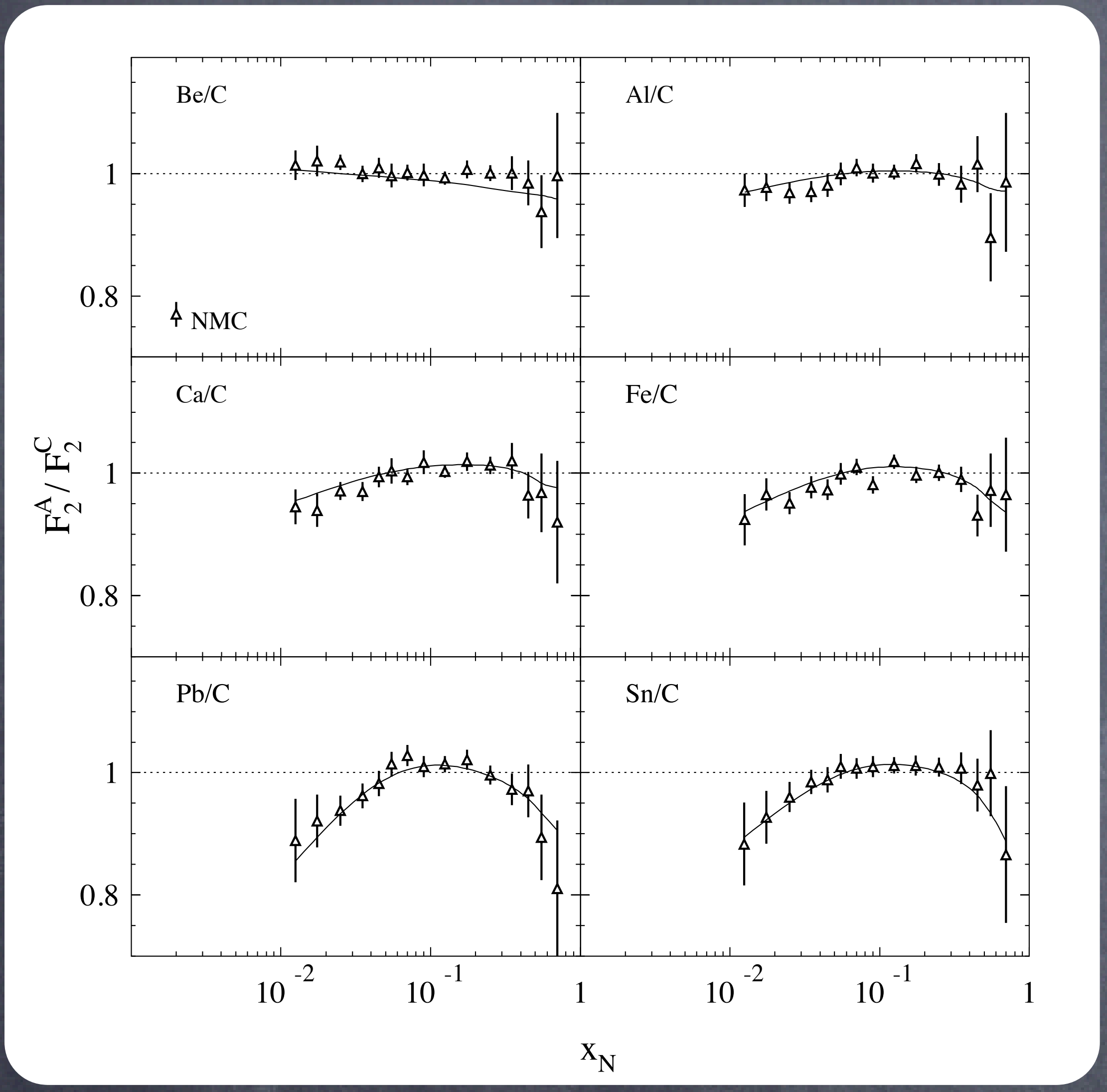

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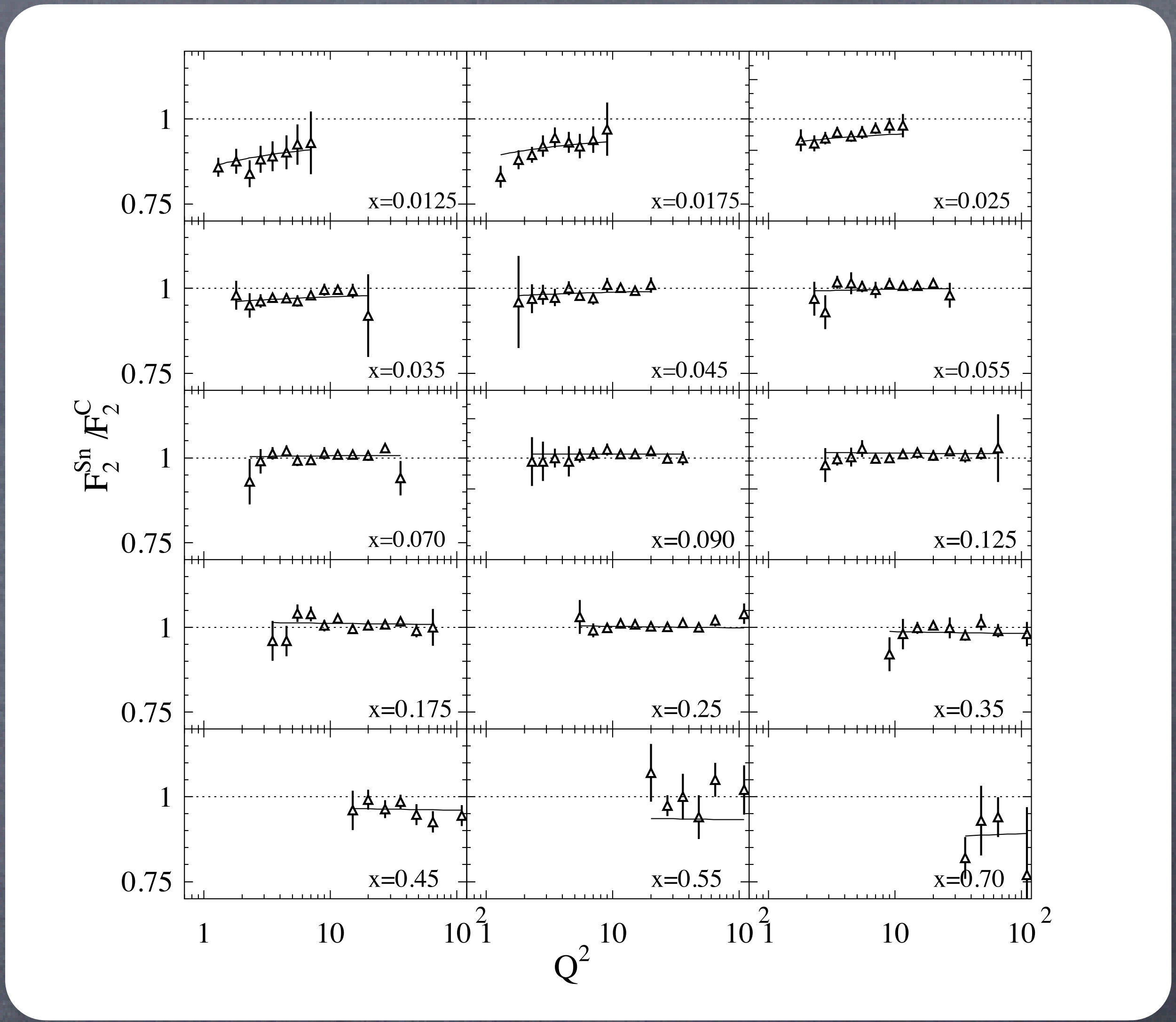

scale dependence

$$f_{i/p}(x, Q^2) \longrightarrow f_{i/A}(x, Q^2)$$

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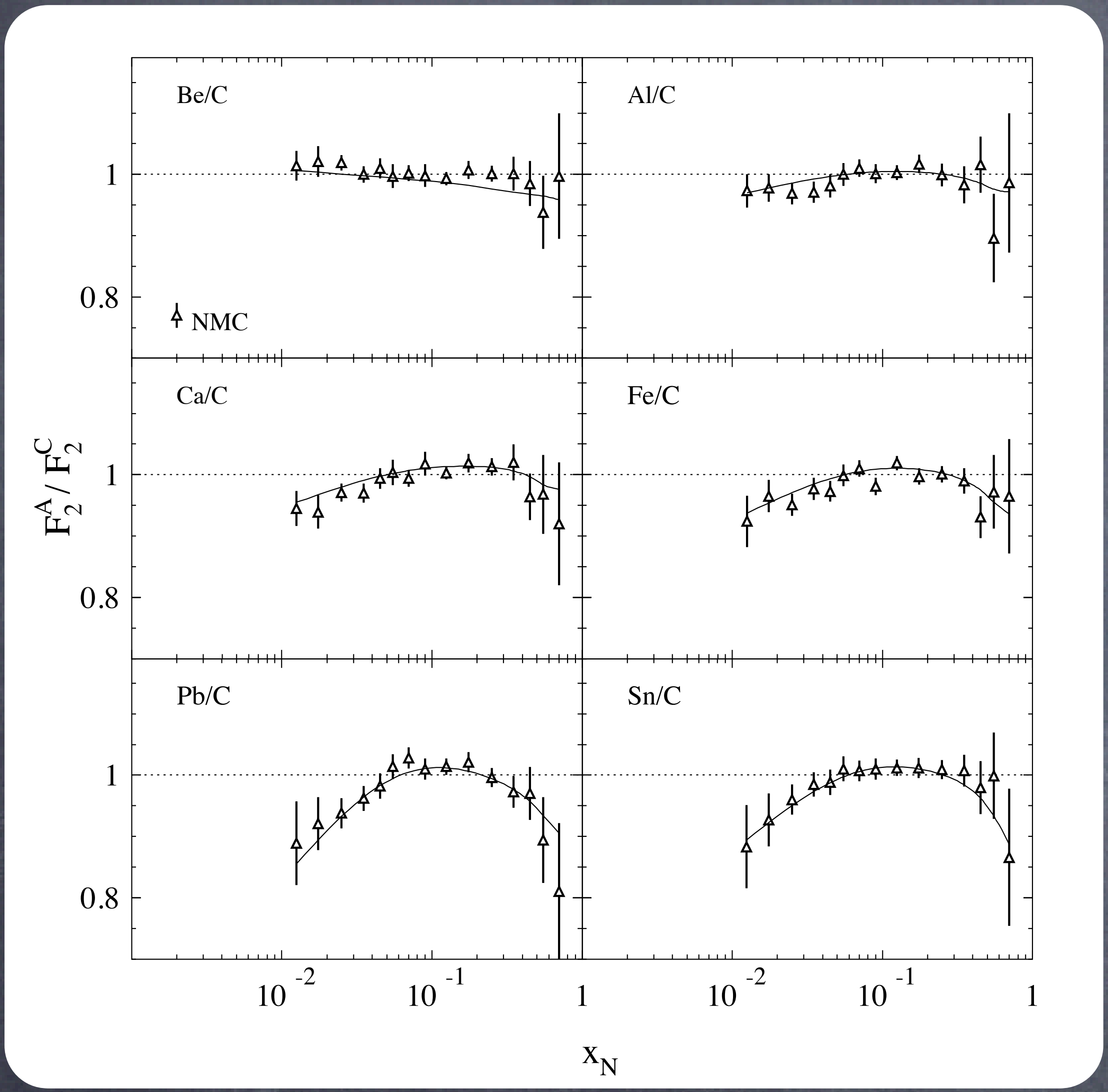
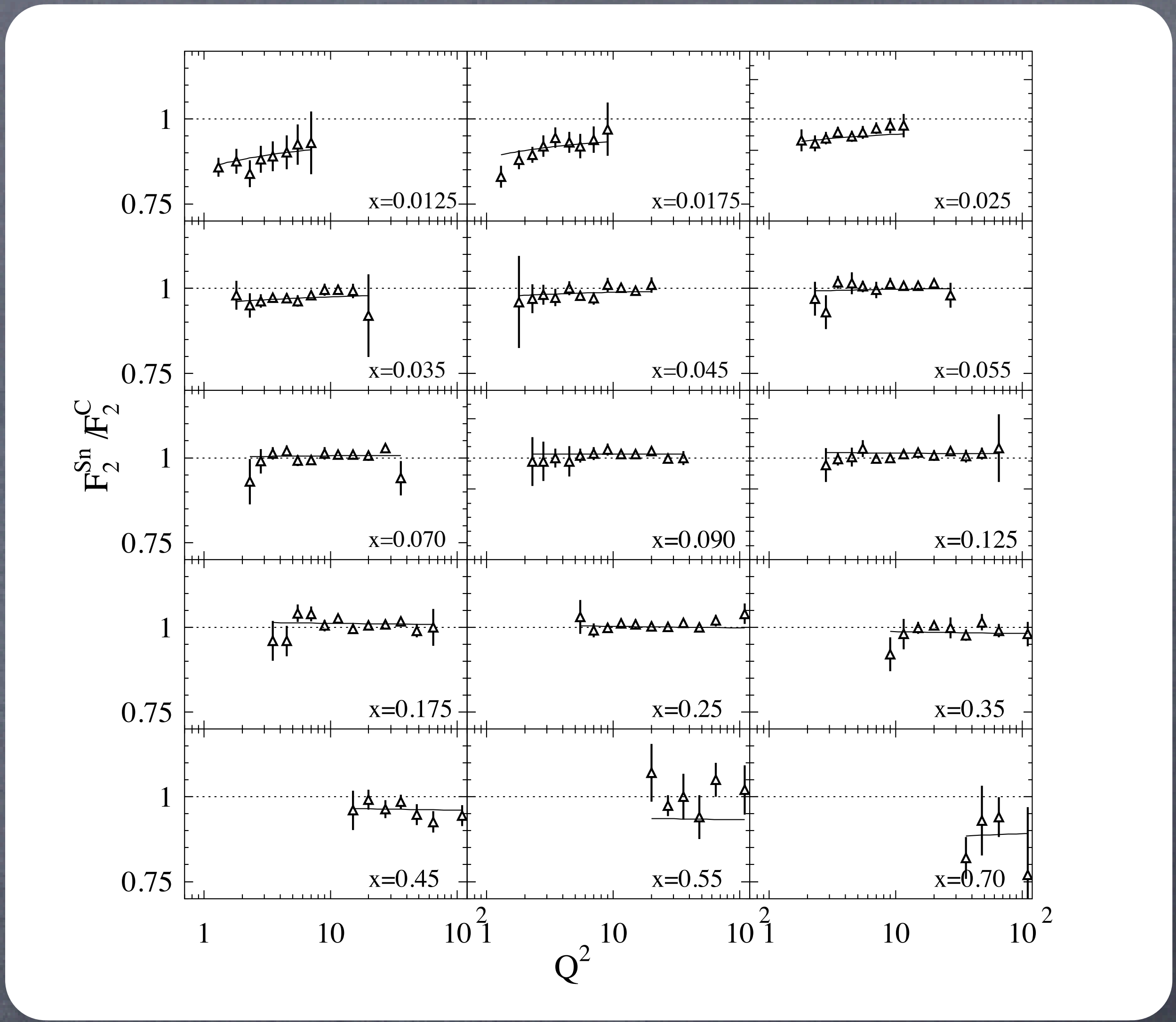


DIS rates to D



Drell Yan rates to D

$$f_{i/p}(x, Q^2) \longrightarrow f_{i/A}(x, Q^2)$$

$$D^h_{i/p}(z, Q^2) \longrightarrow D^h_{i/A}(z, Q^2)$$?

Do nuclear effects factorize into PDFs and FFs?

nFFs factorize all non-perturbative details?

"universal" (interchangeable)?

well defined framework beyond LO?

constrained by data through global NLO fit?

Why it could not work:

factorization breaking — Wiedemann et al. arXiv:1002.2537

non universality of hadronization — Accardi et al. arXiv:0907.3534

modified energy scale dependence — Arleo arXiv:0810.1193

nuclear/high density higher twists — Arleo et al. arXiv:0911.4604

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________ ________ ________ (Please fill in the blanks)

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nPDFs digression:

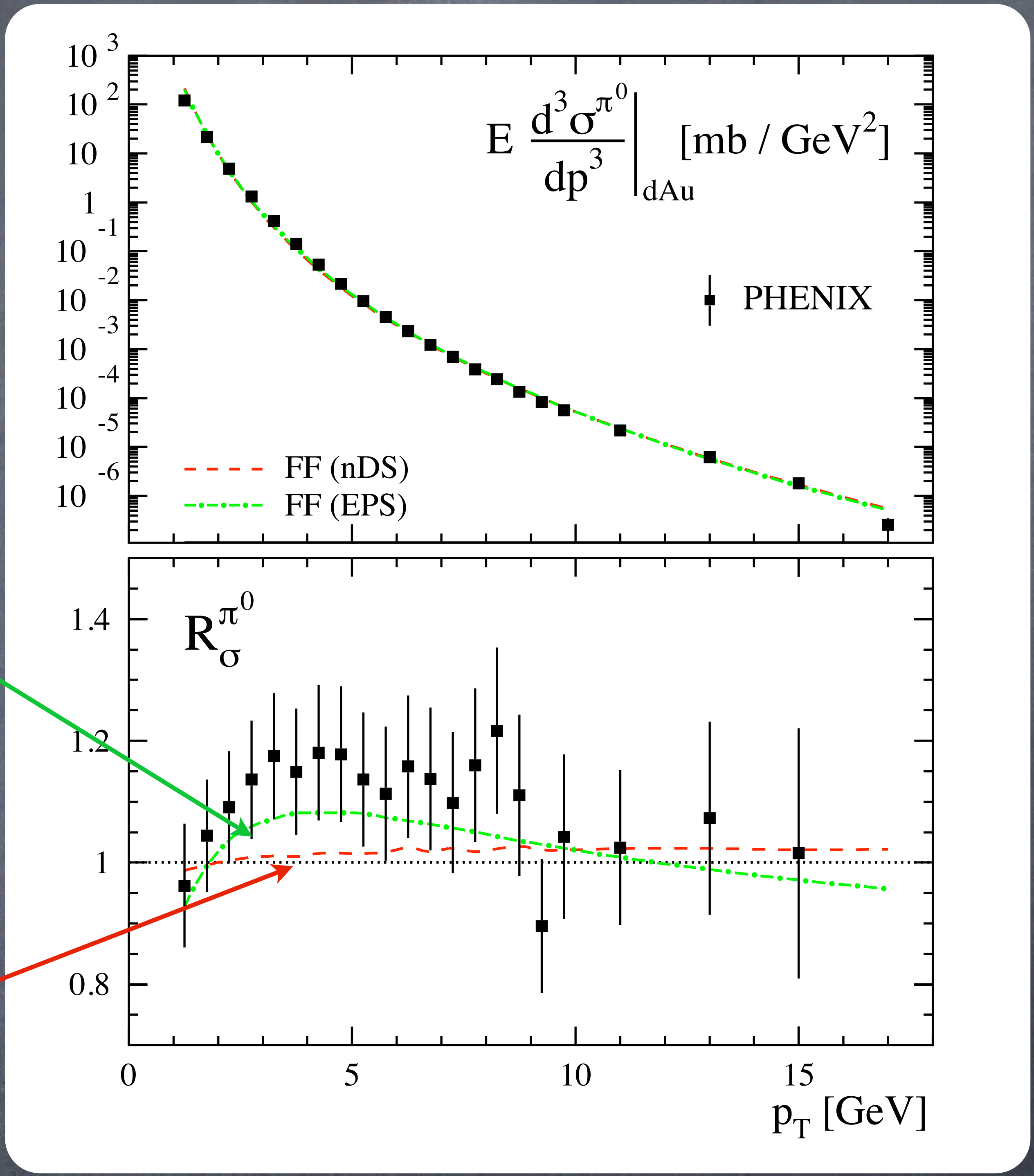
EPS nPDFs

K.Eskola, H.Paukkunen, C.A.Salgado, JHEP0904, 065 (2009)

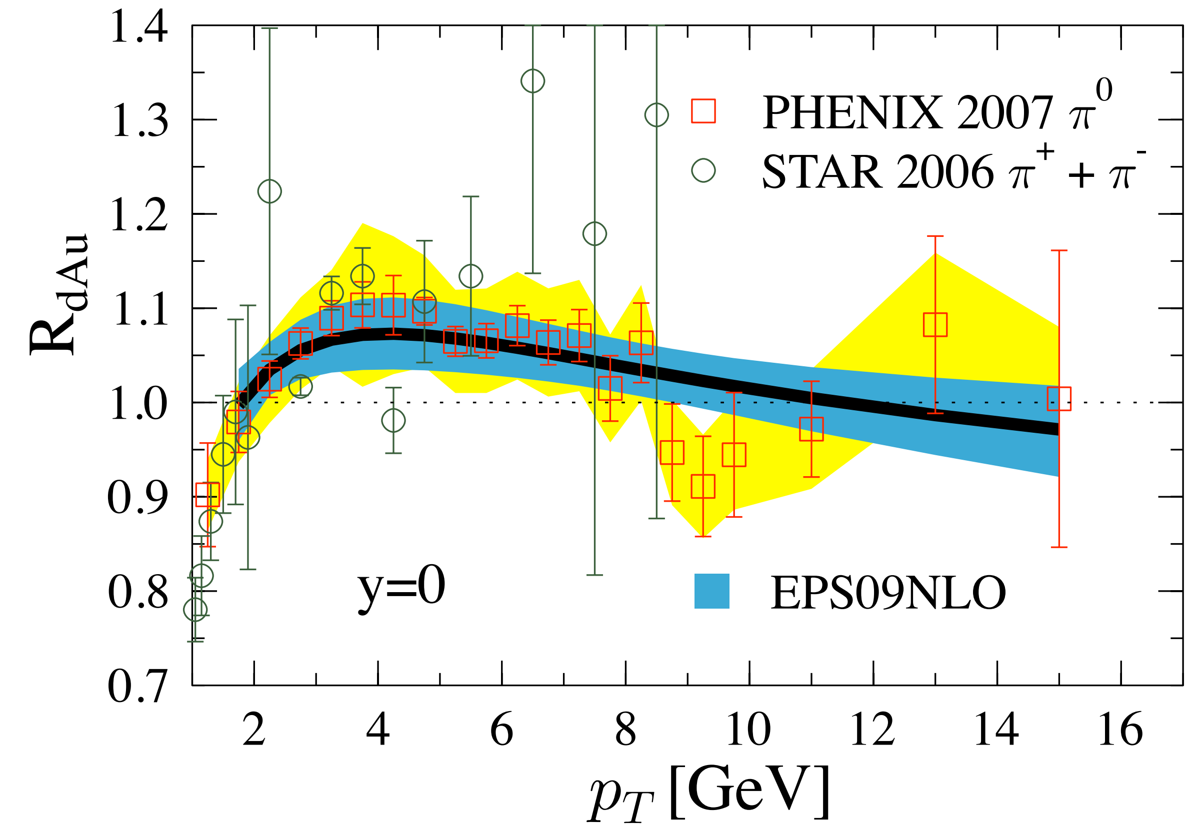
★ designed to reproduce dAu data (assuming no FF effects)

nDS nPDFs

D.de Florian R.S. Phys.Rev.D69 074028 (2004)

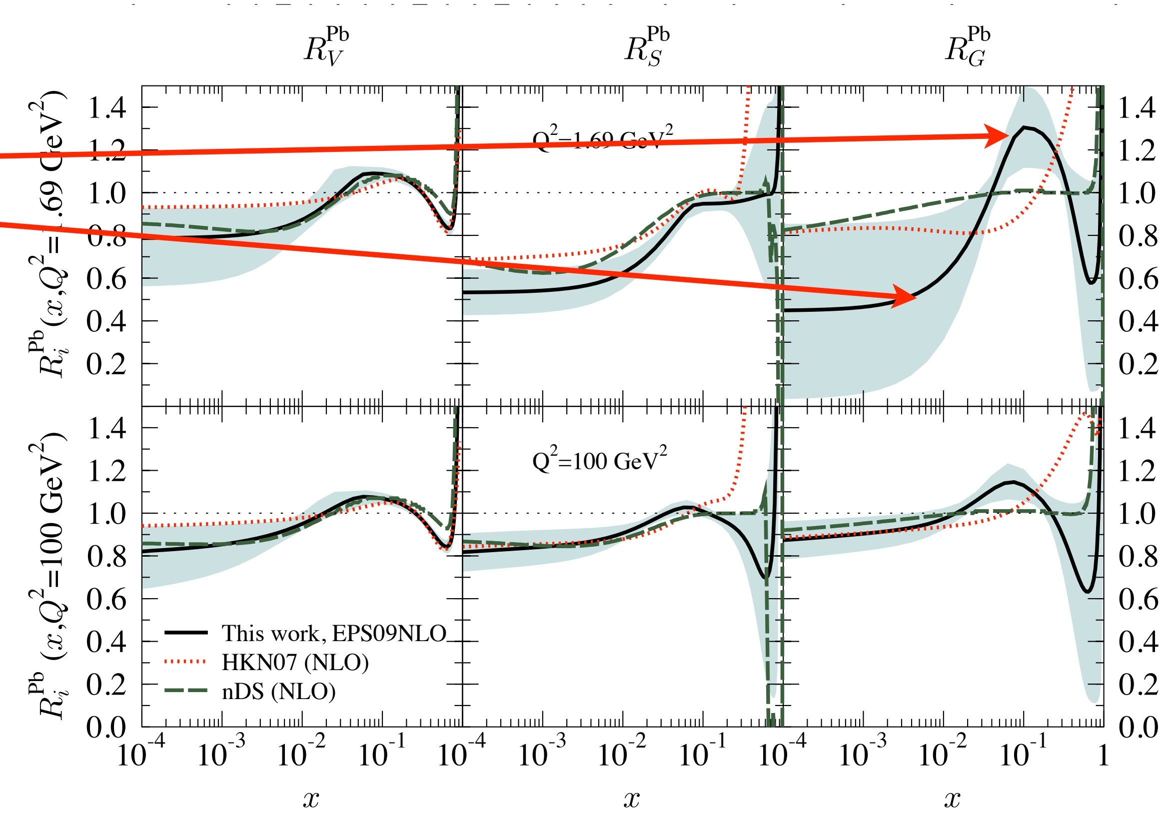


nPDFs digression:



- designed to reproduce dAu data (assuming no FF effects)
- unusual gluons
- extra normalizations: (?)

  STAR 0.90
  PHENIX 1.03



Baseline:

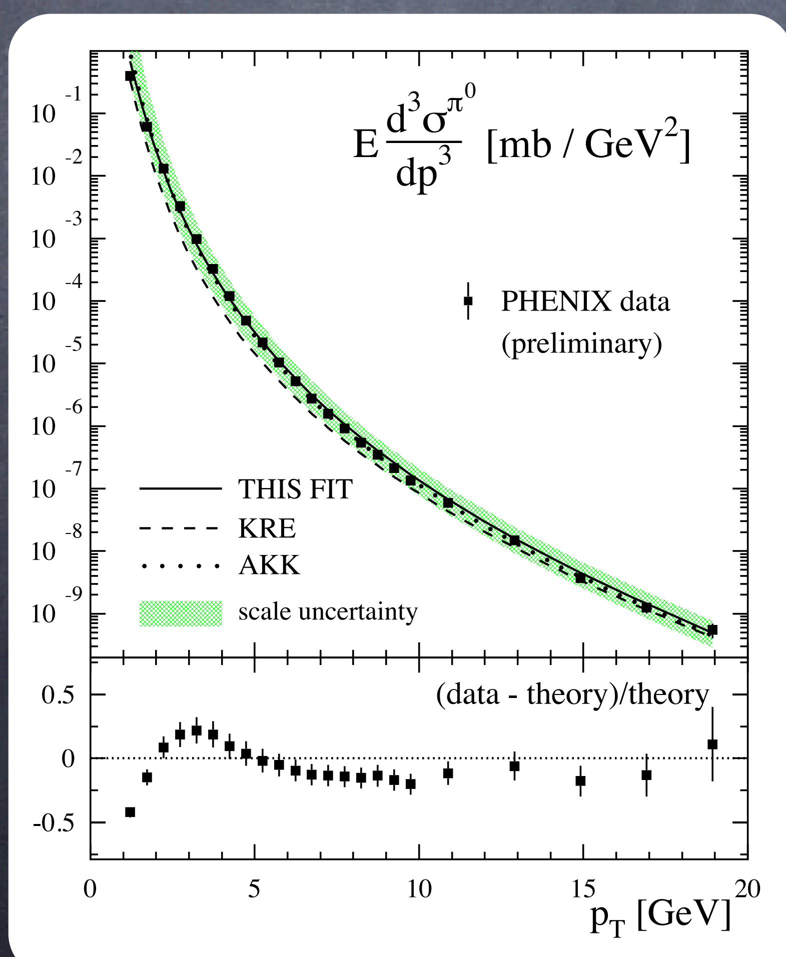
consistency ➡ nDS nPDFs

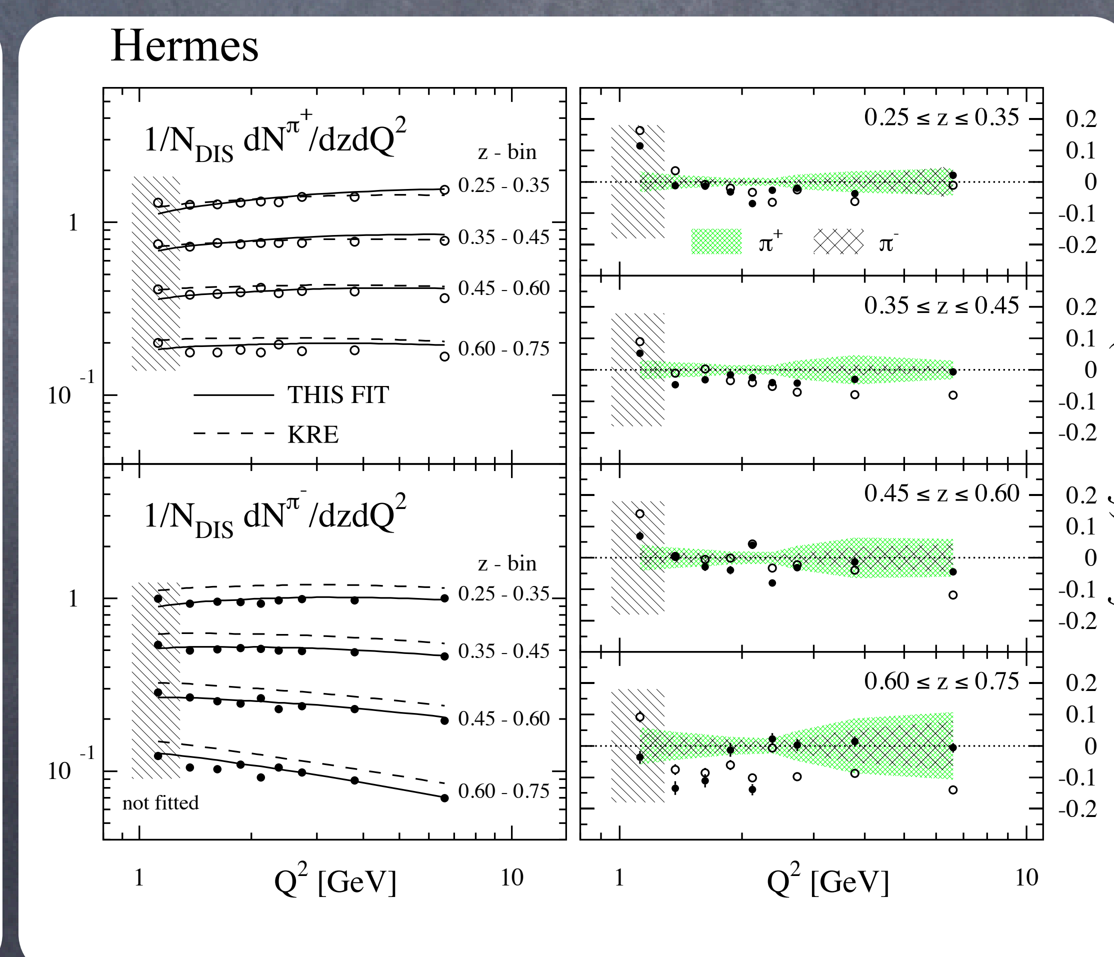
D.de Florian, R.S.
Phys.Rev.D69 074028 (2004)

reference ➡ DSS FFs

D.de Florian, R.S., M.Stratmann
Phys.Rev.D75 114010 (2007)
Phys.Rev.D76 074033 (2007)

pp reference





low pT CMS data
sidis reference

Baseline:

consistency ➔ nDS nPDFs

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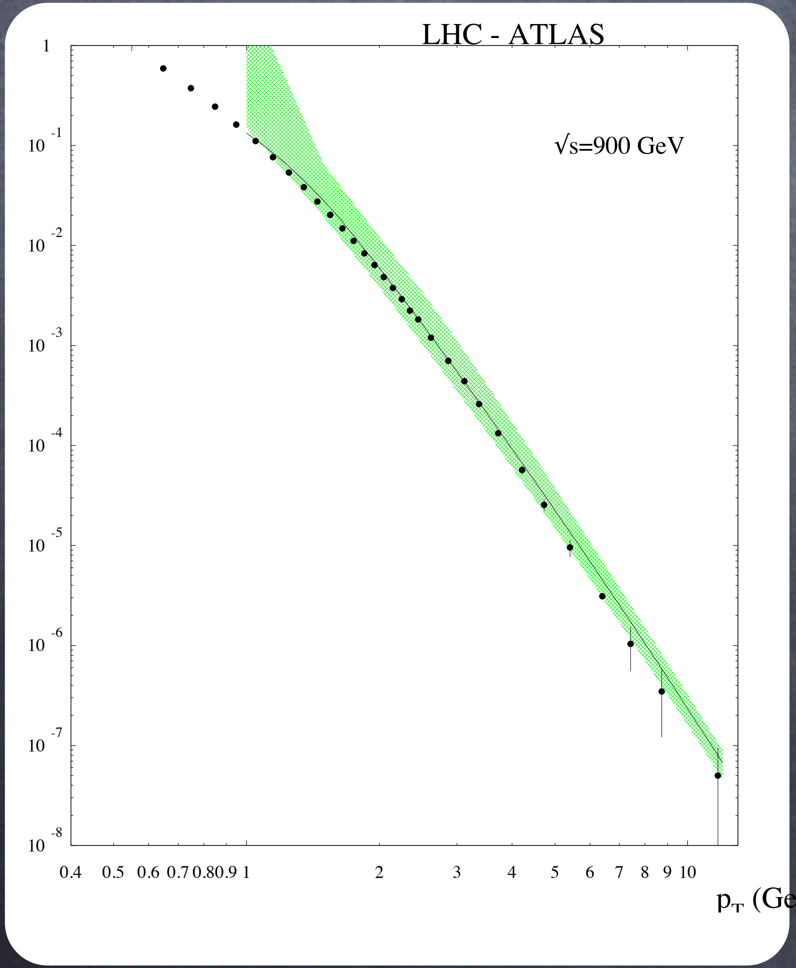
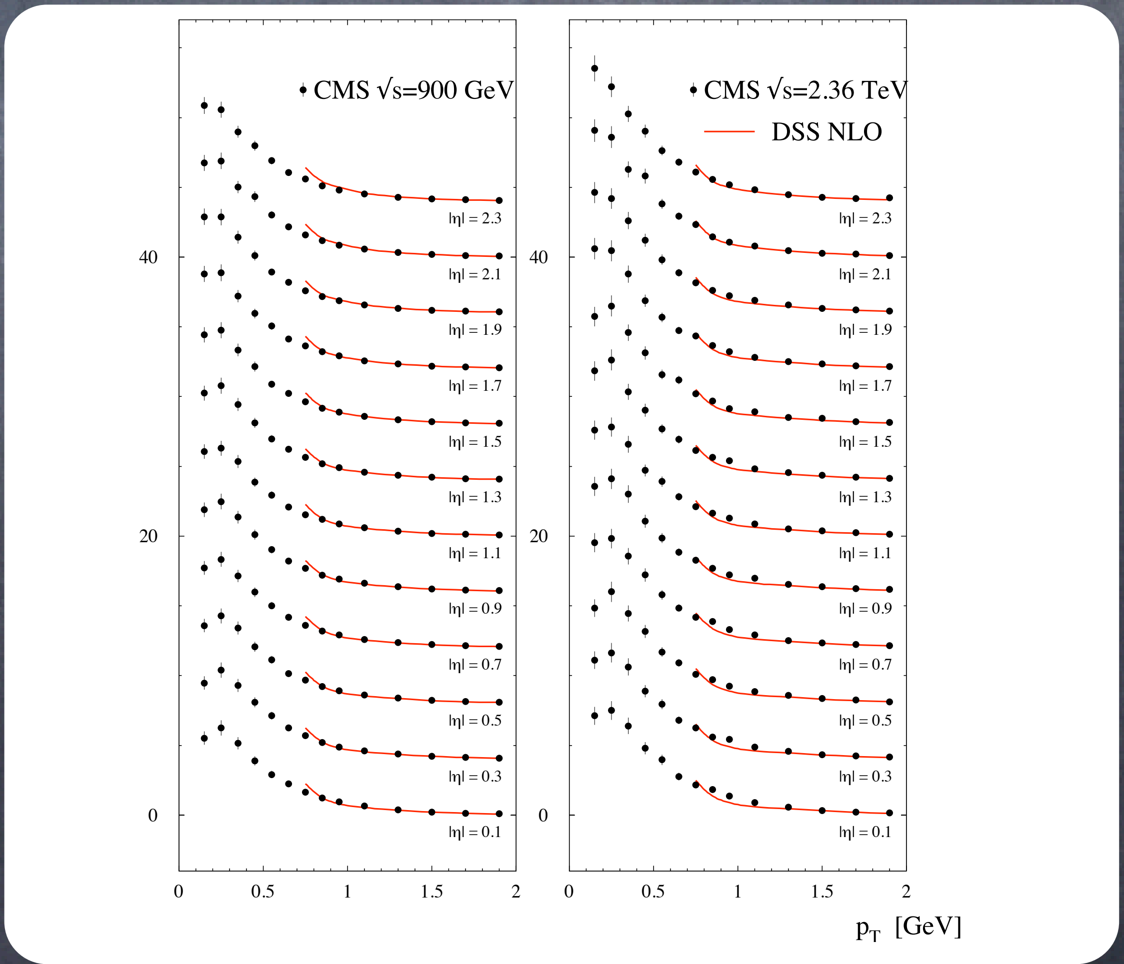


ATLAS
arXiv:1003.3124



low pT
CMS data

CMS
arXiv:1002.0621

Fitting nFFs: convolution approach

$$D^h_{i/A}(z,Q_0^2) = \int_z^1 dy\, W_i(y,A,Q_0^2)\, D^h_i(\frac{z}{y},Q_0^2)$$

works for nPDFs
re-scalings/shifts
modifies FFs
natural language NLO

$W_i(y,A,Q_0^2) = \delta(1-y)$ no effects

$W_i(y,A,Q_0^2) = \delta(1-\epsilon-y)$ z-shift (energy loss)

$W_i(y,A,Q_0^2) = n_i\, y^{\alpha_i}(1-y)^{\beta_i}$ enhancement/suppression, re-shape

weighting coefficients $\epsilon_i, n_i, \alpha_i, \beta_i$ with a smooth A dependence

$n_i = \lambda^{n_i} + \gamma^{n_i} A^{\delta^{n_i}}$ with $\lambda^{n_i}, \gamma^{n_i}, \delta^{n_i}$ parameters to be fitted

A very simple example for pion production:

Toy parameterization

no significant differences between charged pions

$$W_q^\pi(y,A,Q_0^2) = W_{\bar{q}}^\pi(y,A,Q_0^2) = n_q\delta(1-y) + \epsilon_q\,\delta(1-\epsilon_q - y)$$

z-independent energy loss?

$$W_g^\pi(y,A,Q_0^2) = n_g\delta(1-y) + \epsilon_g\,\delta(1-\epsilon_g - y)$$

$n_g \neq n_q$

$\epsilon_g = \epsilon_q$?

simplest A-dependence:

$$\begin{aligned} n_q &= 1 + \gamma_{n_q} A^{2/3} \\ n_g &= 1 + \gamma_{n_g} A^{2/3} \\ \epsilon_q &= \epsilon_g = \gamma_\epsilon A^{2/3}\,. \end{aligned}$$

3 parameters

A	n_q	$\epsilon_q = \epsilon_g$	n_g
He	0.966	0.001	1.015
Ne	0.902	0.002	1.044
Kr	0.745	0.006	1.115
Xe	0.657	0.008	1.155
Au	0.550	0.010	1.203

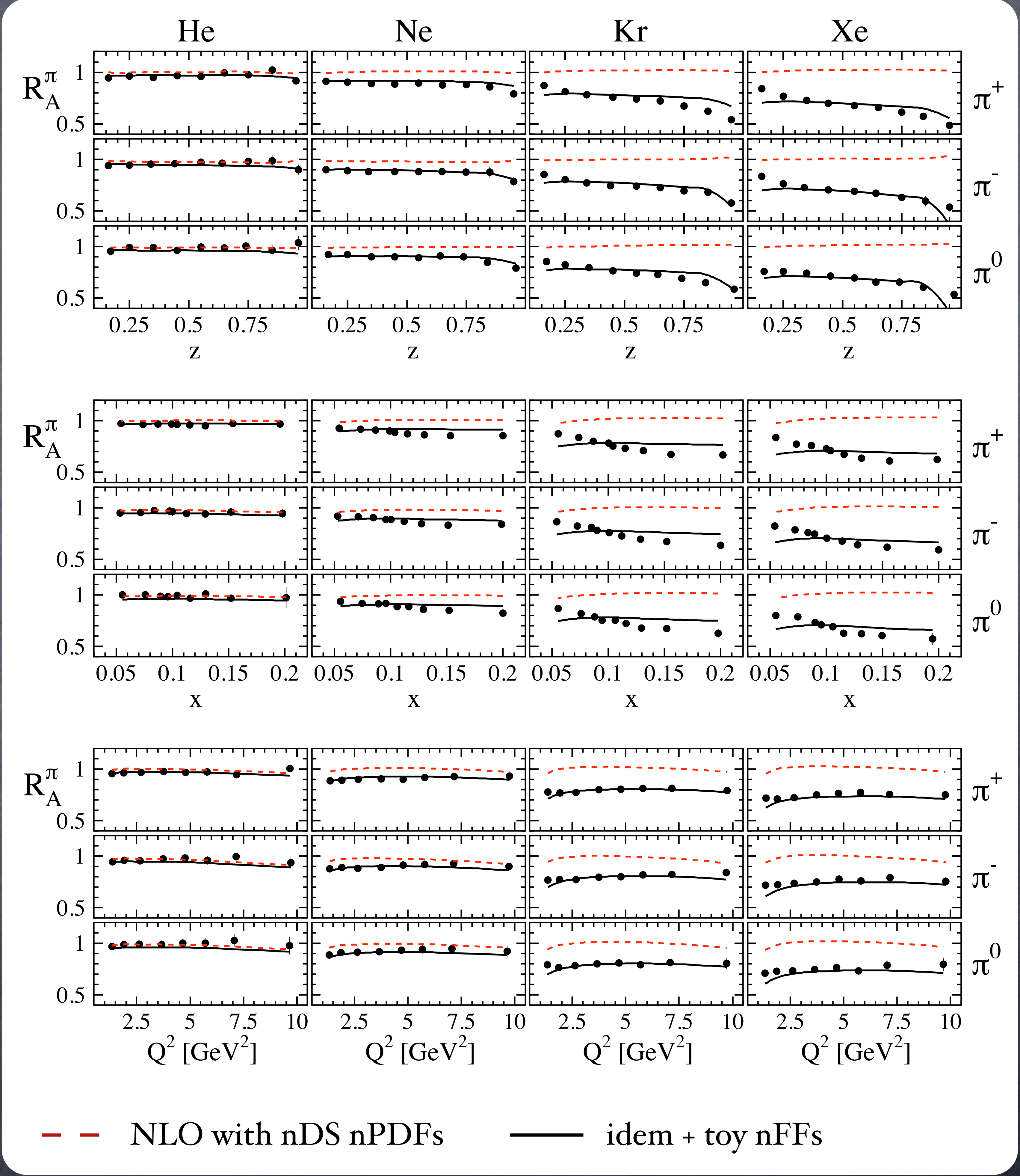
HERMES Nucl. Phys.B 780 1 (2007);

Toy parameterization

normalization & trend

not flexible enough for x-dependence: gluons?

no conflict with standard evolution

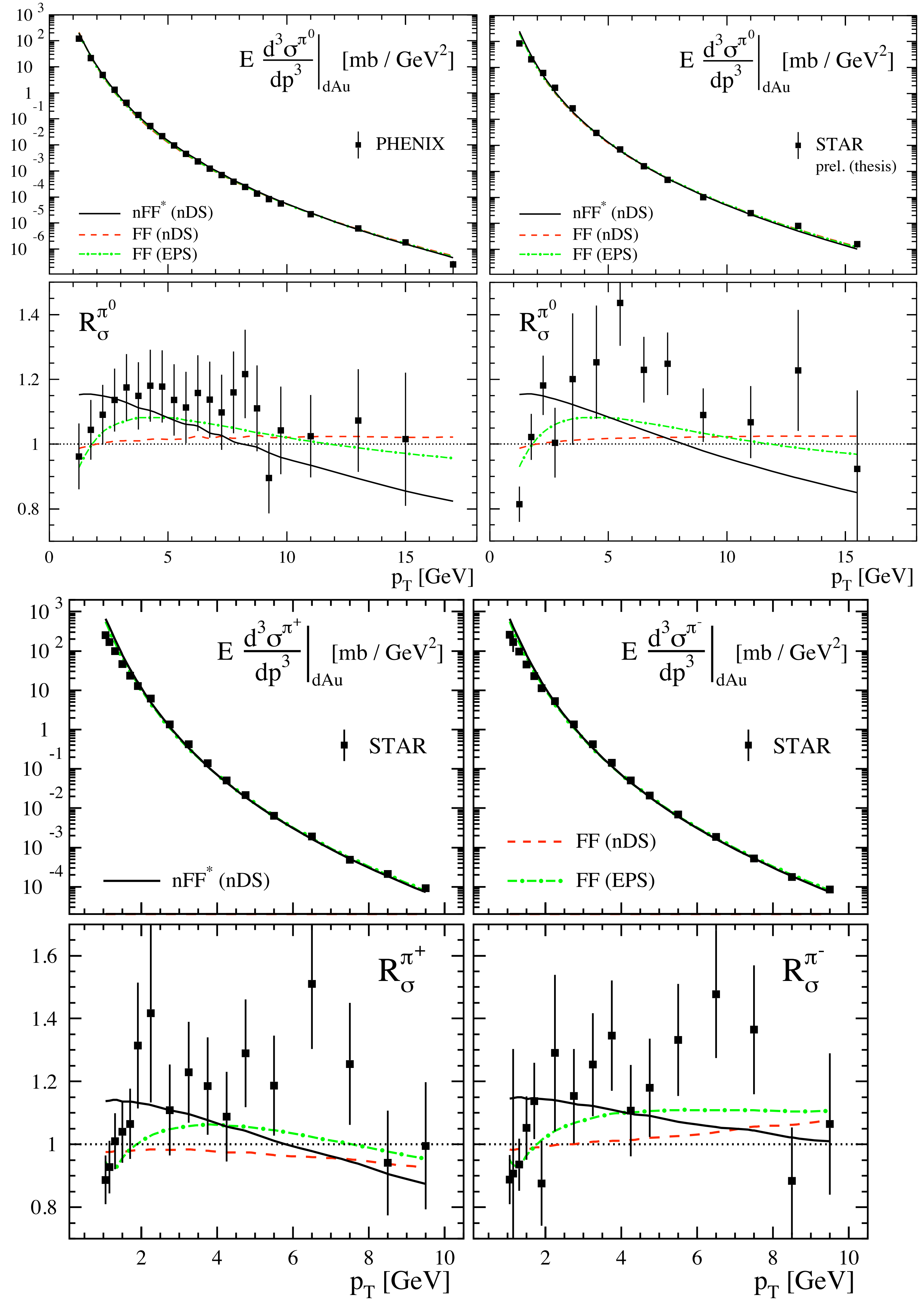


Toy parameterization

pT dependence!

quark/gluon interplay

$\chi^2/d.o.f. \sim 2$



Refined parameterization

quark fragmentation

$$W_q^H(y, A, Q_0^2) = n_q\, y^{\alpha_q}(1-y)^{\beta_q} + n'_q\delta(1-\epsilon_q-y)$$
$$W_g^H(y, A, Q_0^2) = n_g\, y^{\alpha_g}(1-y)^{\beta_g} + n'_g\delta(1-\epsilon_g-y)$$

gluon fragmentation

$$n_i = \lambda^{n_i} + \gamma^{n_i} A^{\delta^{n_i}}$$

smooth A-dependence

$$\lambda^n \sim 1 \qquad \lambda^{n'} \sim 0$$

vanishing effects as $A \longrightarrow 1$

$\sim$ 14 parameters

$\chi^2 = 396.0$

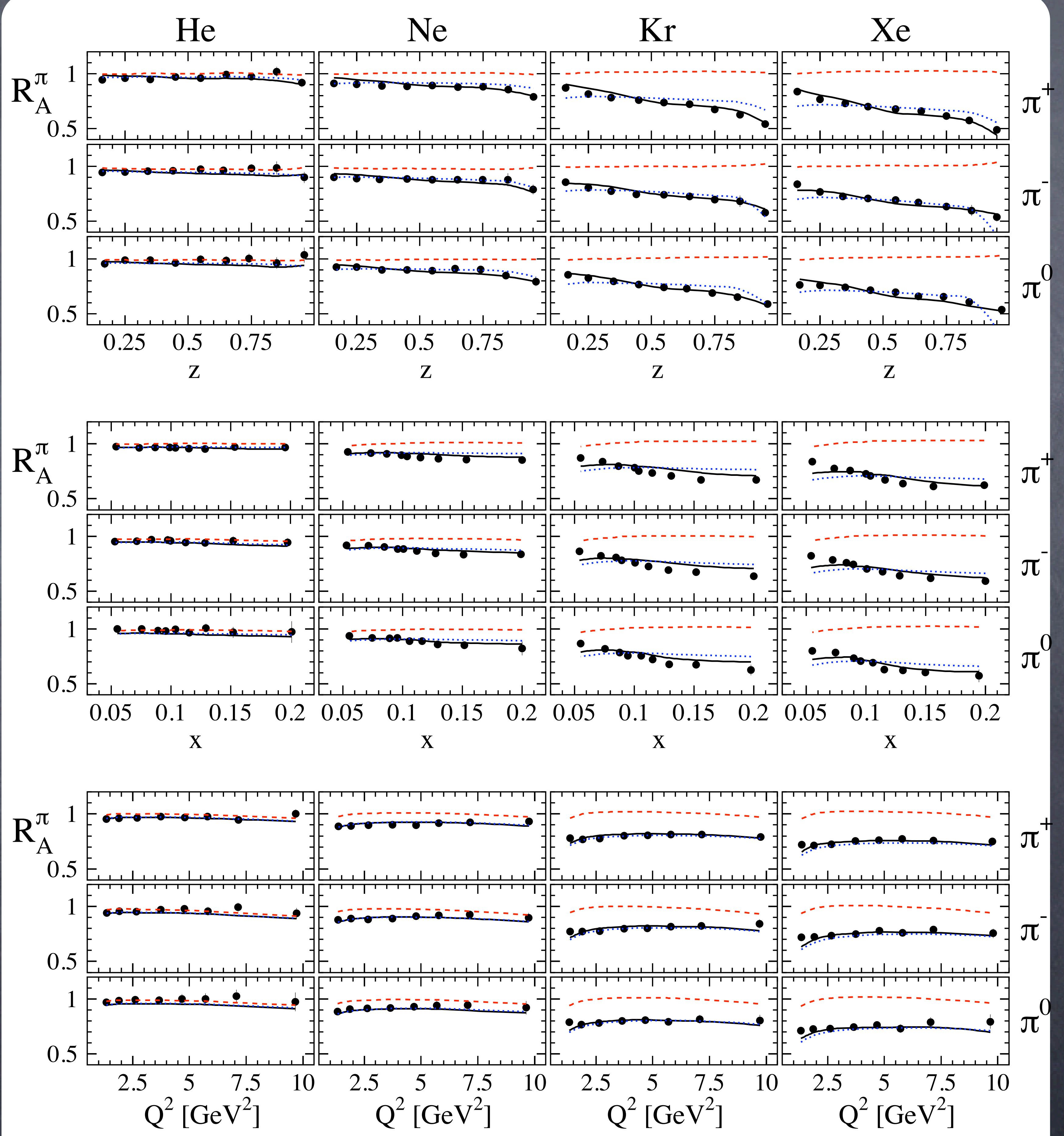
381 data points

14 parameters

$\chi^2/d.o.f = 1.08$

z and x dependence

no conflict with standard evolution



$\chi^2 = 396.0$

381 data points

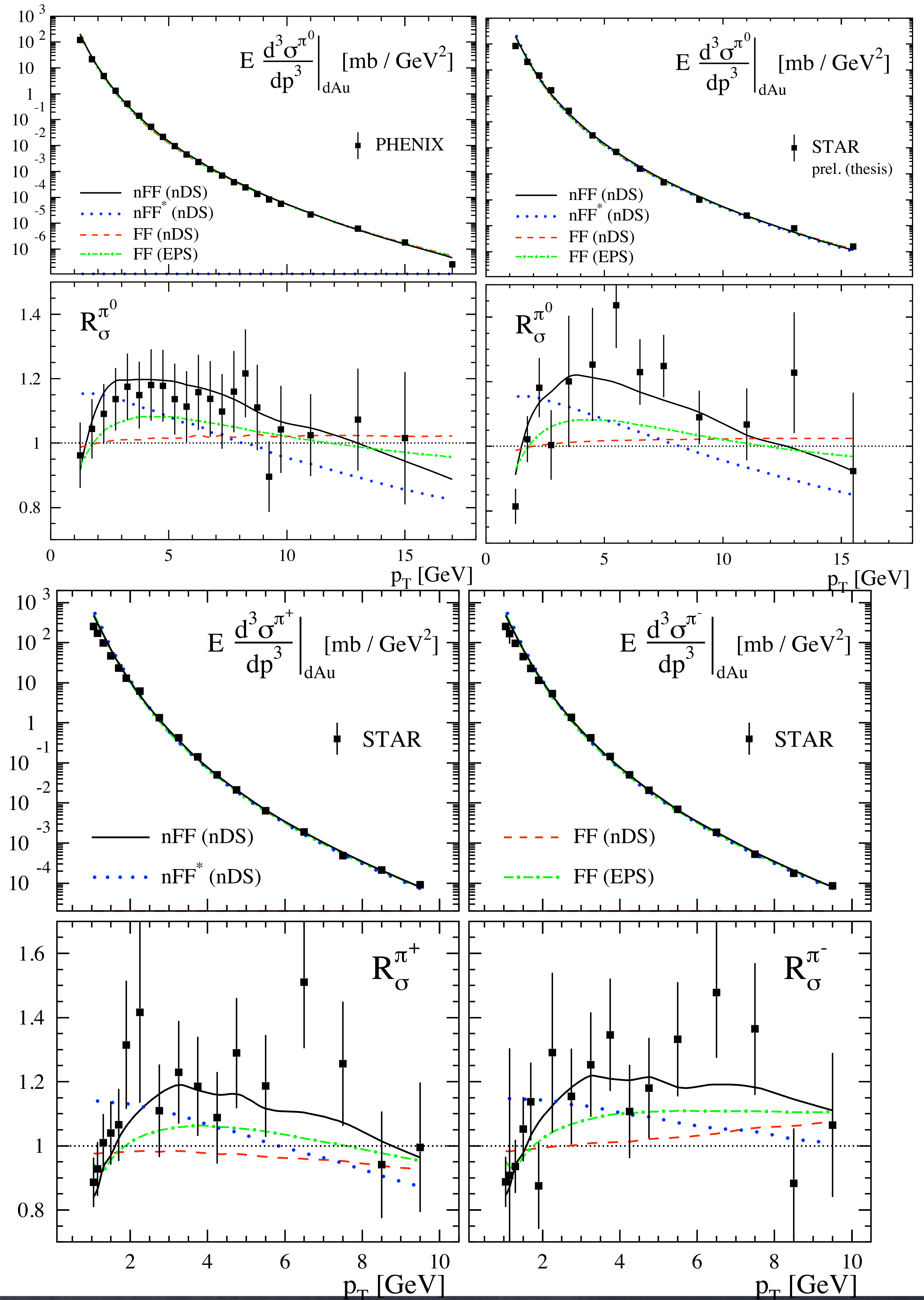
14 parameters

$\chi^2/d.o.f = 1.08$

good description:

normalization

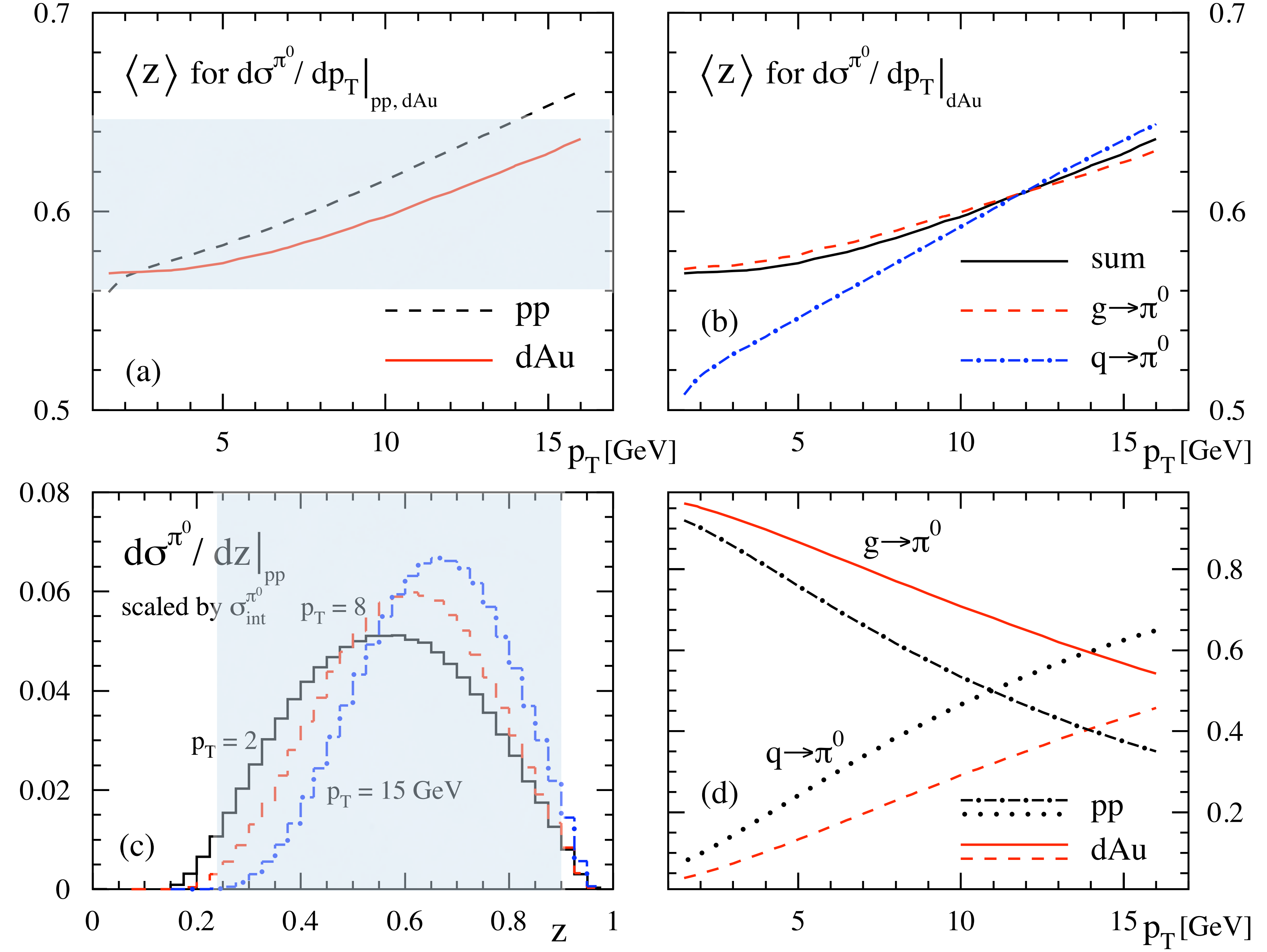
pT dependence



R_{dAu} rates are not trivial!

high-z dominated

"safe" z-range



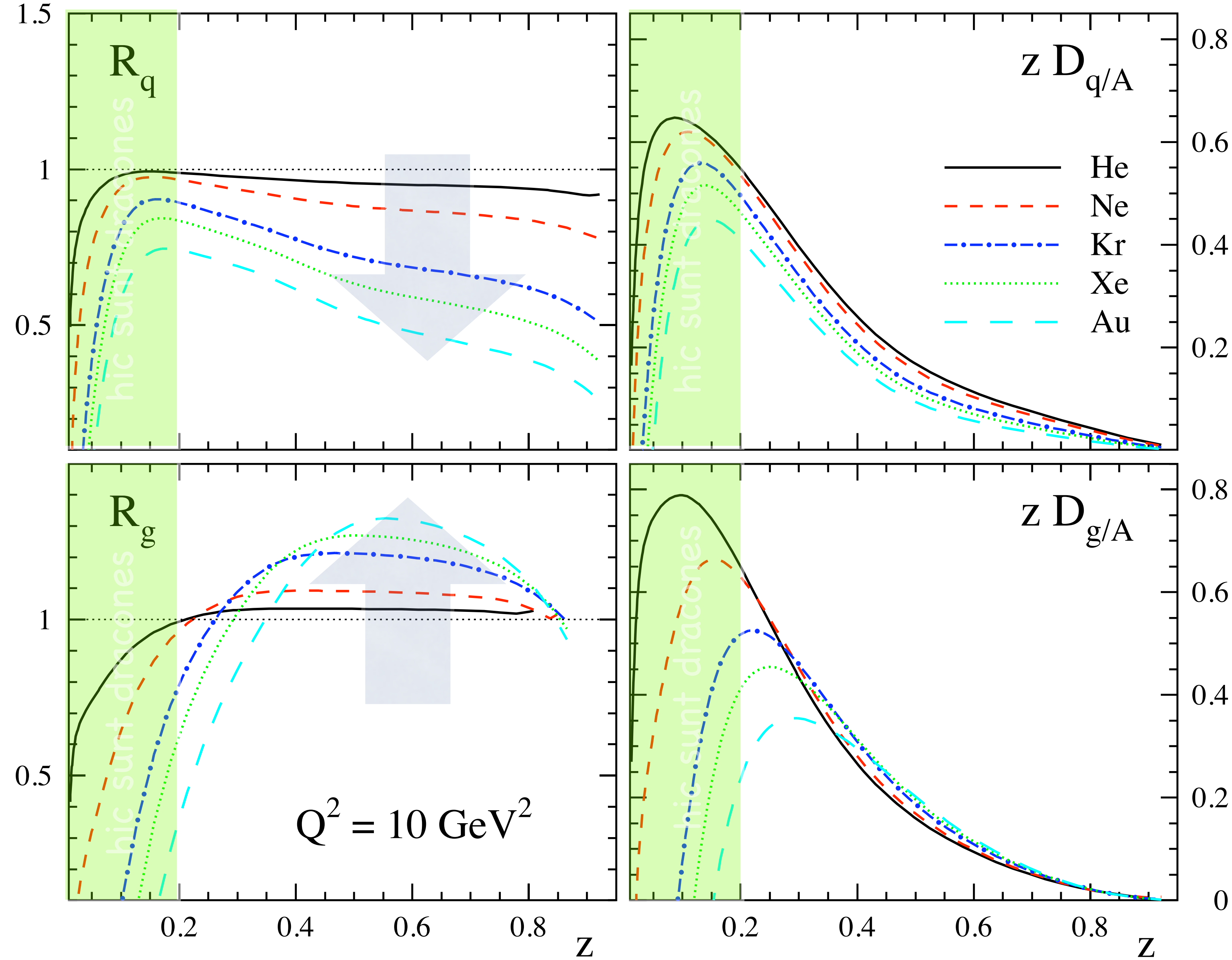
gluon/quark balance

z-dependence

$$R_q = \frac{D_{q/A}(z,Q^2)}{D_{q/p}(z,Q^2)}$$

quarks mimic SIDIS

gluons do the opposite

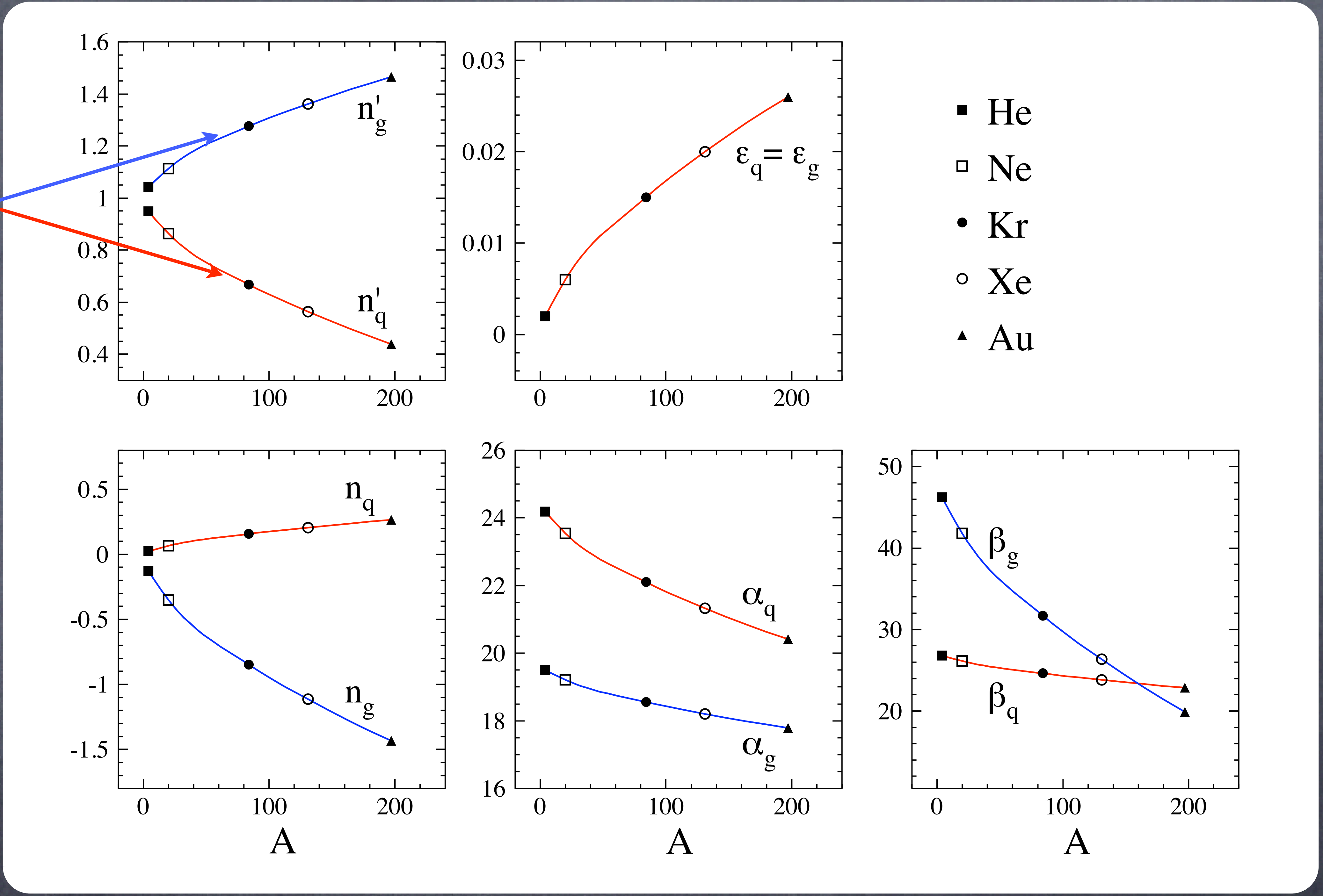


low z behavior not supported by data: artifact?

A-dependence

compensation?

almost linear



$$W_q^H(y, A, Q_0^2) = n_q\, y^{\alpha_q}(1-y)^{\beta_q} + n'_q \delta(1-\epsilon_q - y)$$
$$W_g^H(y, A, Q_0^2) = n_g\, y^{\alpha_g}(1-y)^{\beta_g} + n'_g \delta(1-\epsilon_g - y)$$

Centrality classes

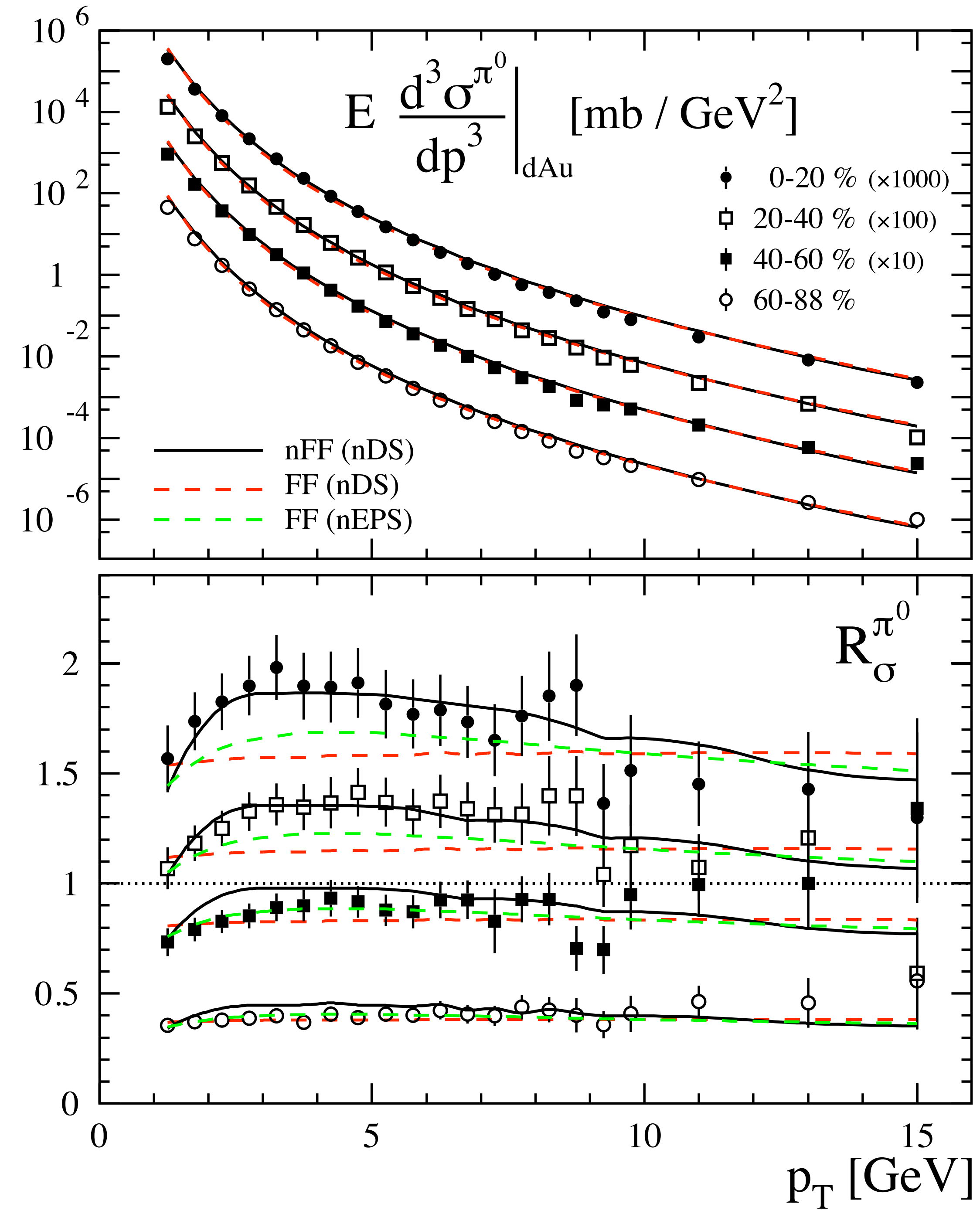
nFFs as an average:

$\sim$ underestimate central

$\sim$ overestimate peripheral

scale factor

$$\mathcal{C} \equiv \left\langle \frac{E\, d^3\sigma^{\pi^0}/dp^3\big|_{dAu}^{c.c.}}{E\, d^3\sigma^{\pi^0}/dp^3\big|_{dAu}^{m.b.}} \right\rangle_{c.c.}$$



Conclusions

A NLO pQCD factorizable scheme with effective nFF

process-independent universal nFF standard evolution equations

A, z, Q^2, ν and pT-dependence of SIDIS and dAU data

effective nFFs as tools for "distilling" data

changes in quark fragmentation "look like" mostly energy loss

effects in gluons are quite different

cross sections and rates result from non trivial interplay

predictions based on nFFs can be tested by upcoming data

JLAB, RHIC, LHC and in the future at EIC

dAu or pA data can help to further constrain nPDFs,

serve the reference for AA data,

provided we have a clear picture of nFF