Medium-modified fragmentation functions and nPDFs

Rodolfo Sassot
Universidad de Buenos Aires

Progress in high pT phyisics at RHIC, Brookhaven, March 2010

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in collaboration with M. Stratmann and P. Zurita

Phys.Rev.D81 054001 (2010)

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Motivation

➡ high pT hadroproduction in pA and AA: RHIC, LHC

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- study hadronization in different environments
- factorization & universality in a nucleus?
- relevant for the extraction of nPDFs

Phenomenology:

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Early evidence:

SLAC Phys.Rev.Lett. 40, 1624 (1978)
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Precise dAu:

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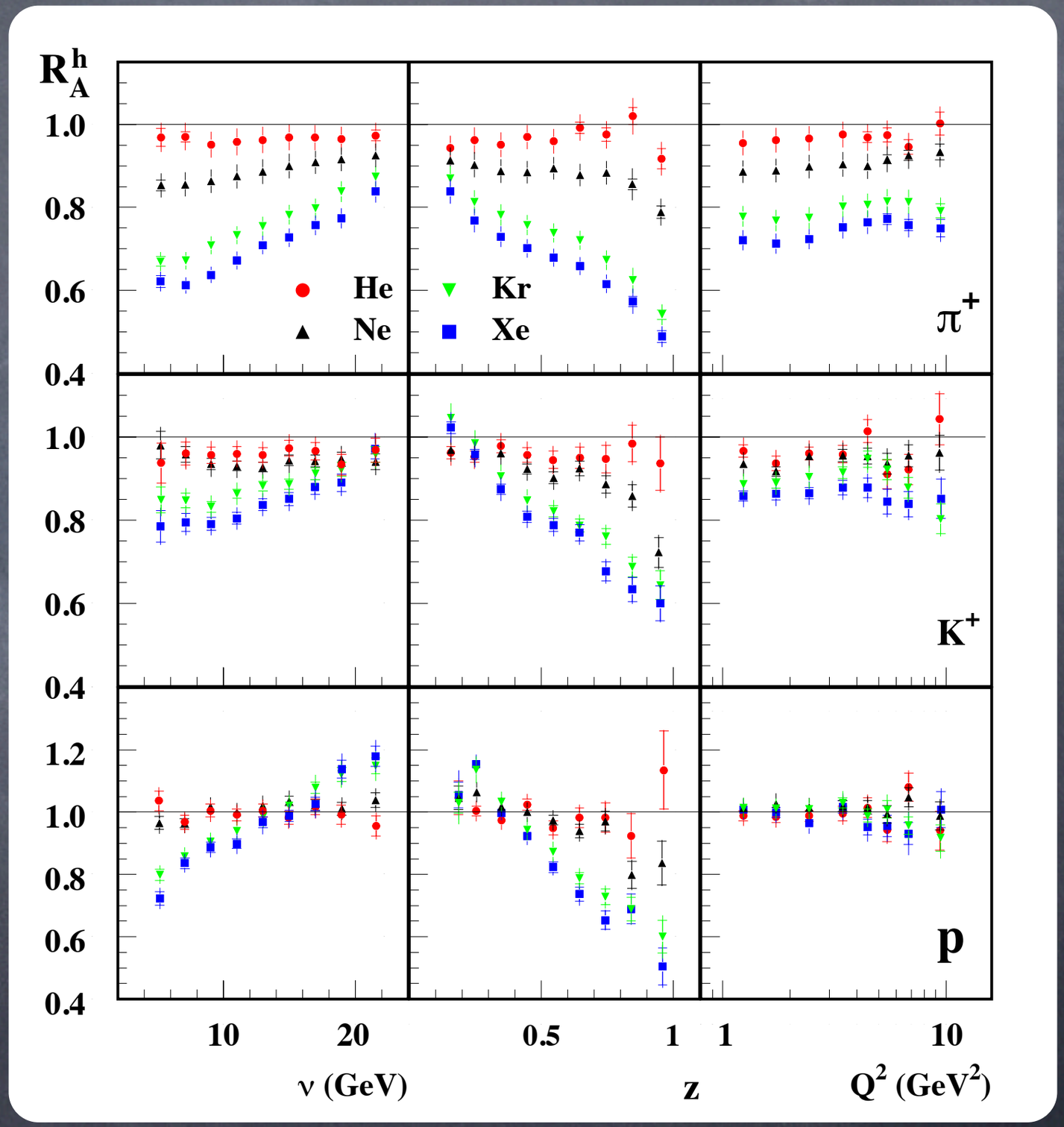
Phenomenology:



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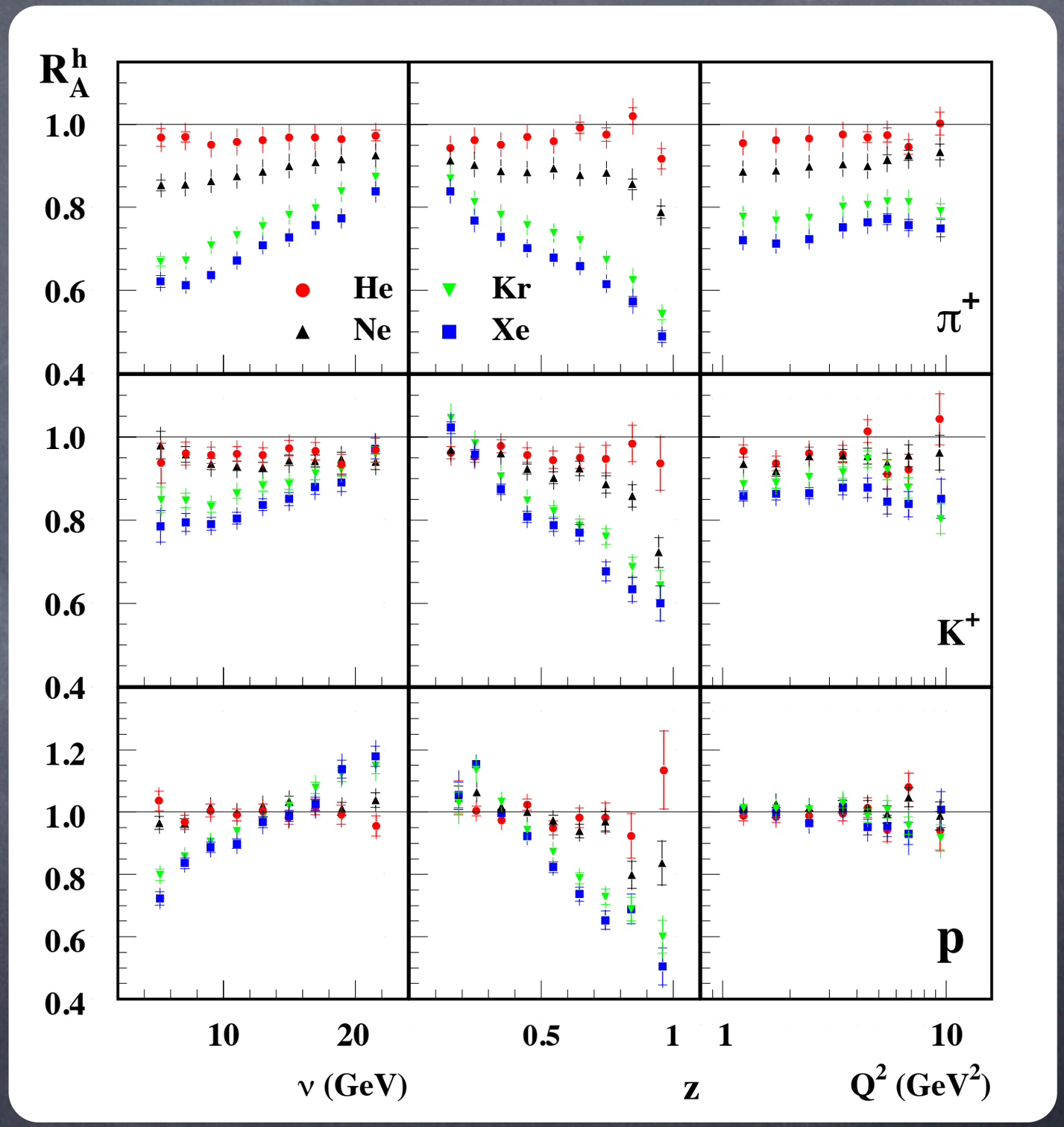

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$$R(z, Q^2, \nu) = \frac{\left(\frac{N^{sidis}}{N^{inc}}\right)_A}{\left(\frac{N^{sidis}}{N^{inc}}\right)_D}$$

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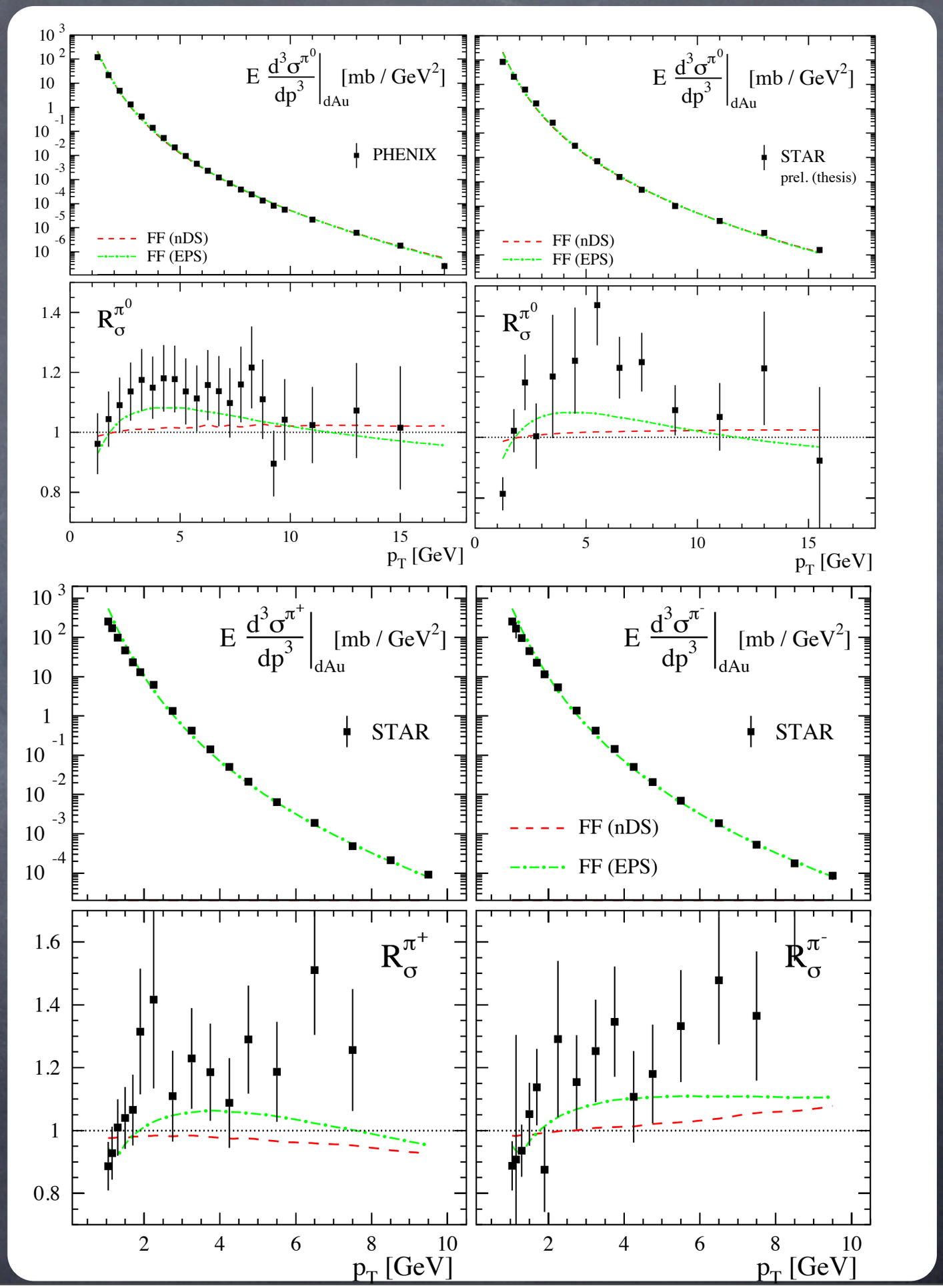

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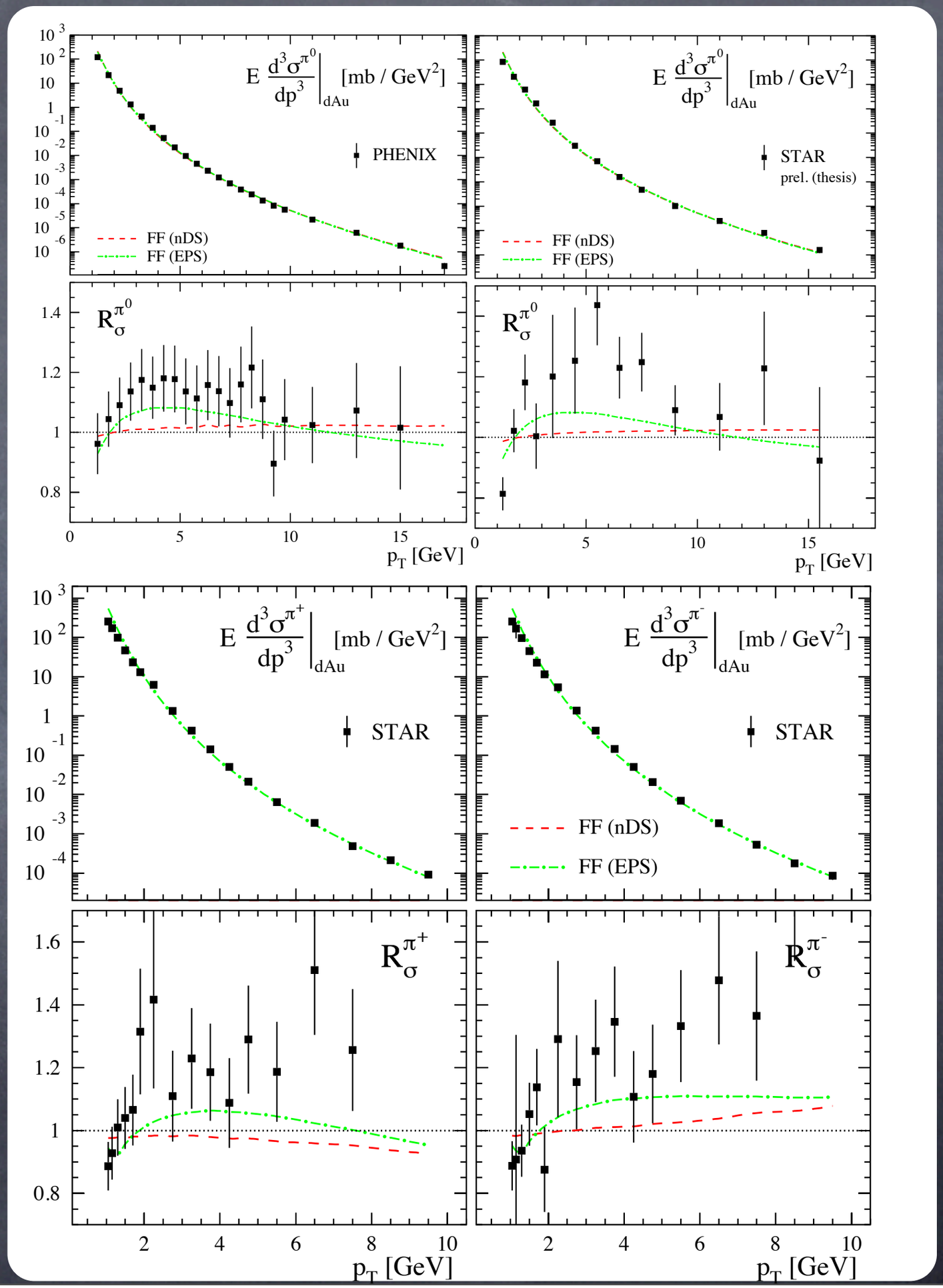

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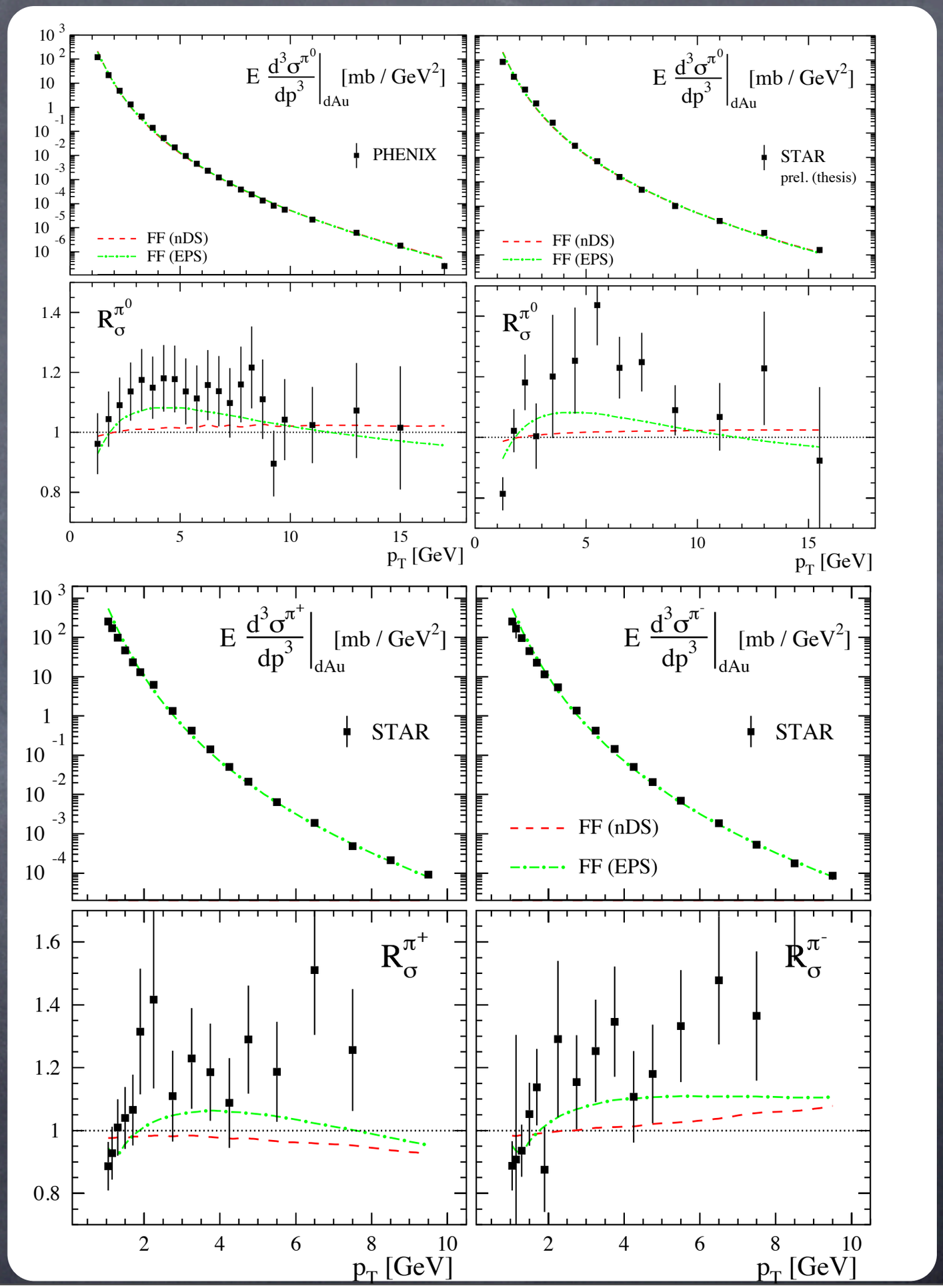
$$R^H_\sigma(A, p_T) \equiv \frac{1}{2\,A} \frac{E\, d^3\sigma^H/dp^3\big|_{dA}}{E\, d^3\sigma^h/dp^3\big|_{pp}}$$



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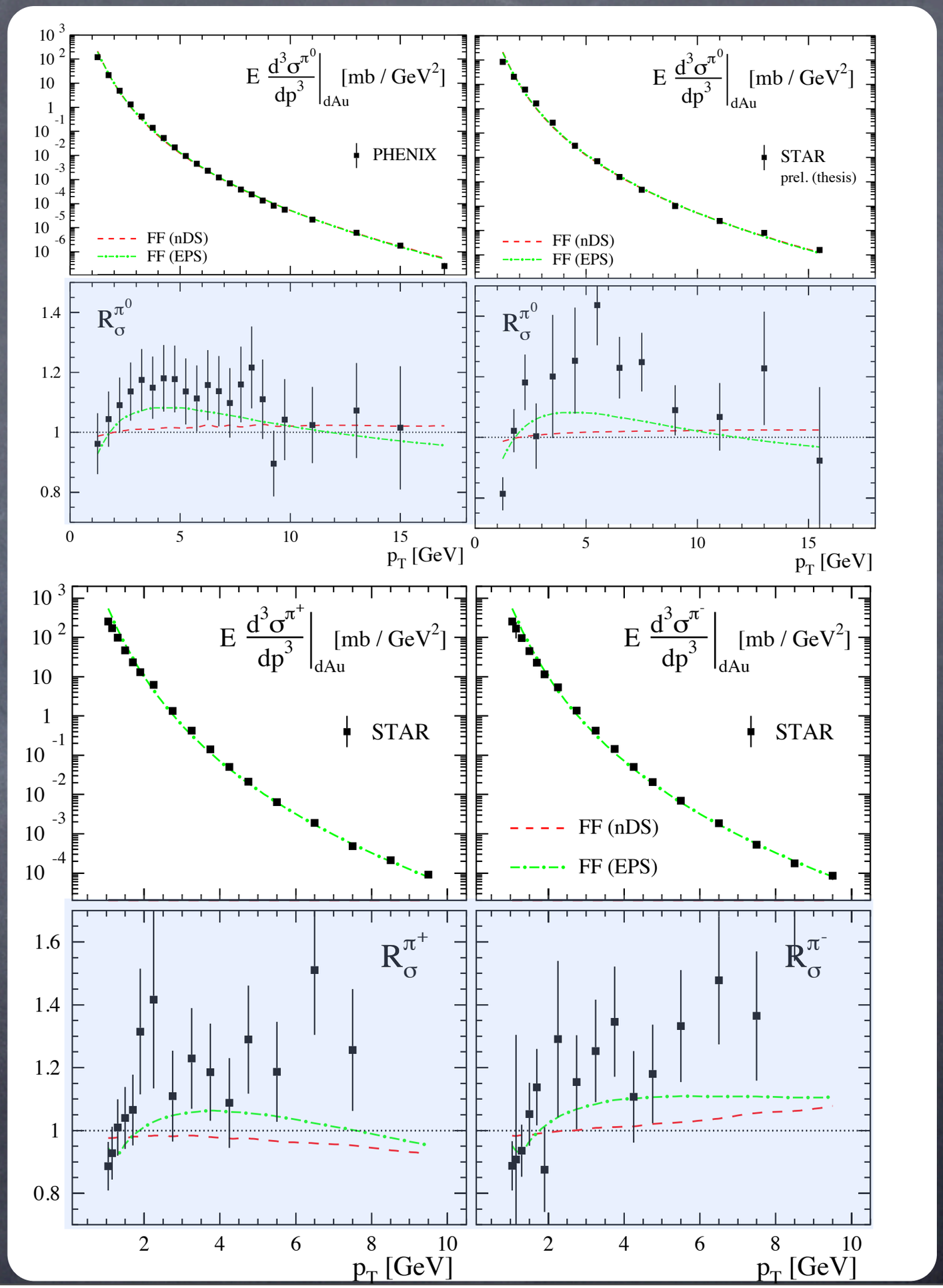

$$R_\sigma^H(A, p_T) \equiv \frac{1}{2\,A}\,\frac{E\,d^3\sigma^H/dp^3\big|_{dA}}{E\,d^3\sigma^h/dp^3\big|_{pp}}$$

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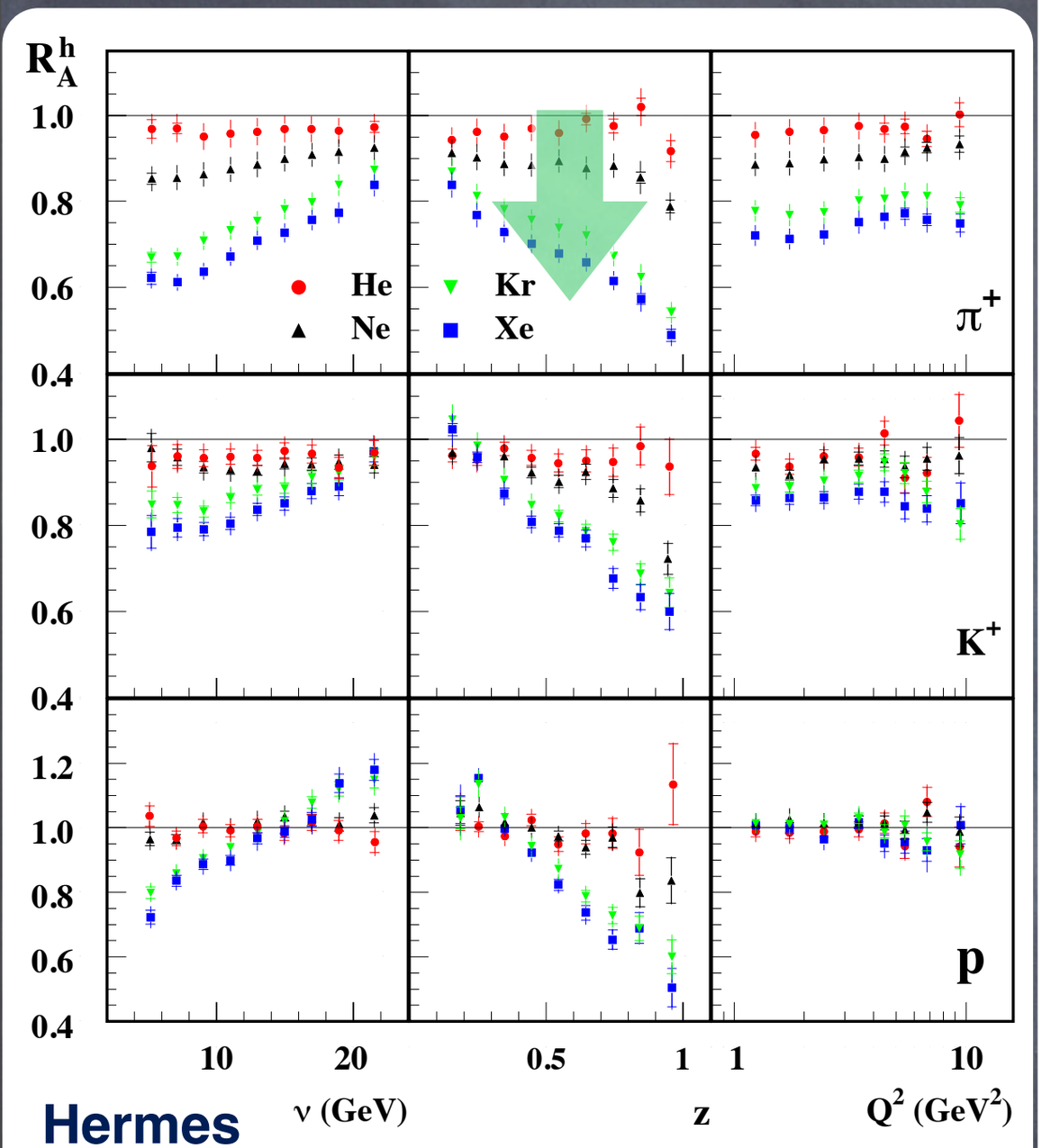

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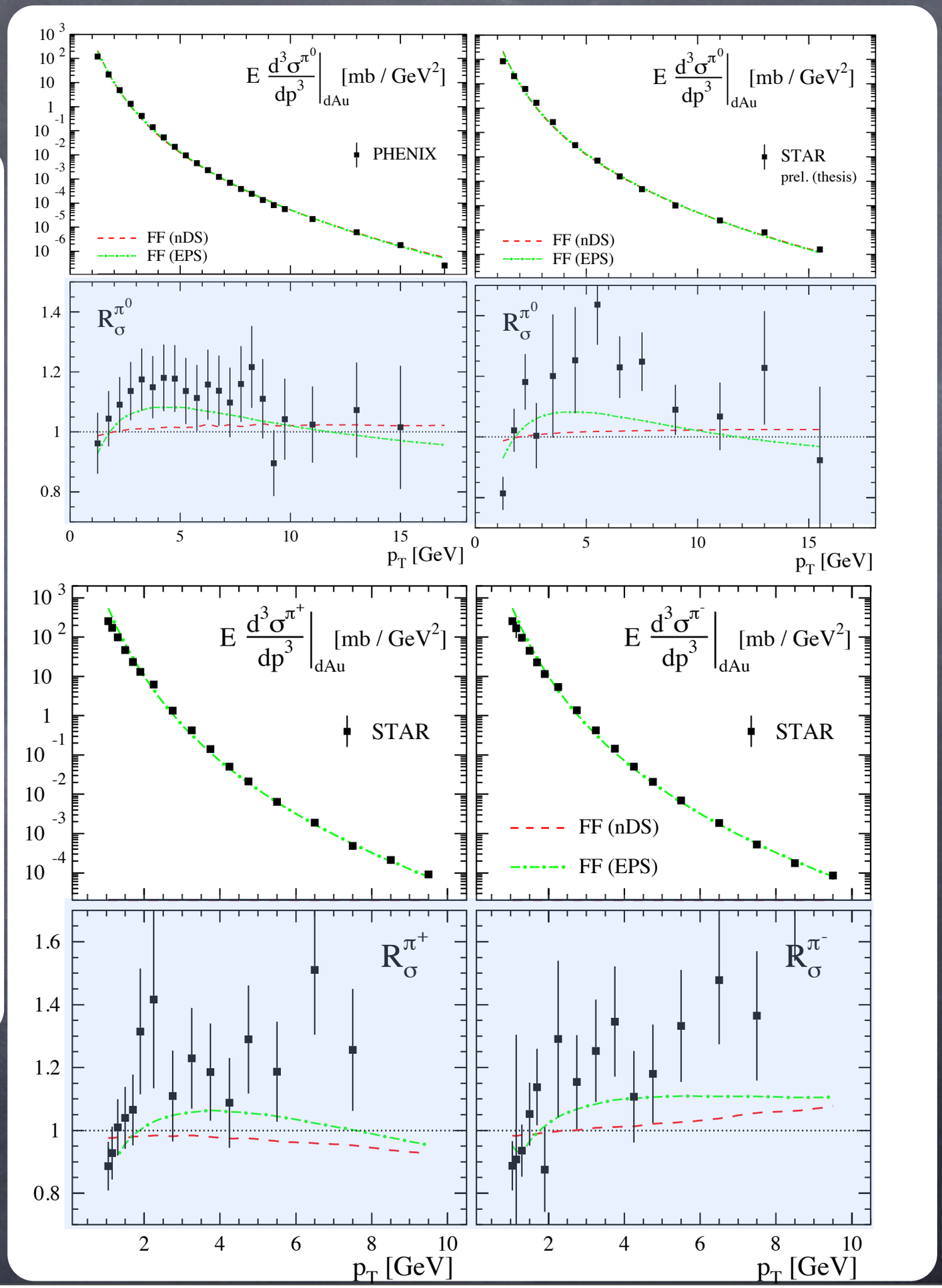

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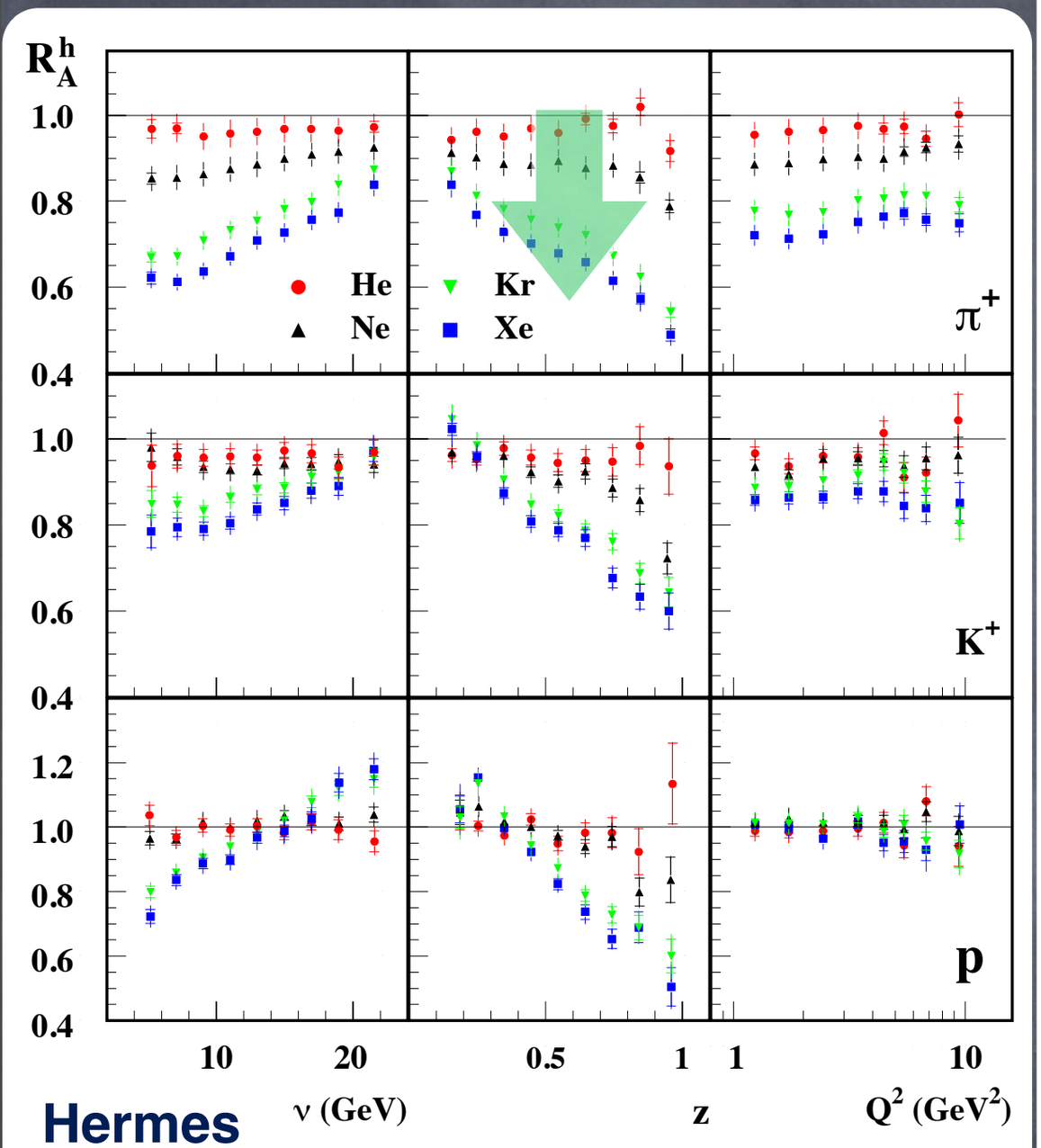

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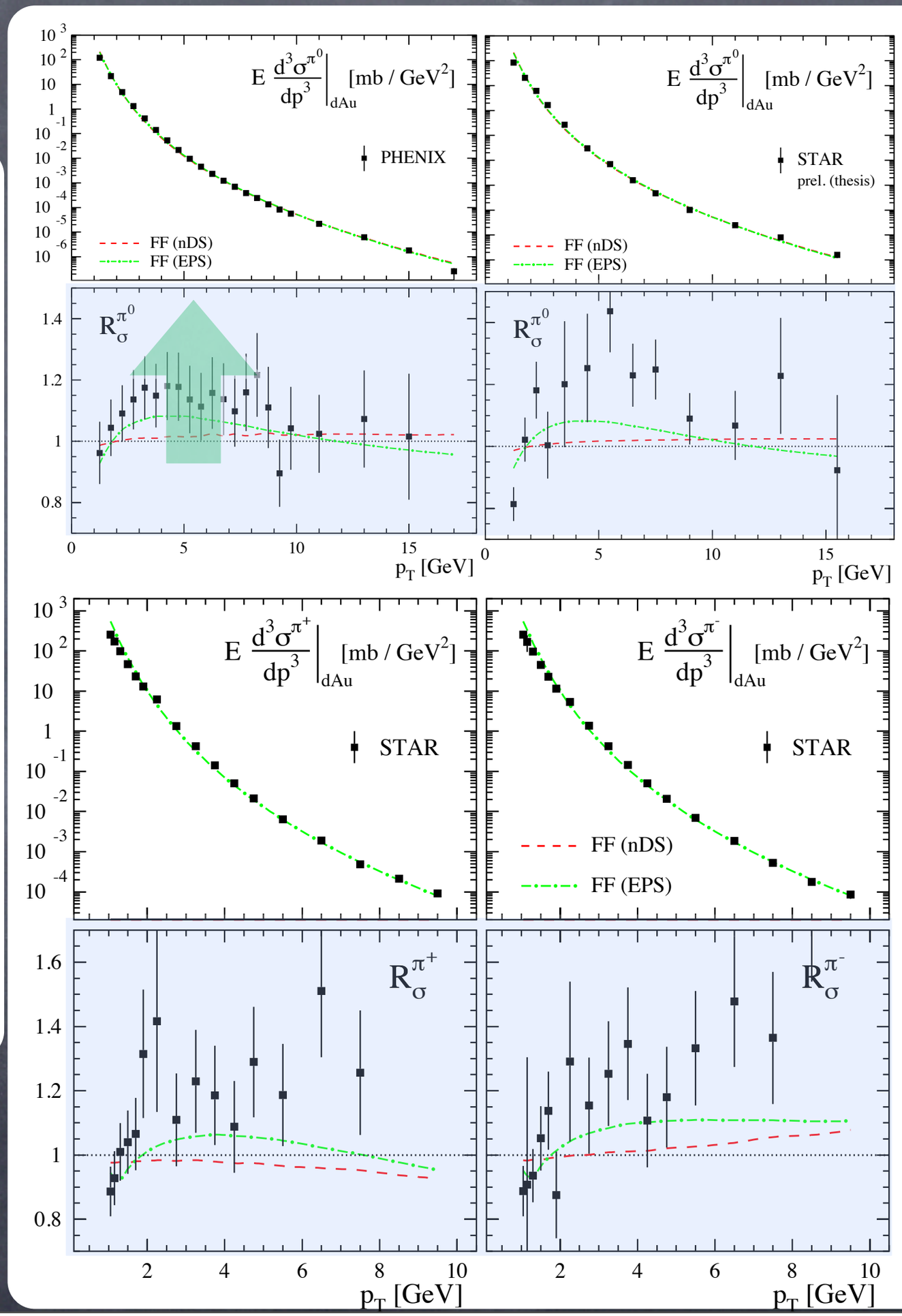
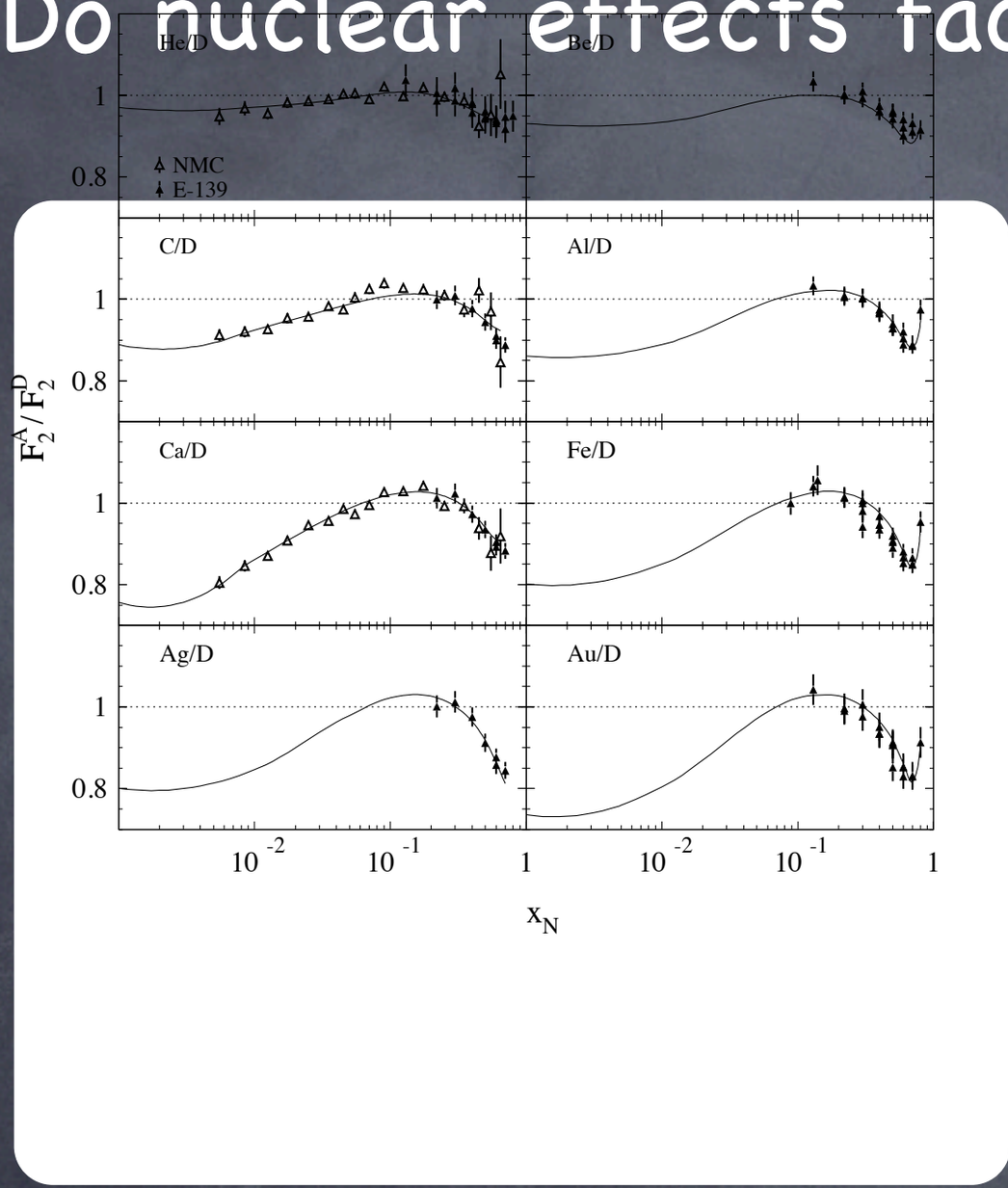
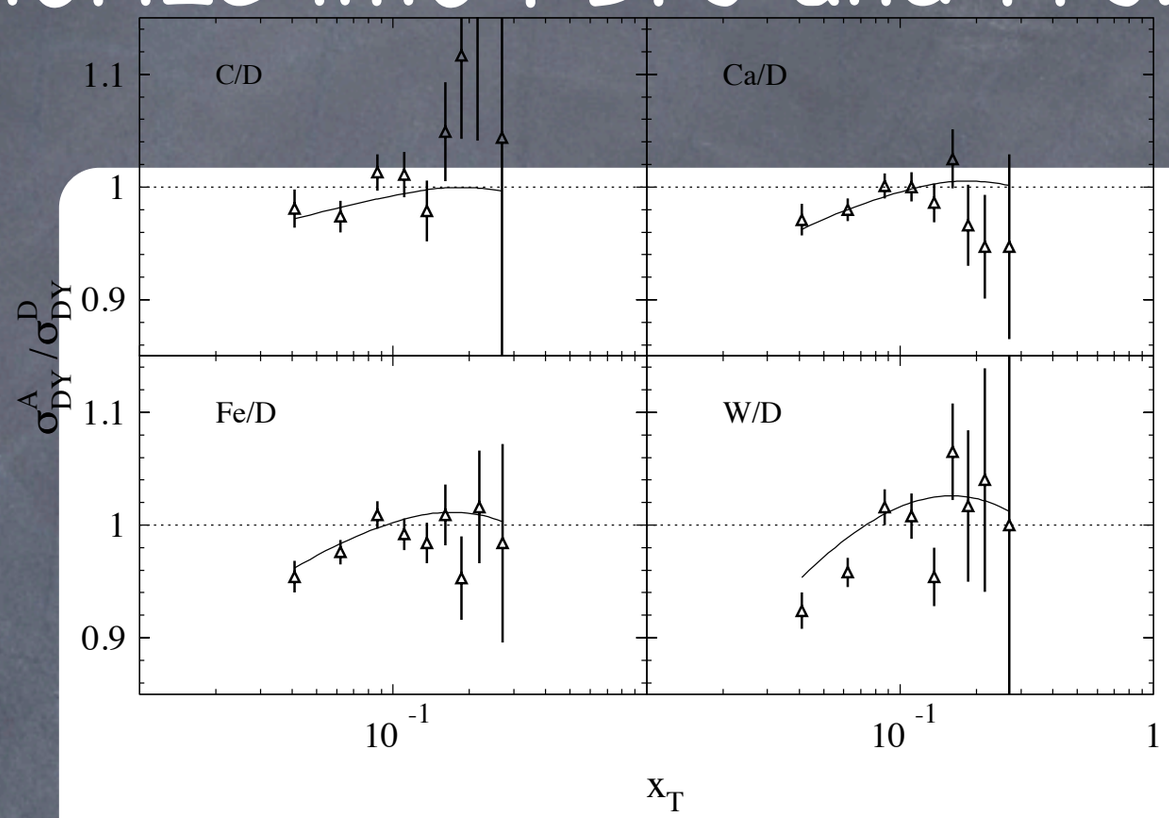


Do nuclear effects factorize into PDFs and FFs?



DIS rates to D



Drell Yan rates to D

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

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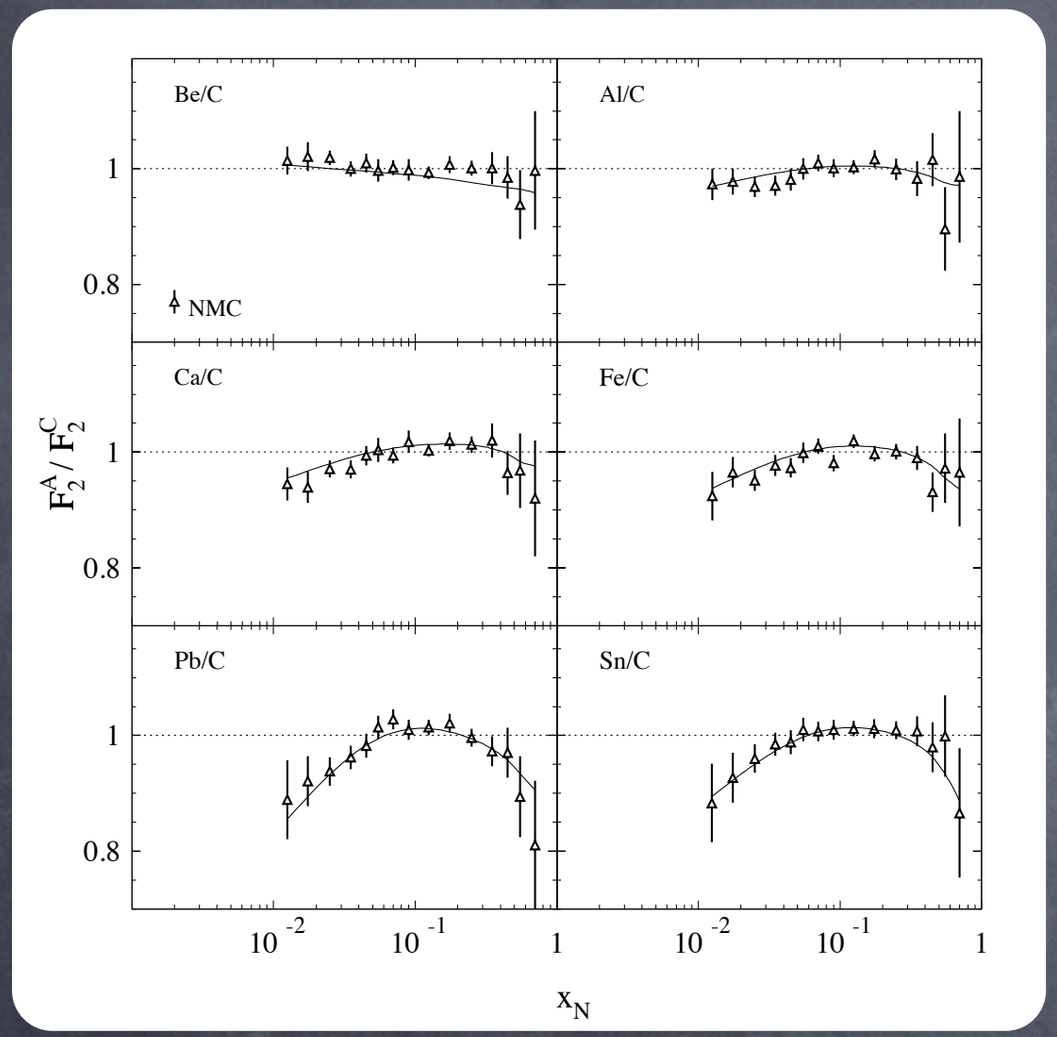
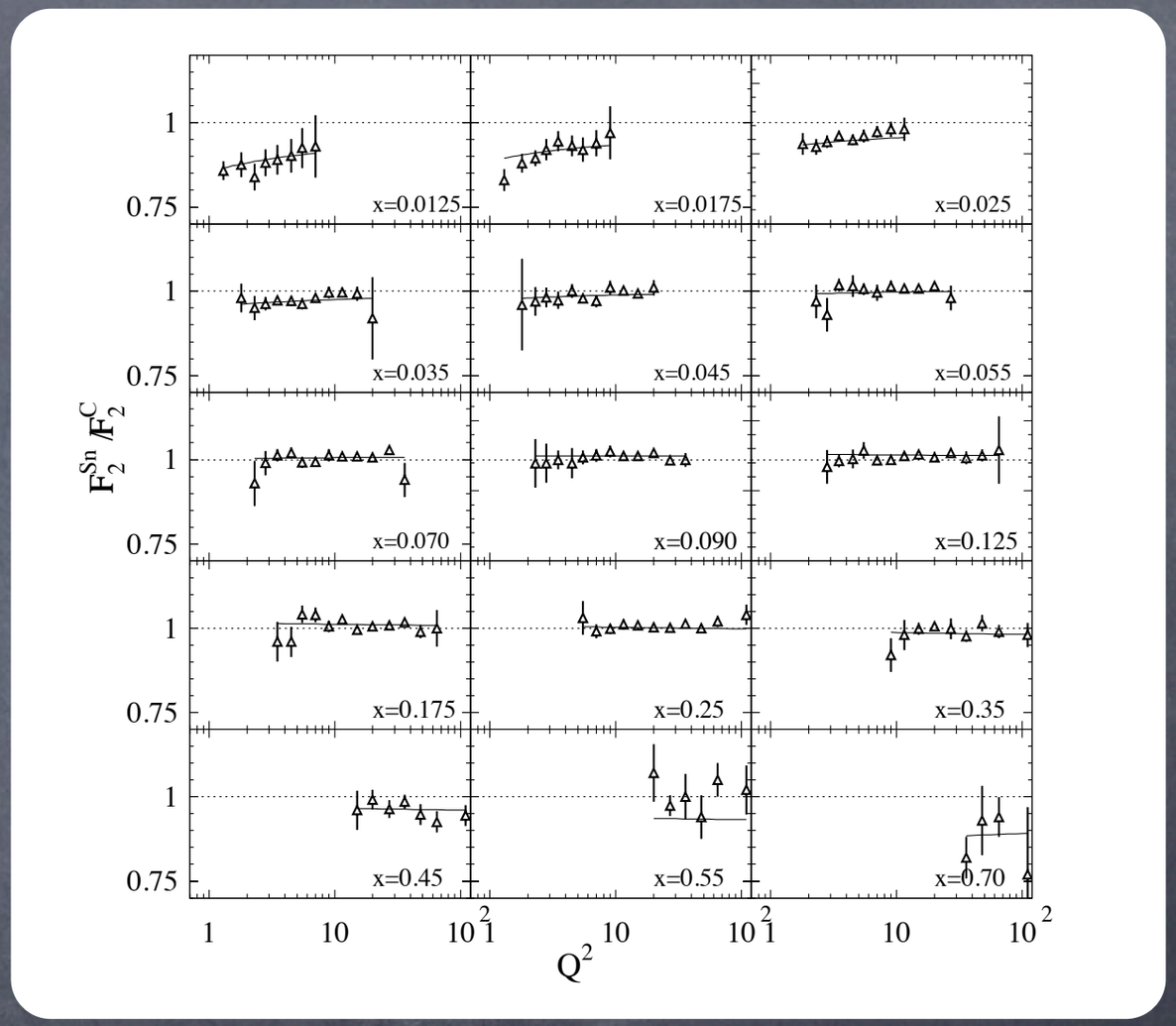


DIS rates to C



scale dependence

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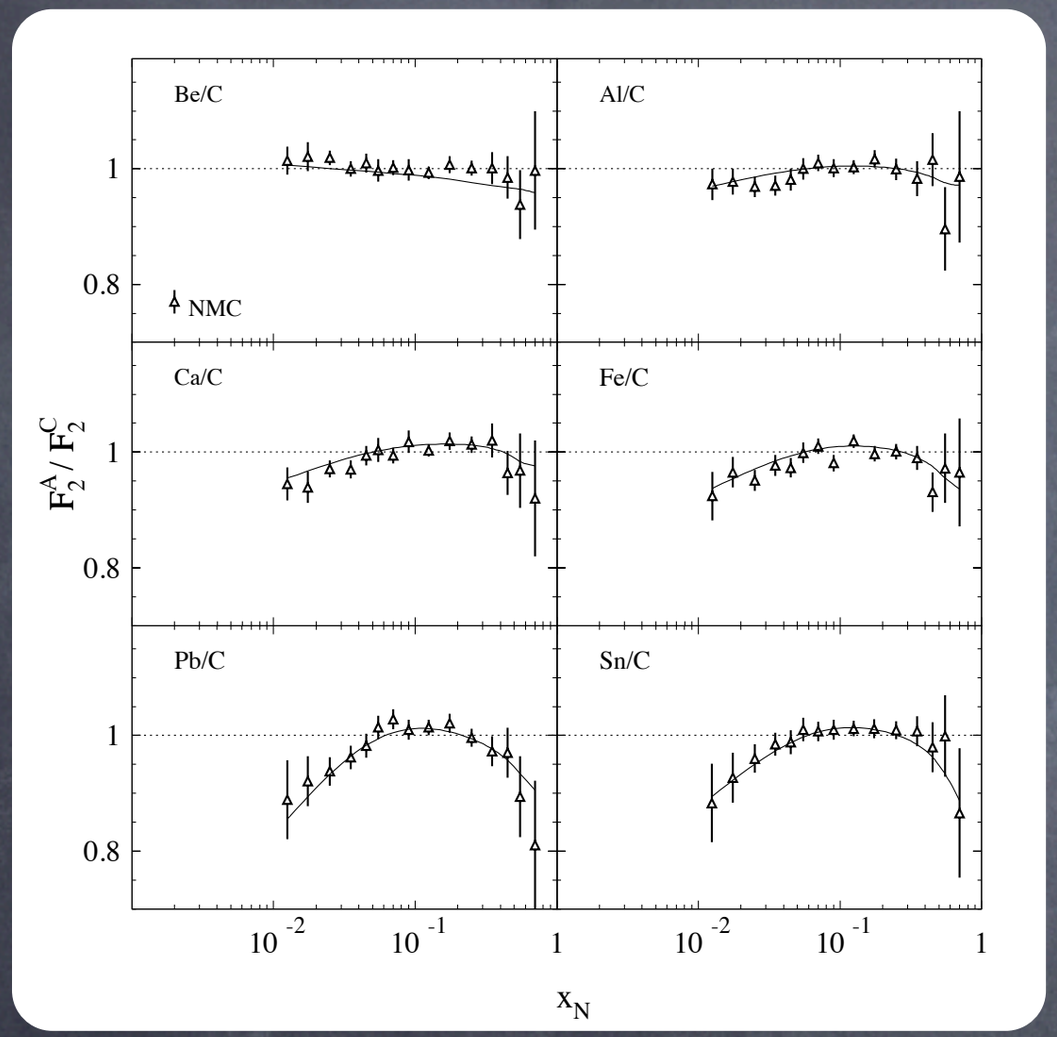

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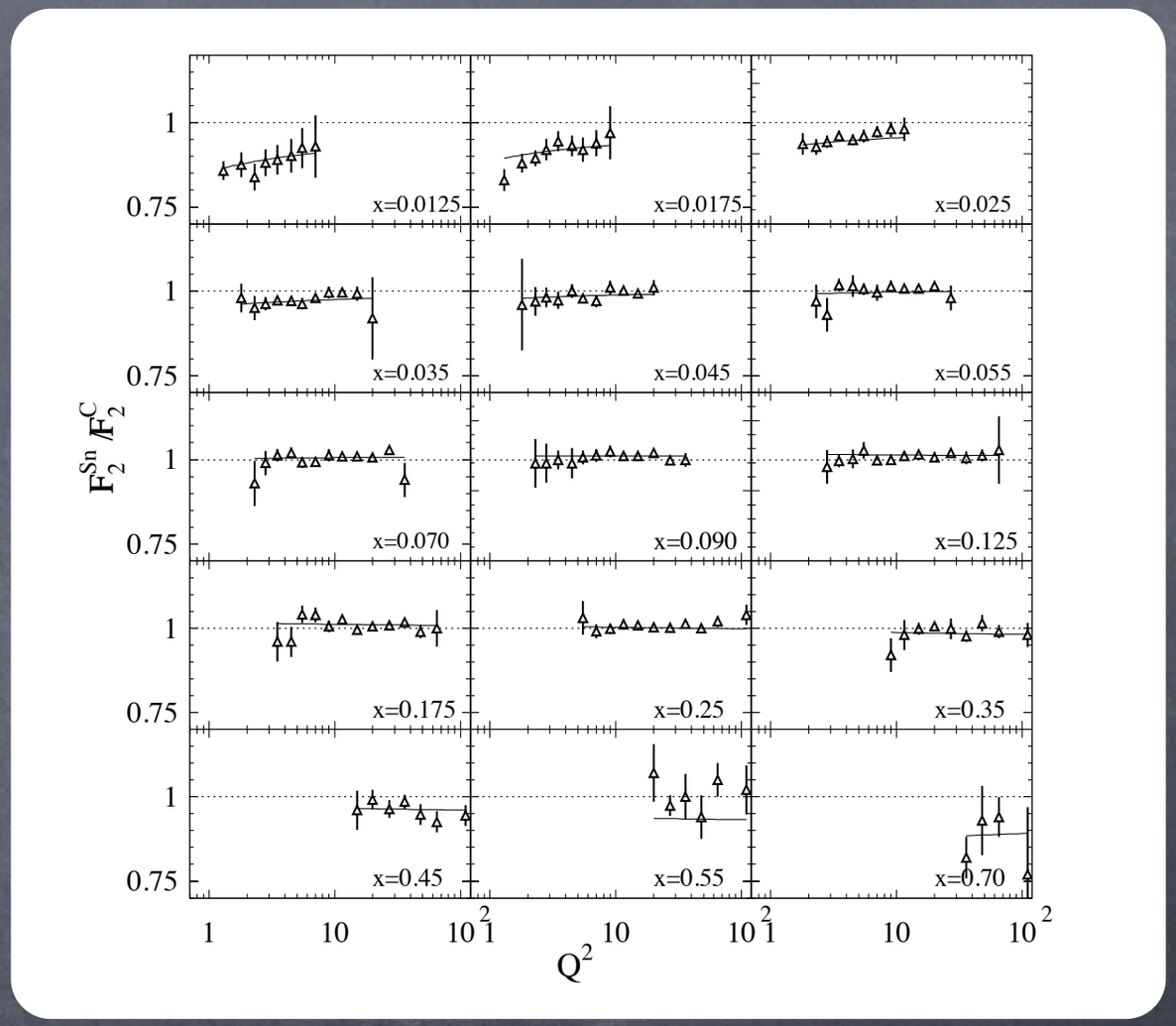

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D.de Florian R.Sassot Phys.Rev.D69 074028 (2004)
M.Hirai, S.Kumano, T.H.Nagai Phys.Rev.C76 065207 (2007)
K.Eskola, H.Paukkunen, C.A.Salgado, JHEP0904, 065 (2009)

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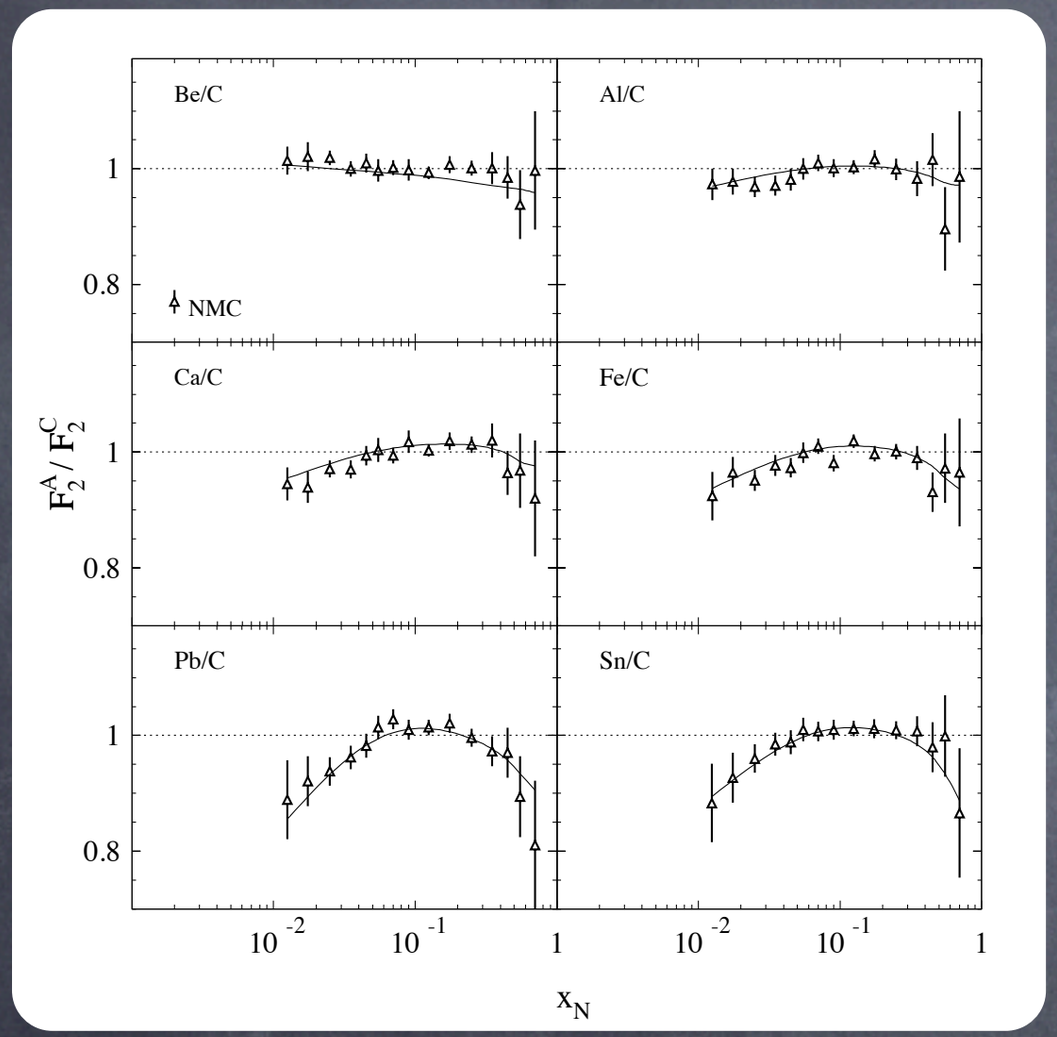

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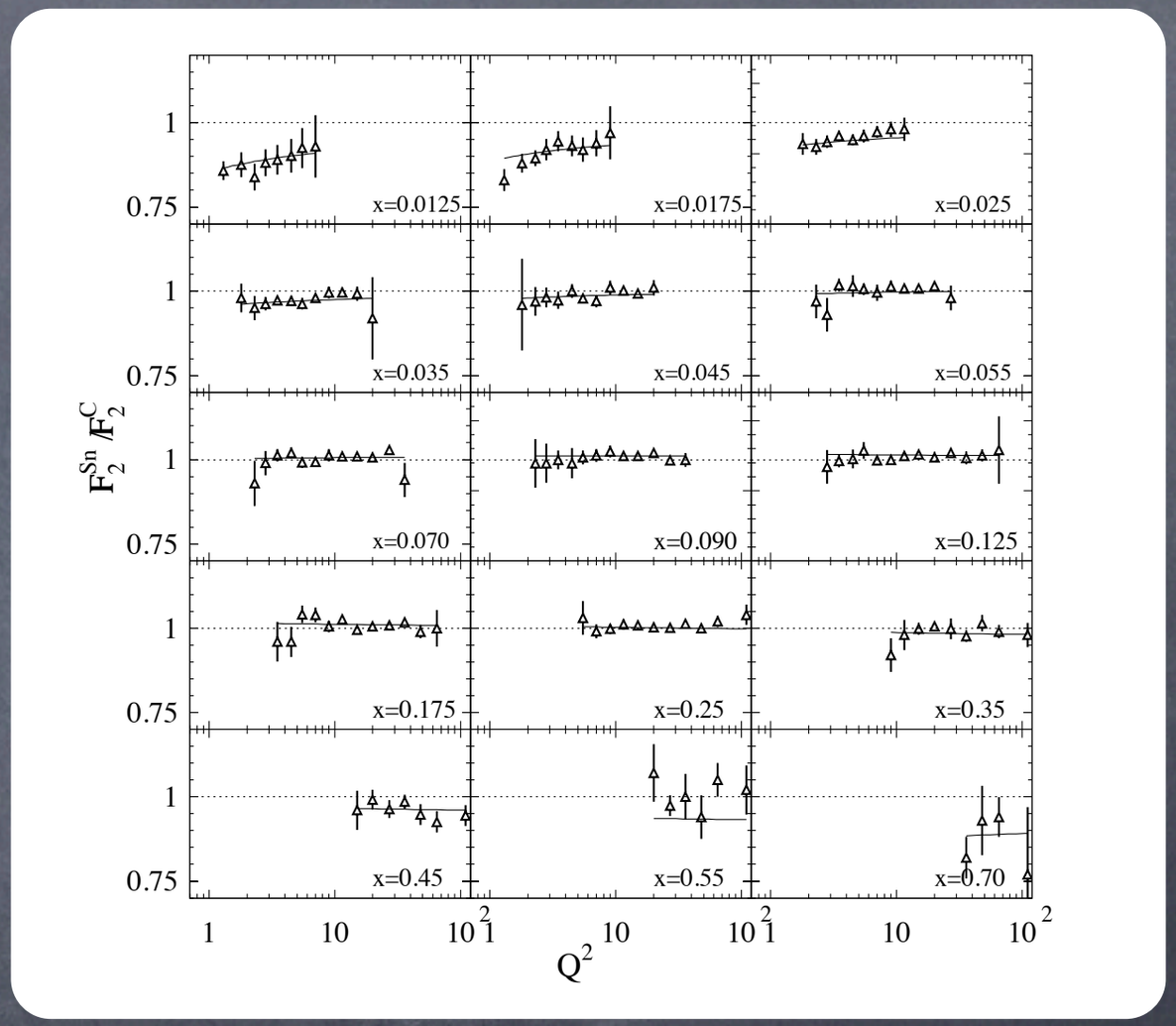

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well defined framework beyond LO?

constrained by data through global NLO fit?

Why it could not work:

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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)

nPDFs digression:

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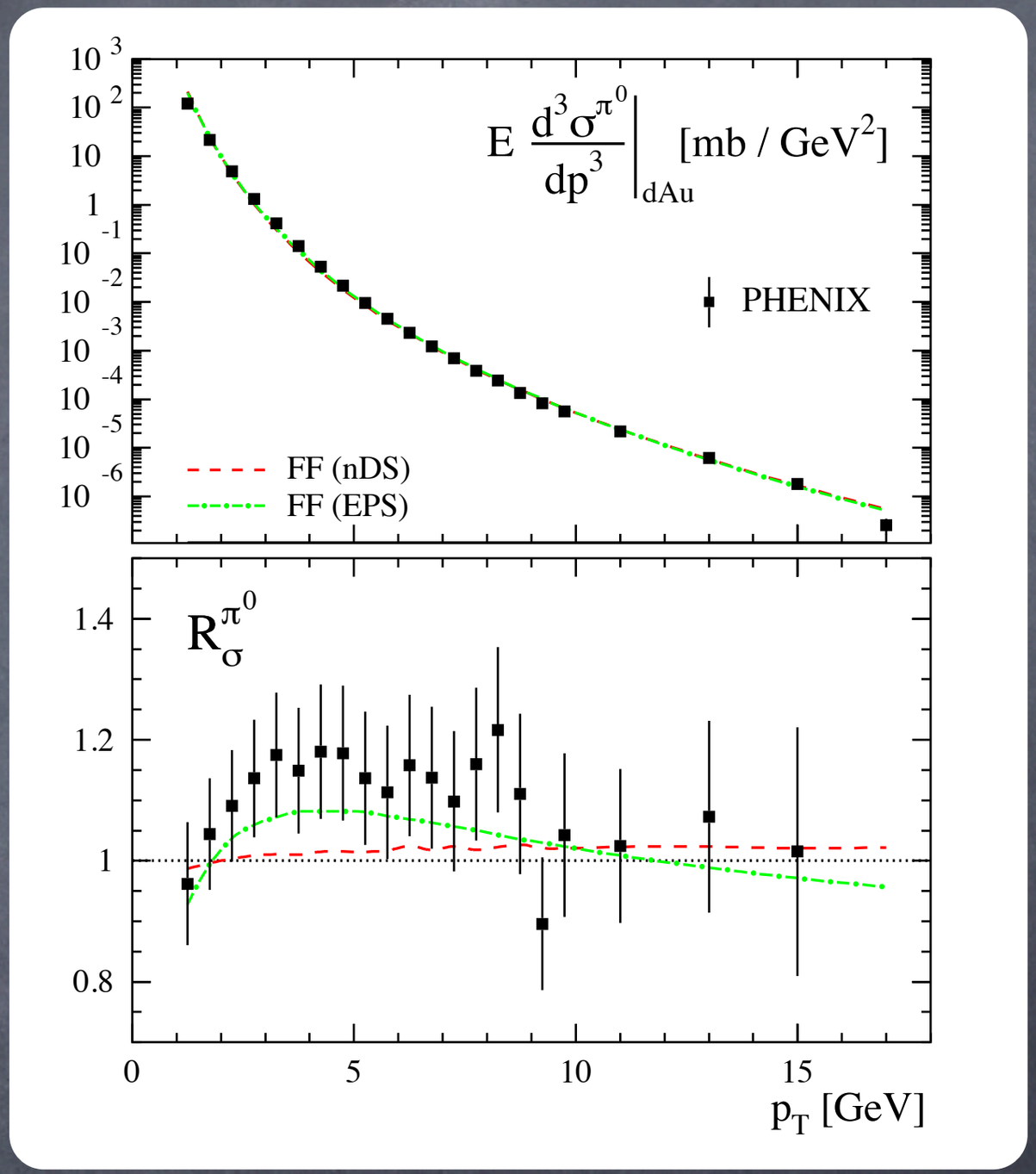

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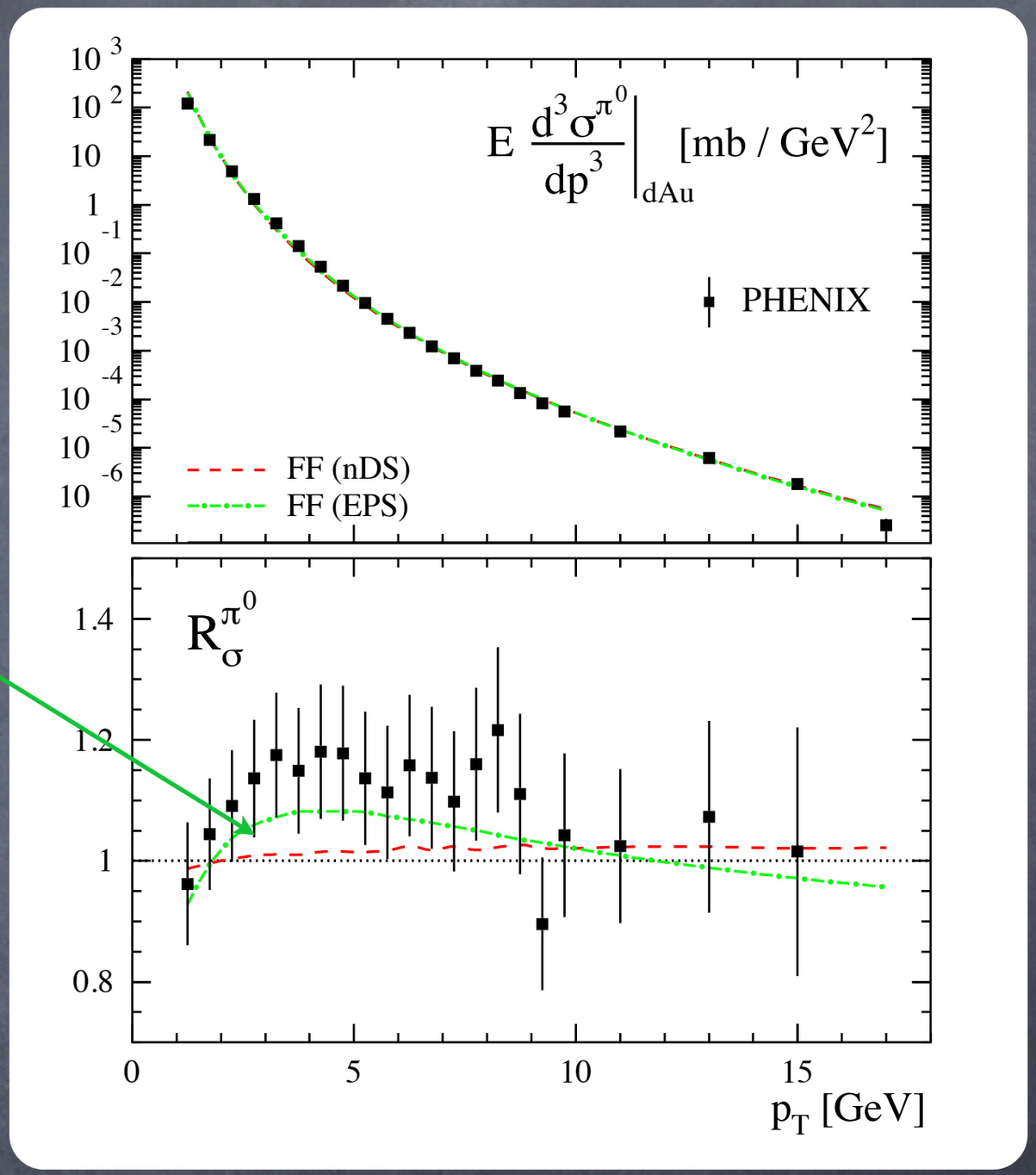

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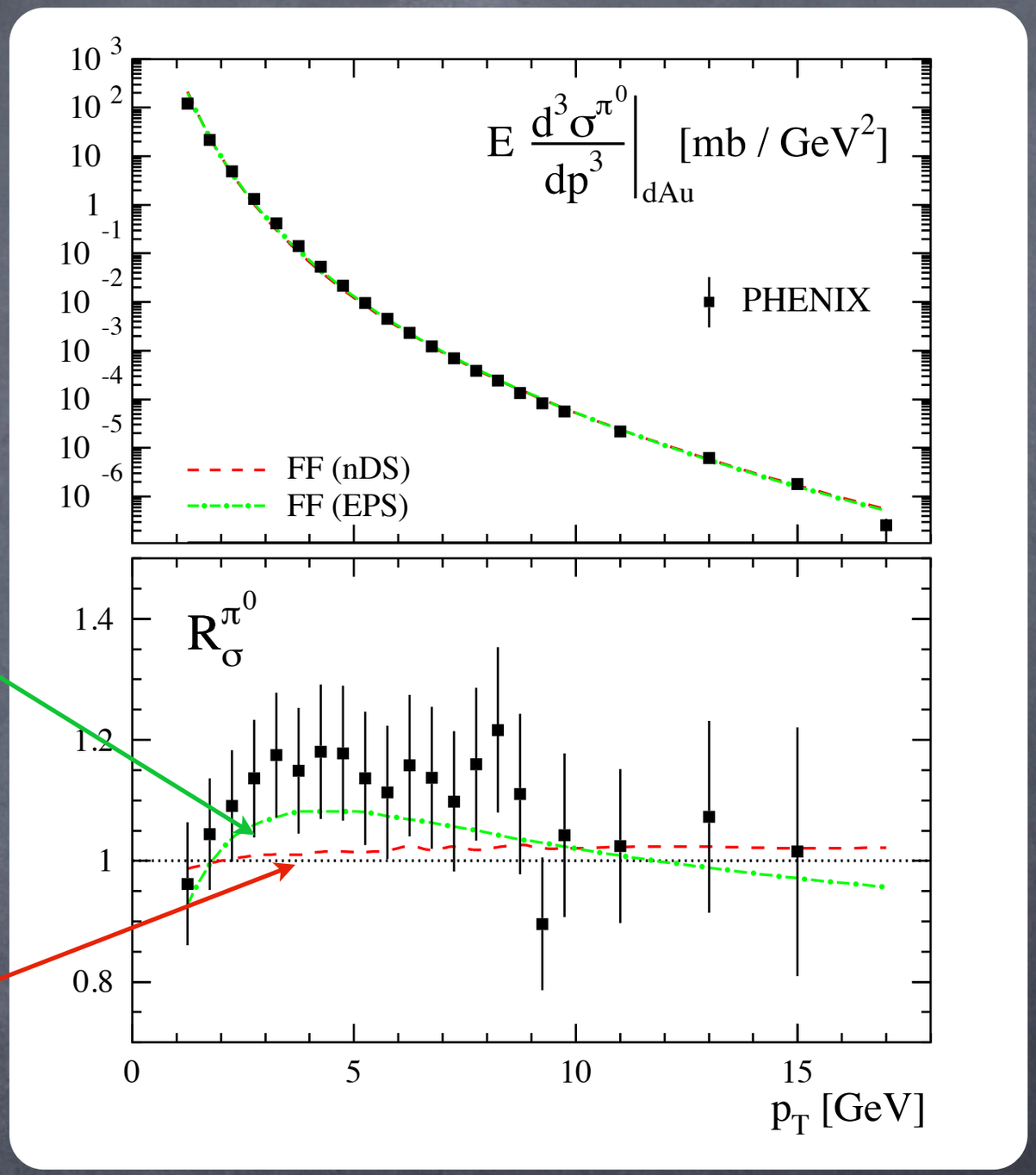

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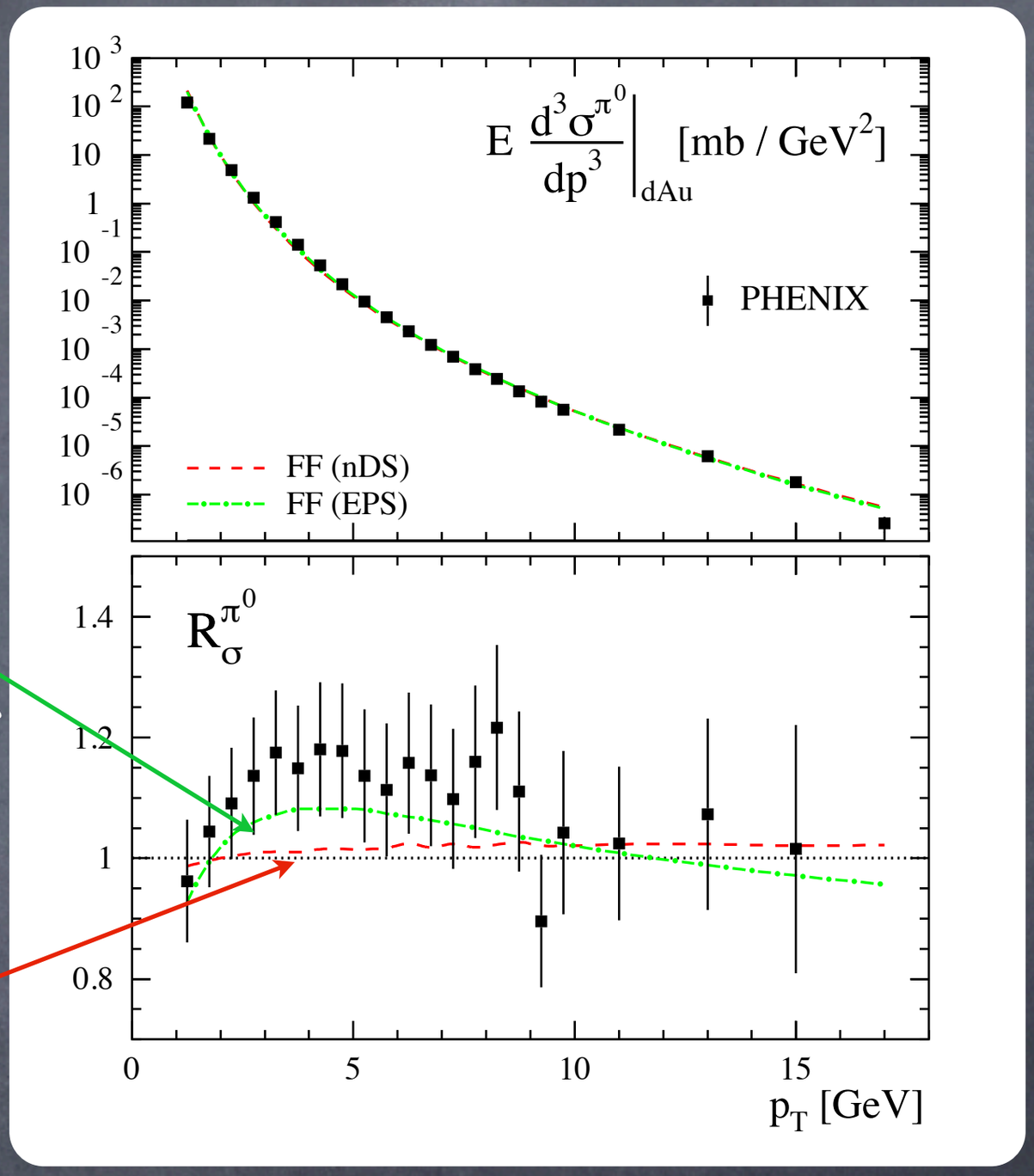

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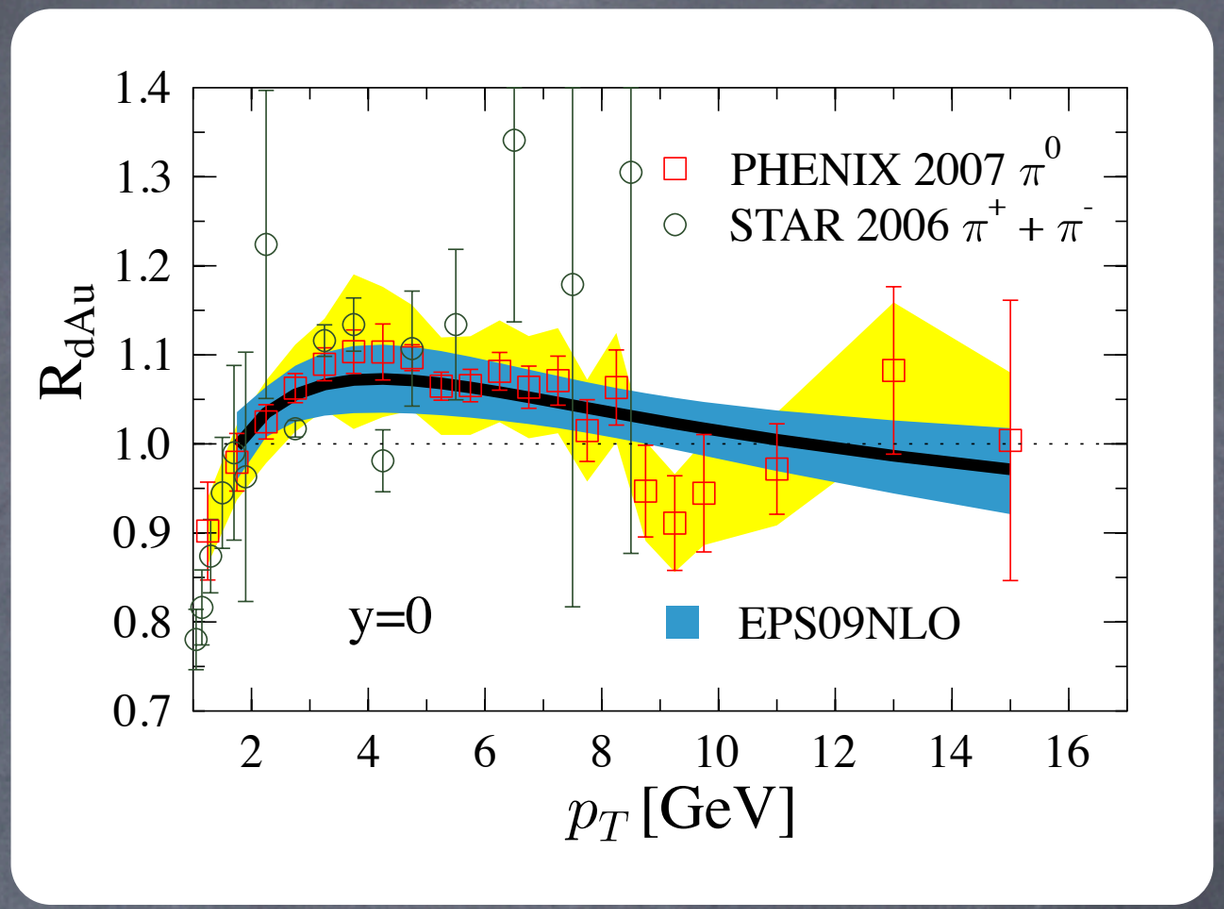

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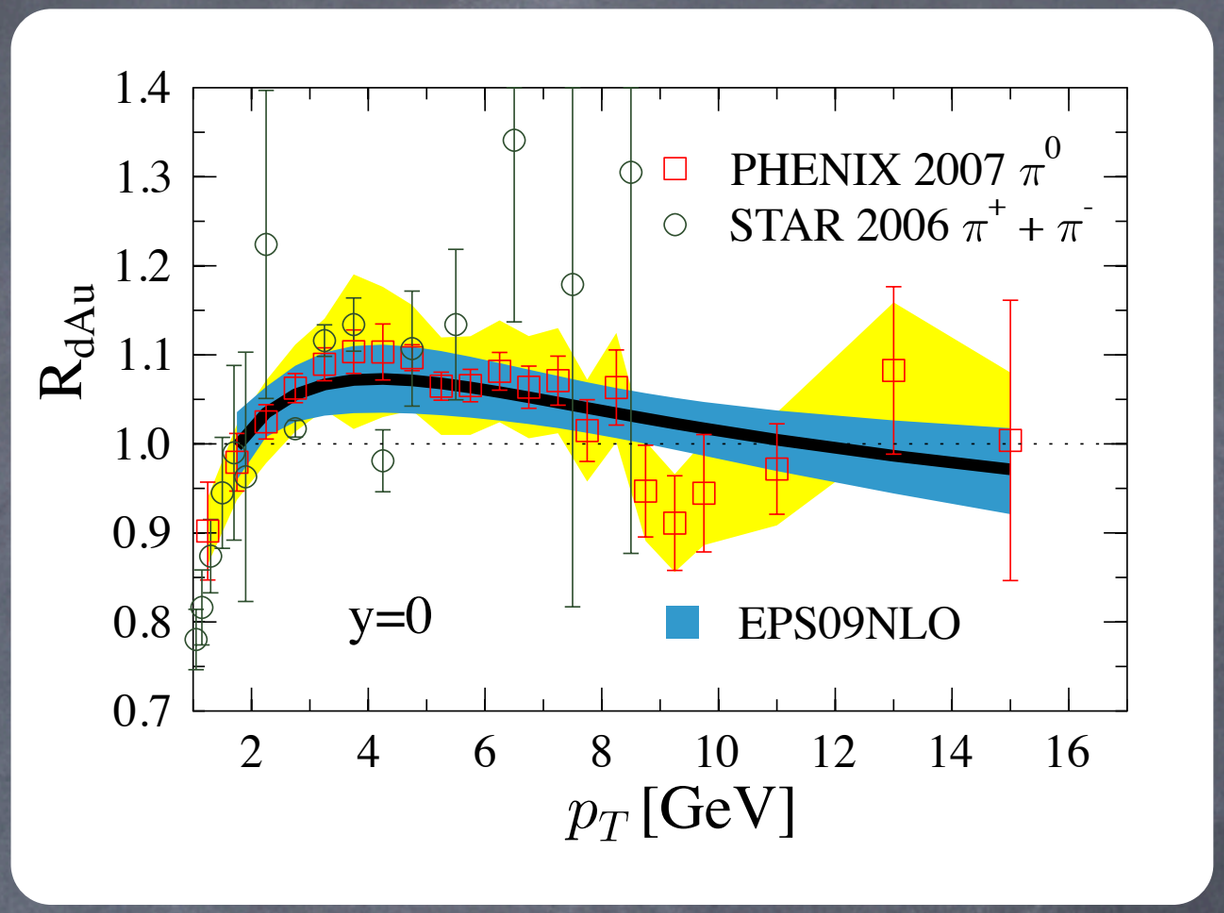

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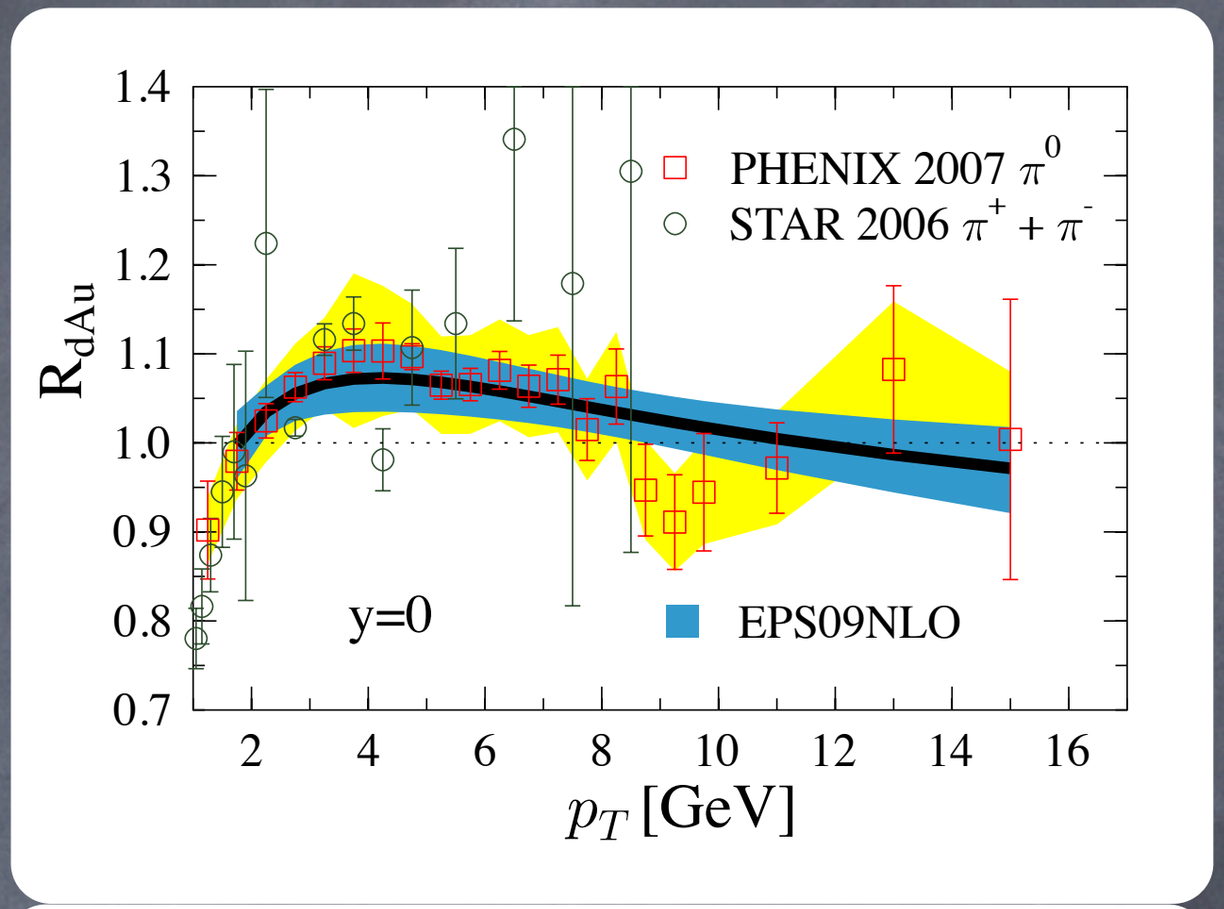

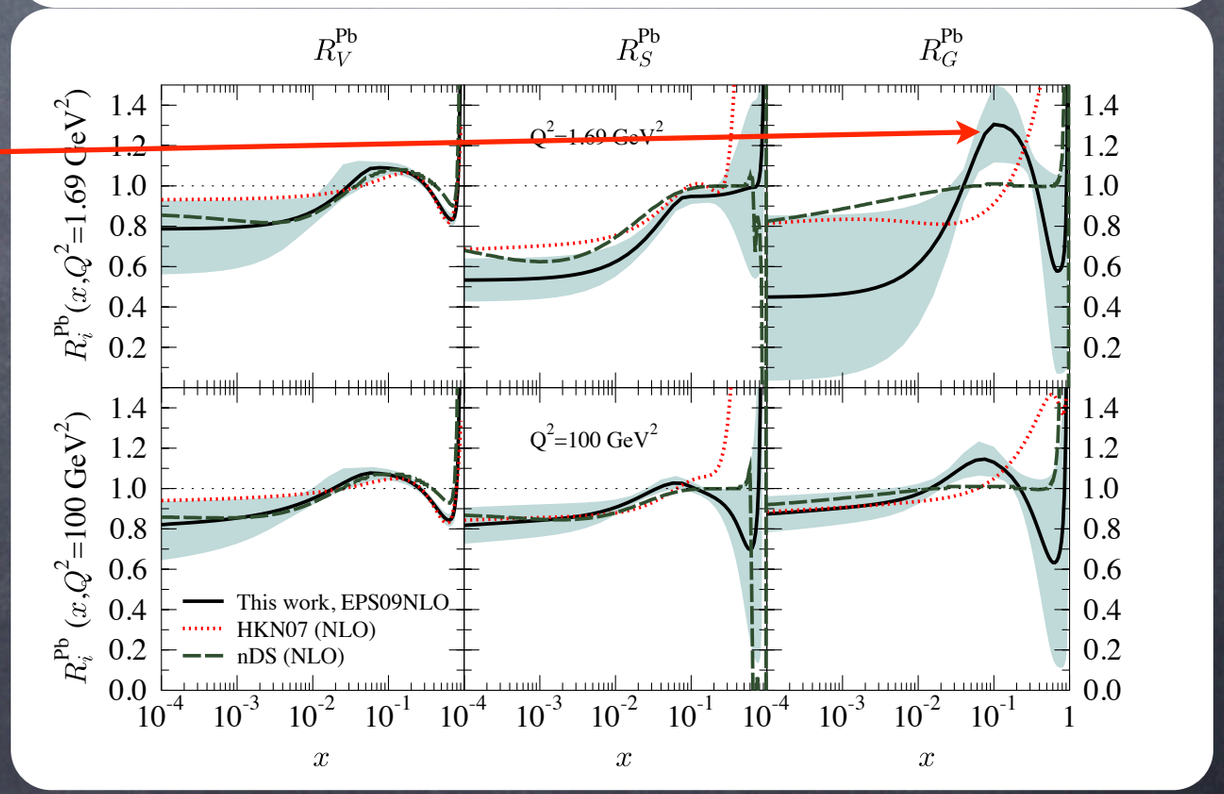

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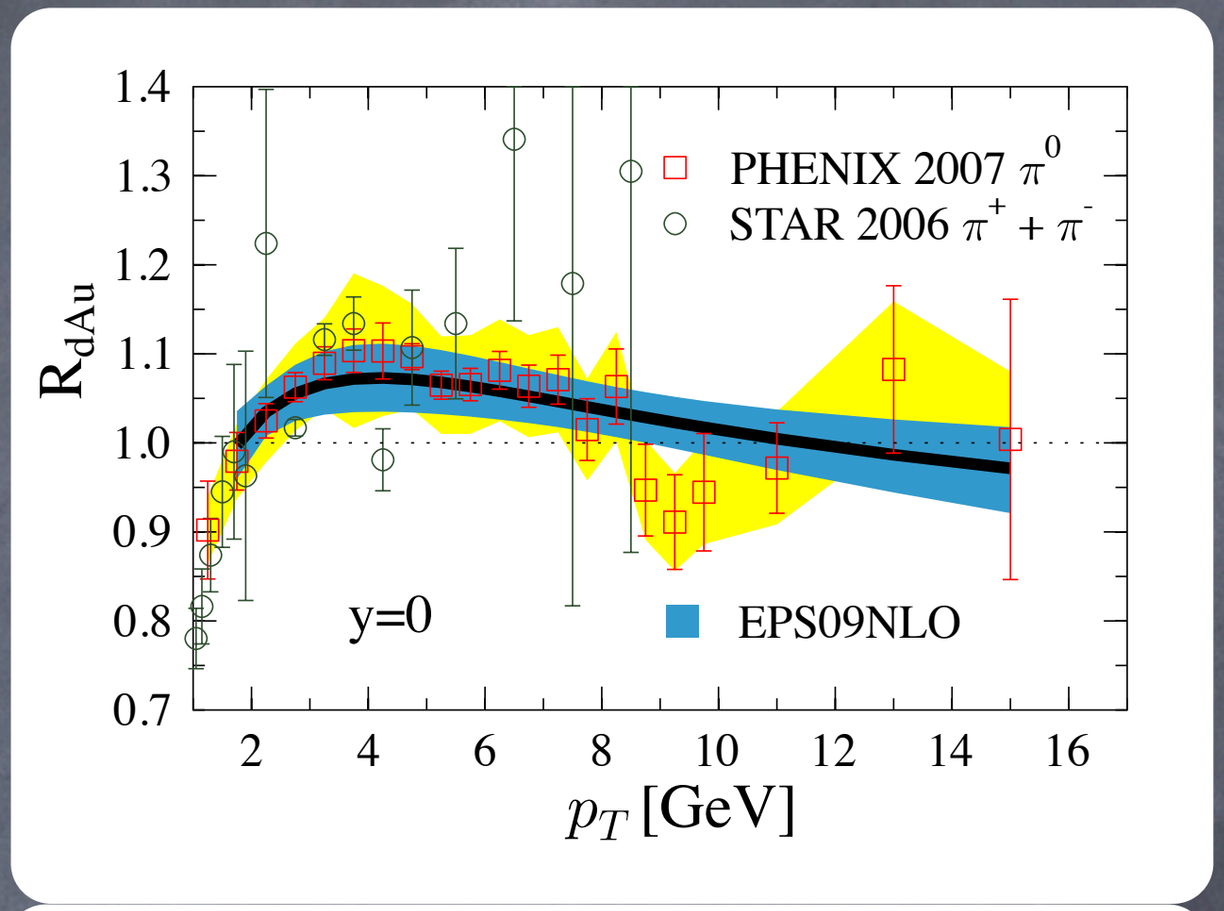

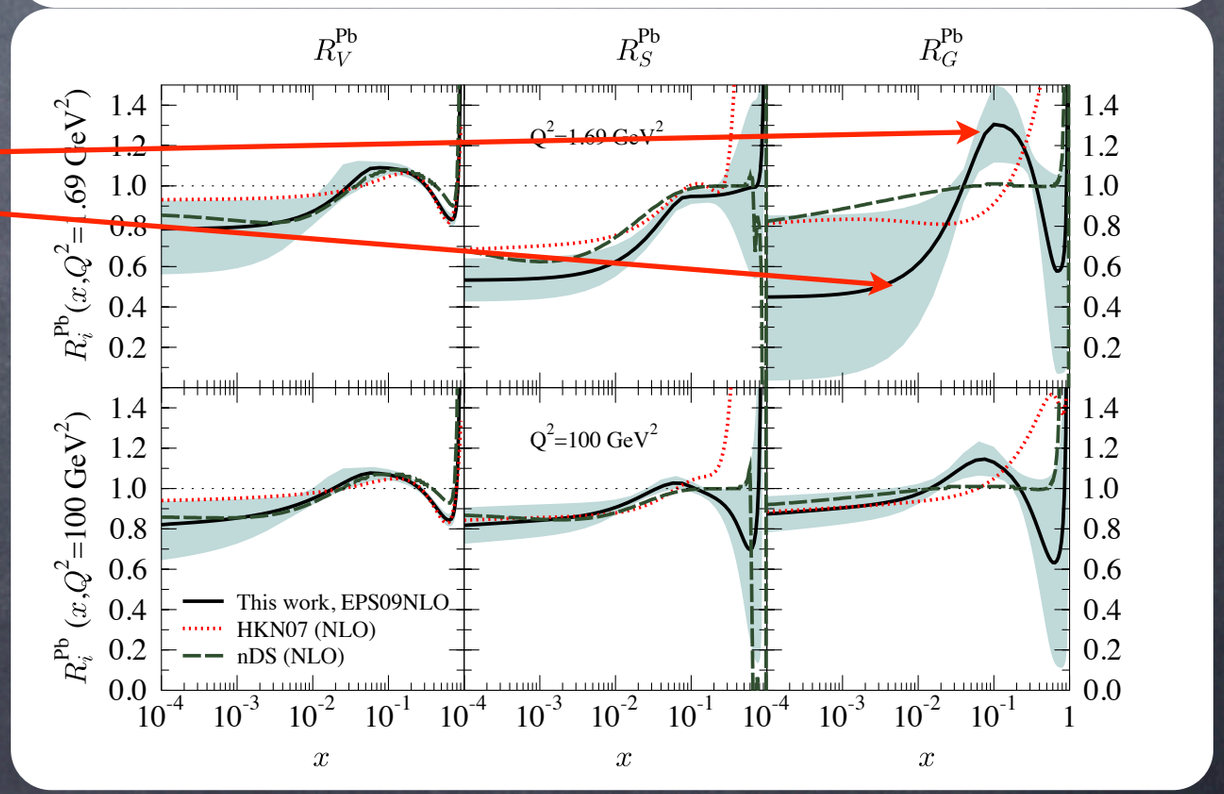

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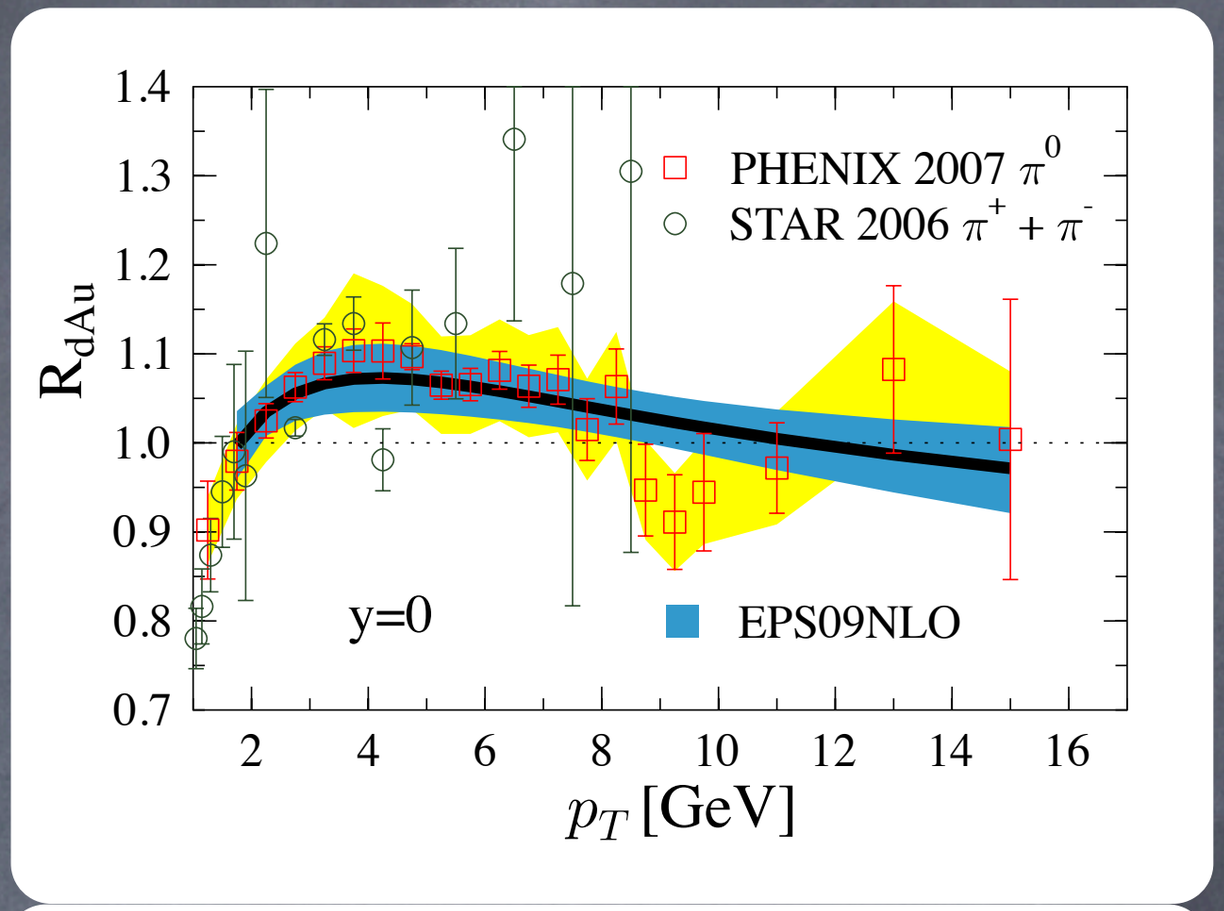
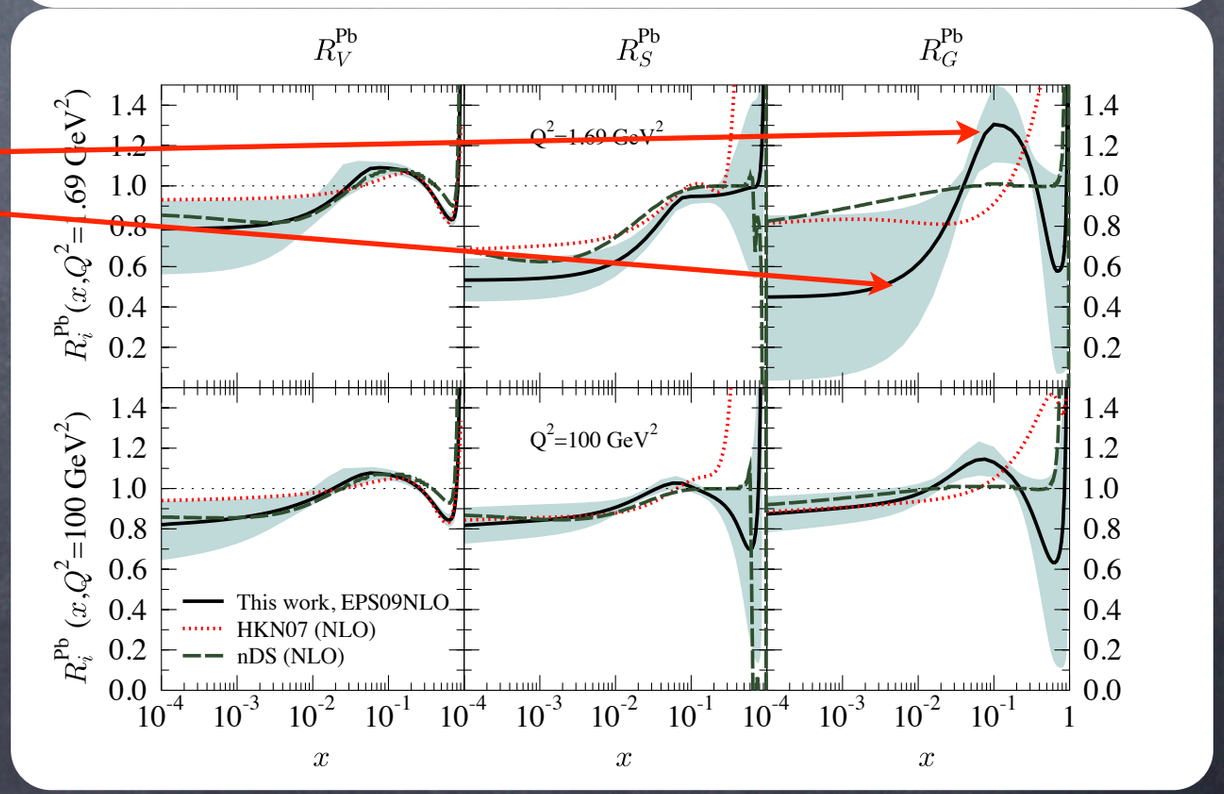
- ★ extra normalizations: (?)

STAR 0.90
PHENIX 1.03





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consistency ➡ nDS nPDFs

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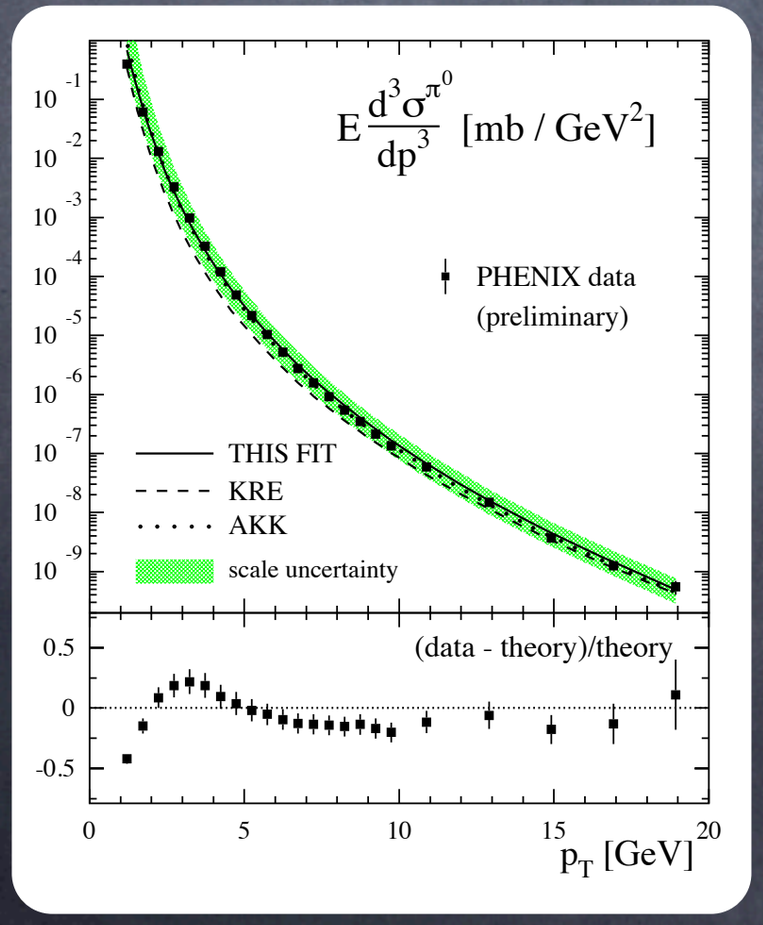

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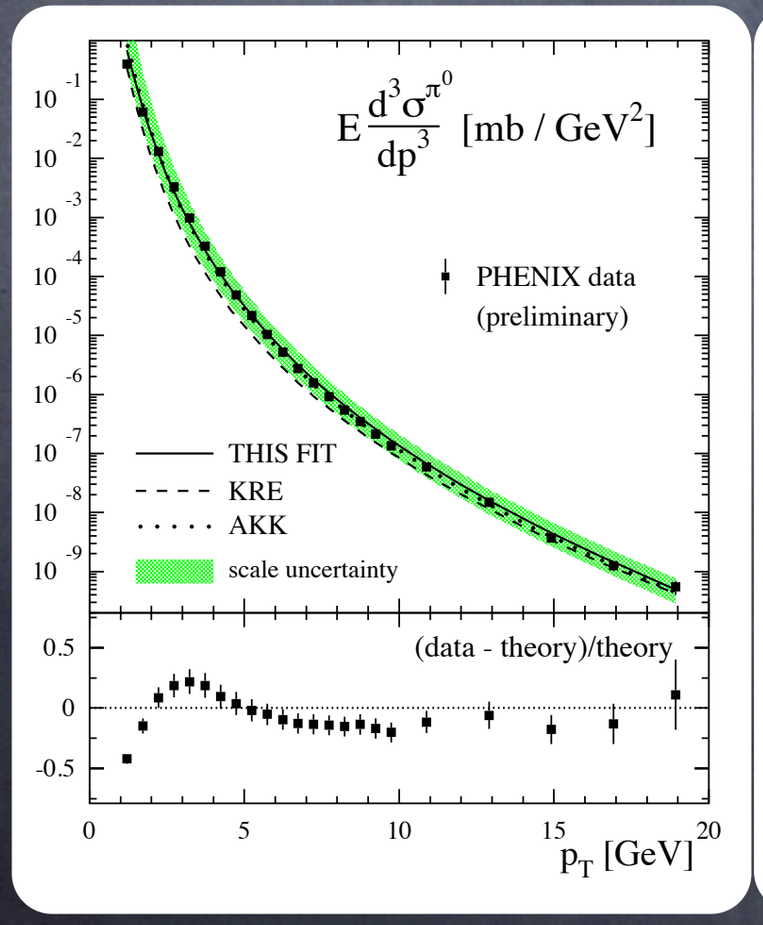

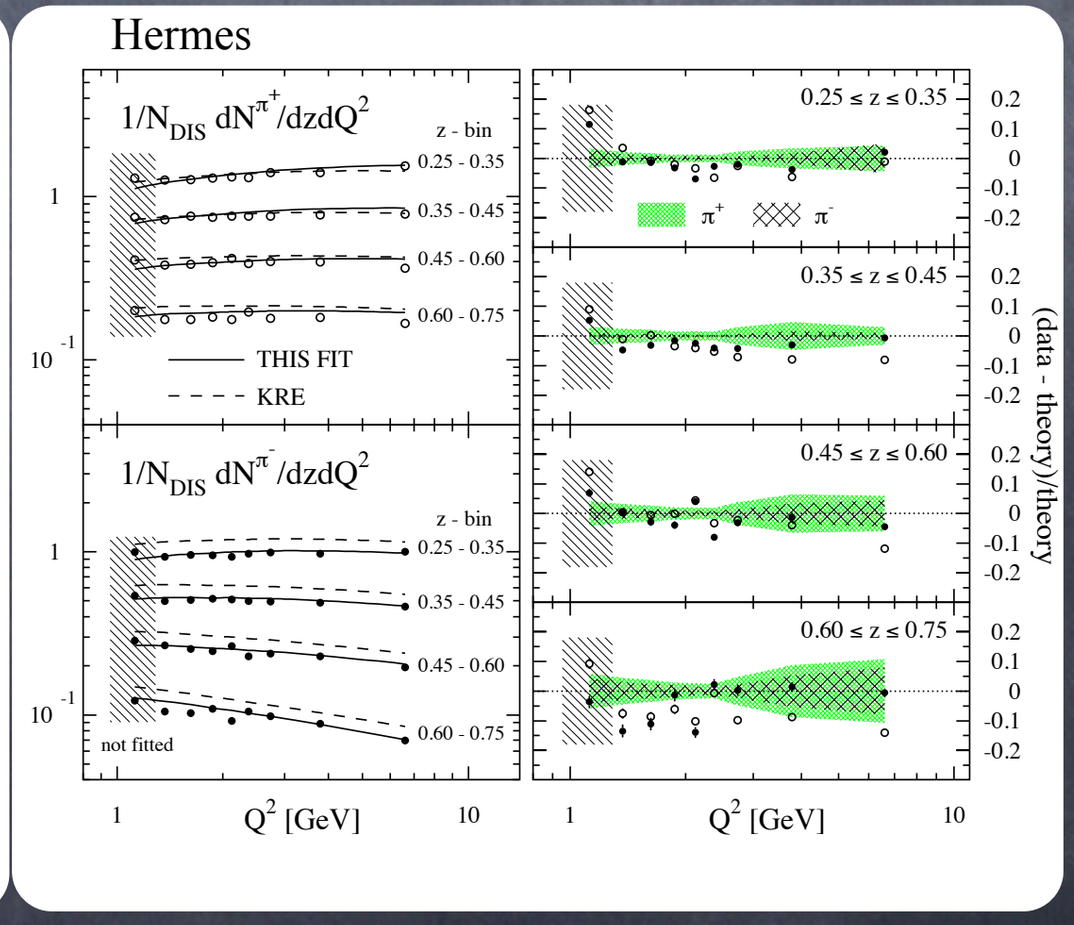

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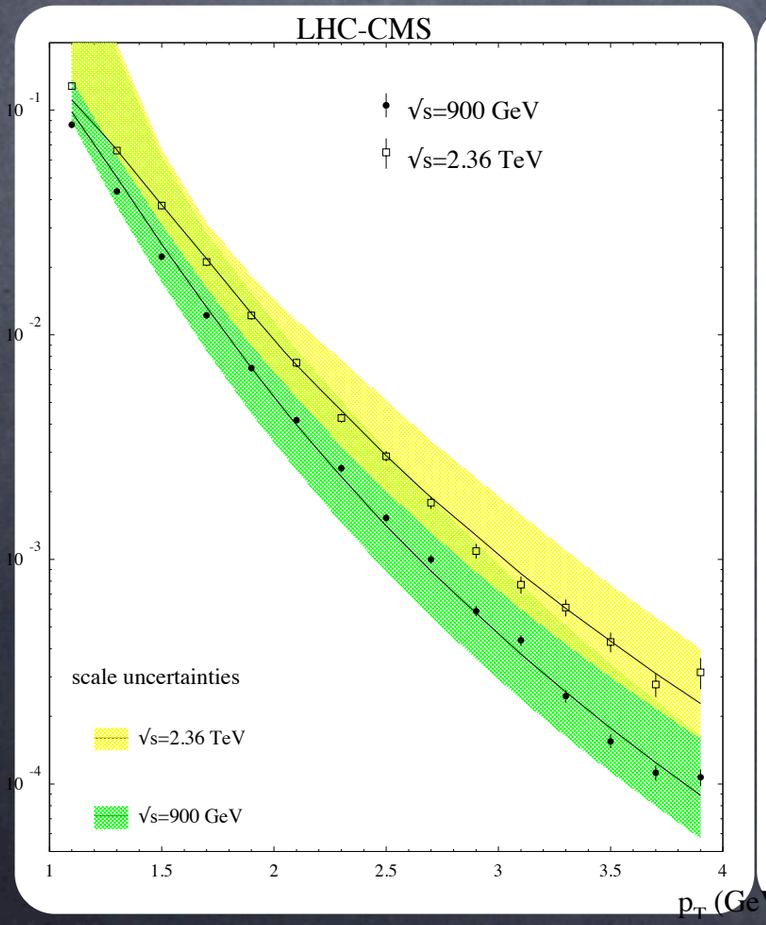

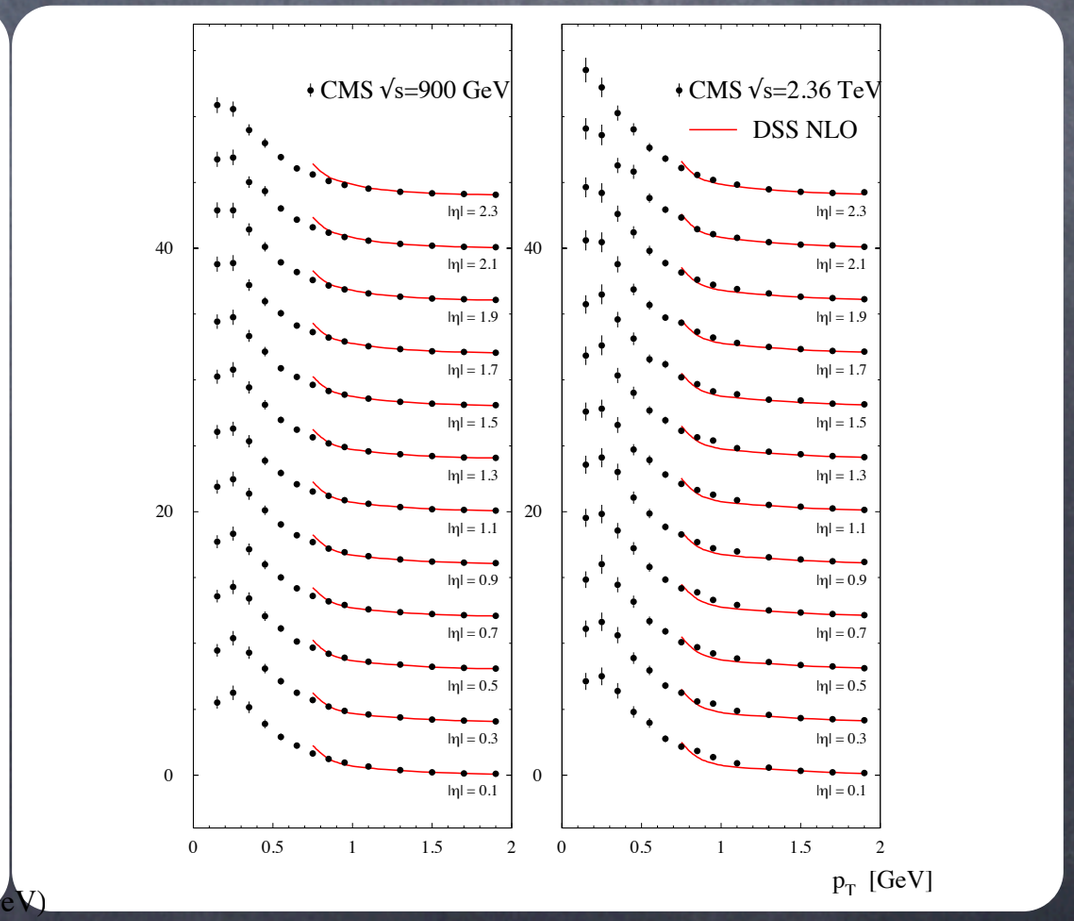

low pT
CMS data

CMS
arXiv:1002.0621

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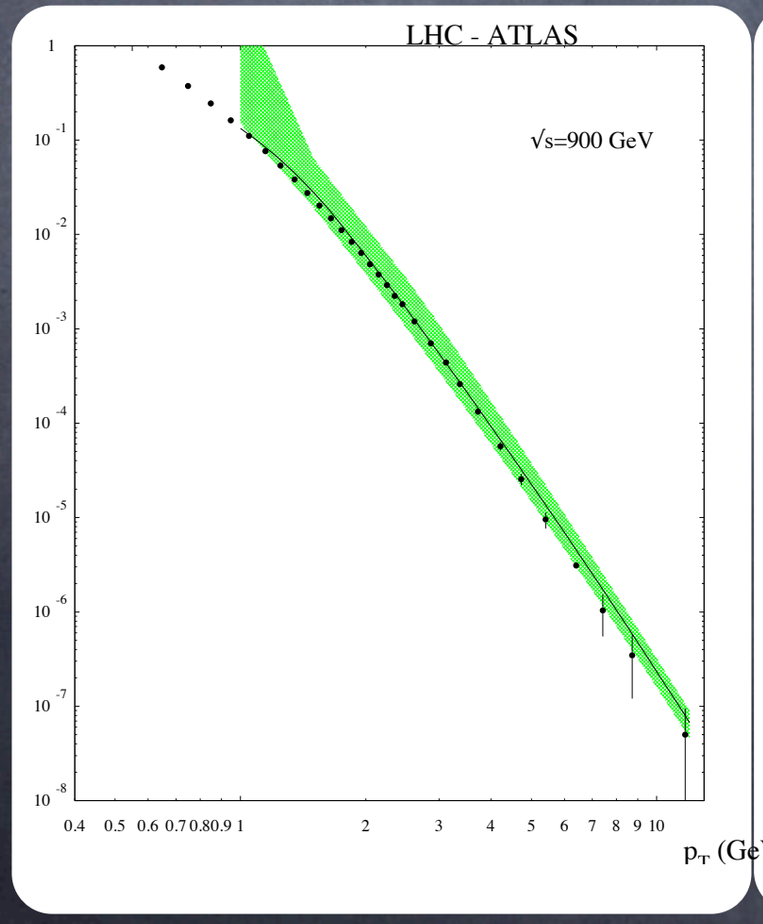
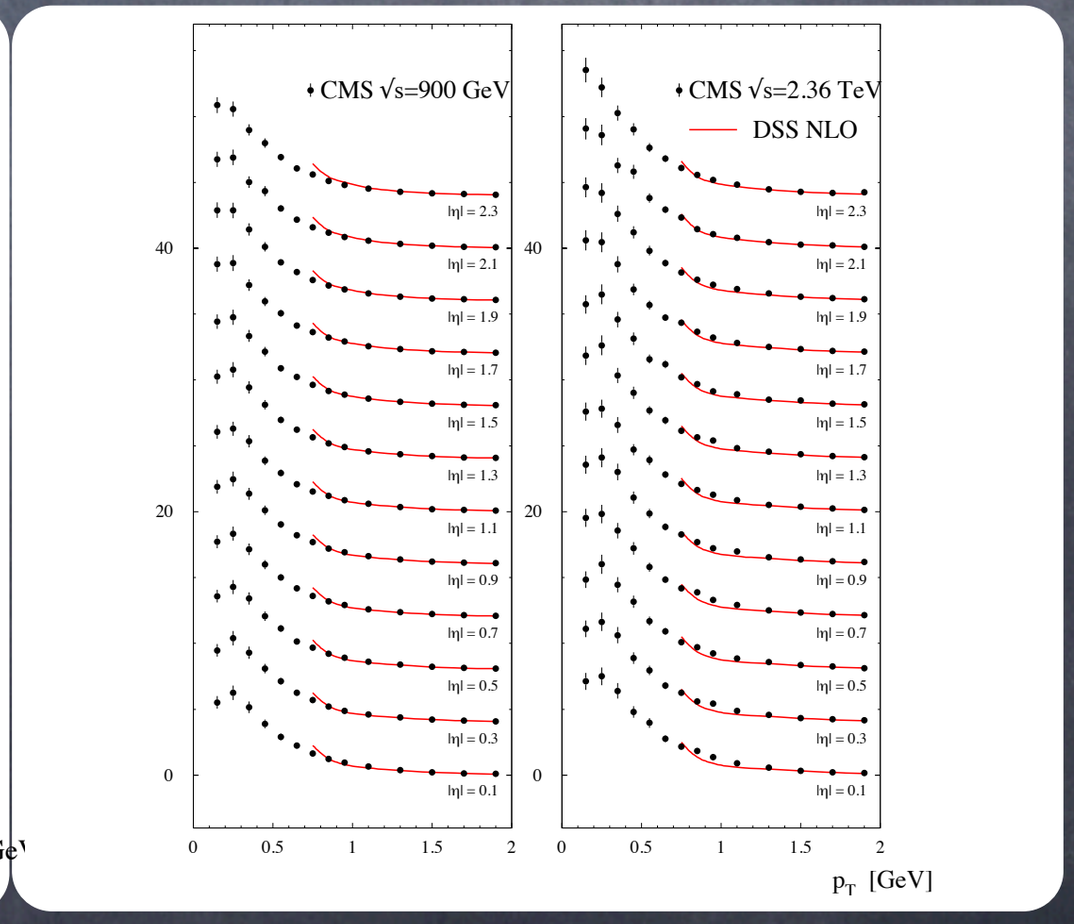


ATLAS
arXiv:1003.3124



low pT
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Fitting nFFs: convolution approach

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

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

Fitting nFFs: convolution approach

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

works for nPDFs
re-scalings/shifts
modifies FFs
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$$W_i(y, A, Q_0^2) = \delta(1-y)$$

no effects

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z-shift (energy loss)

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

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A very simple example for pion production:

Toy parameterization

no significant differences between charged pions

$$W_q^\pi(y, A, Q_0^2) = W_{\bar{q}}^\pi(y, A, Q_0^2)$$

Toy parameterization

no significant differences between charged pions

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

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z-independent

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z-independent energy loss?

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z-independent energy loss?

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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

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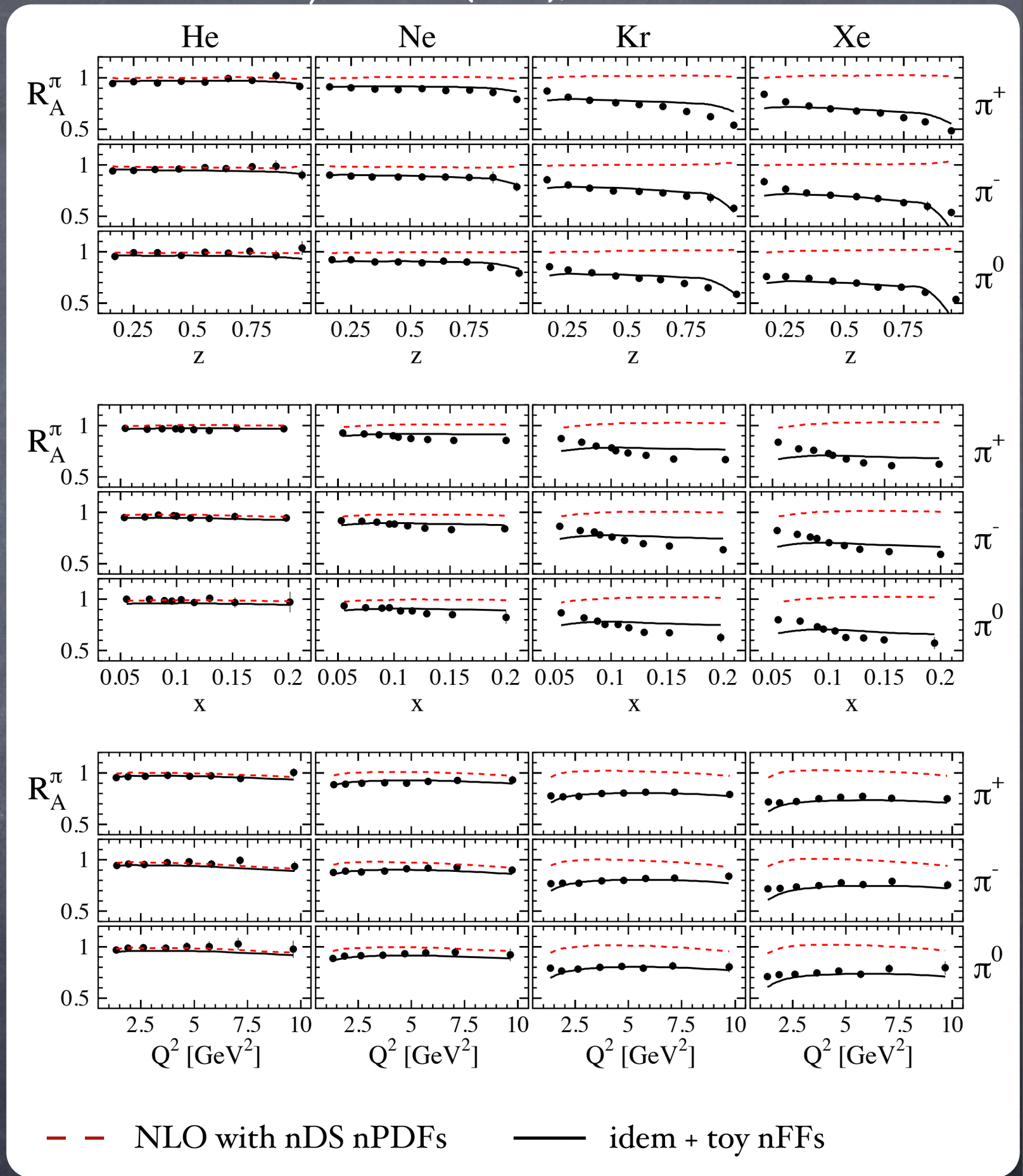
3 parameters

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

Toy parameterization

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



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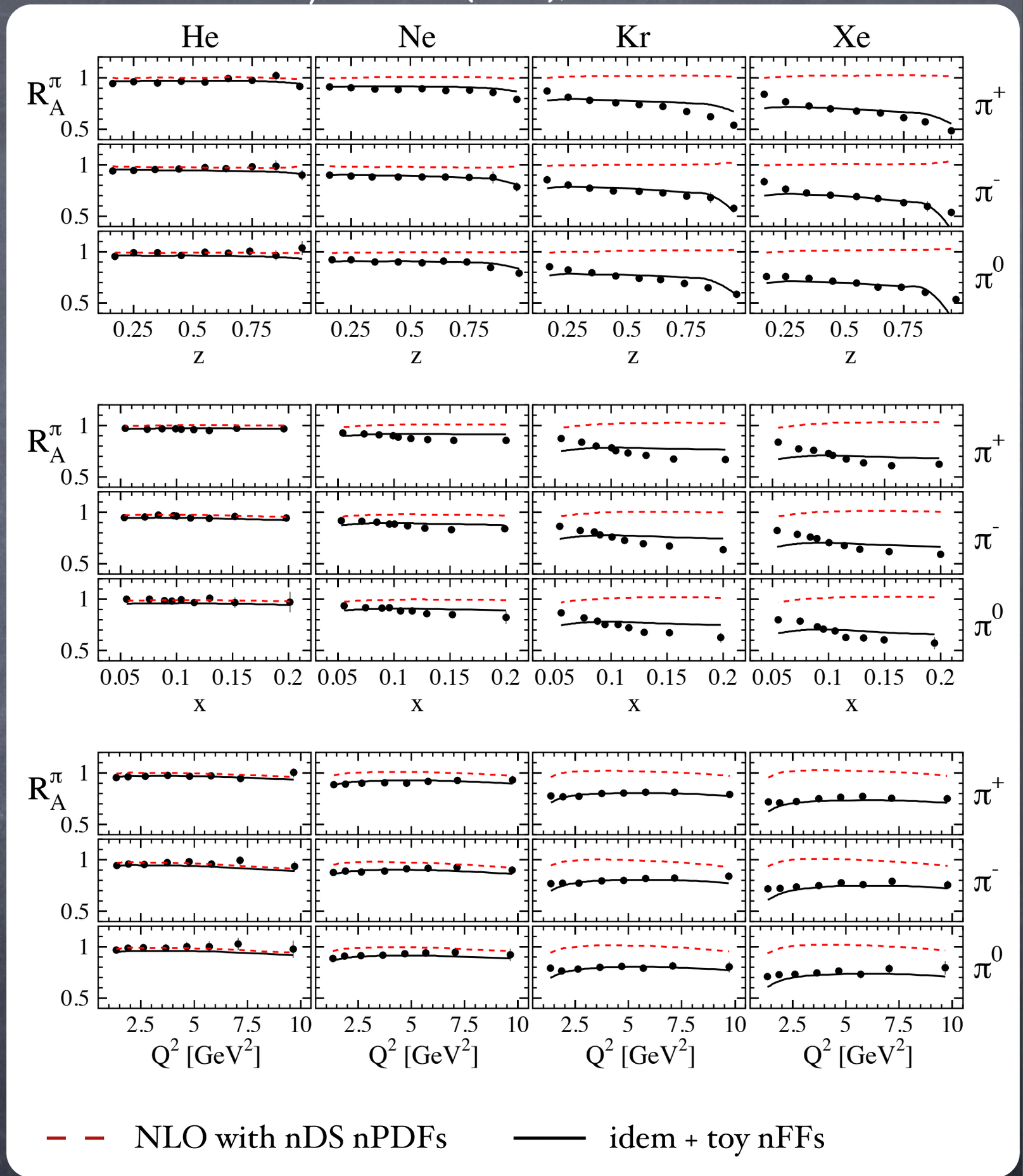
Toy parameterization

normalization & trend



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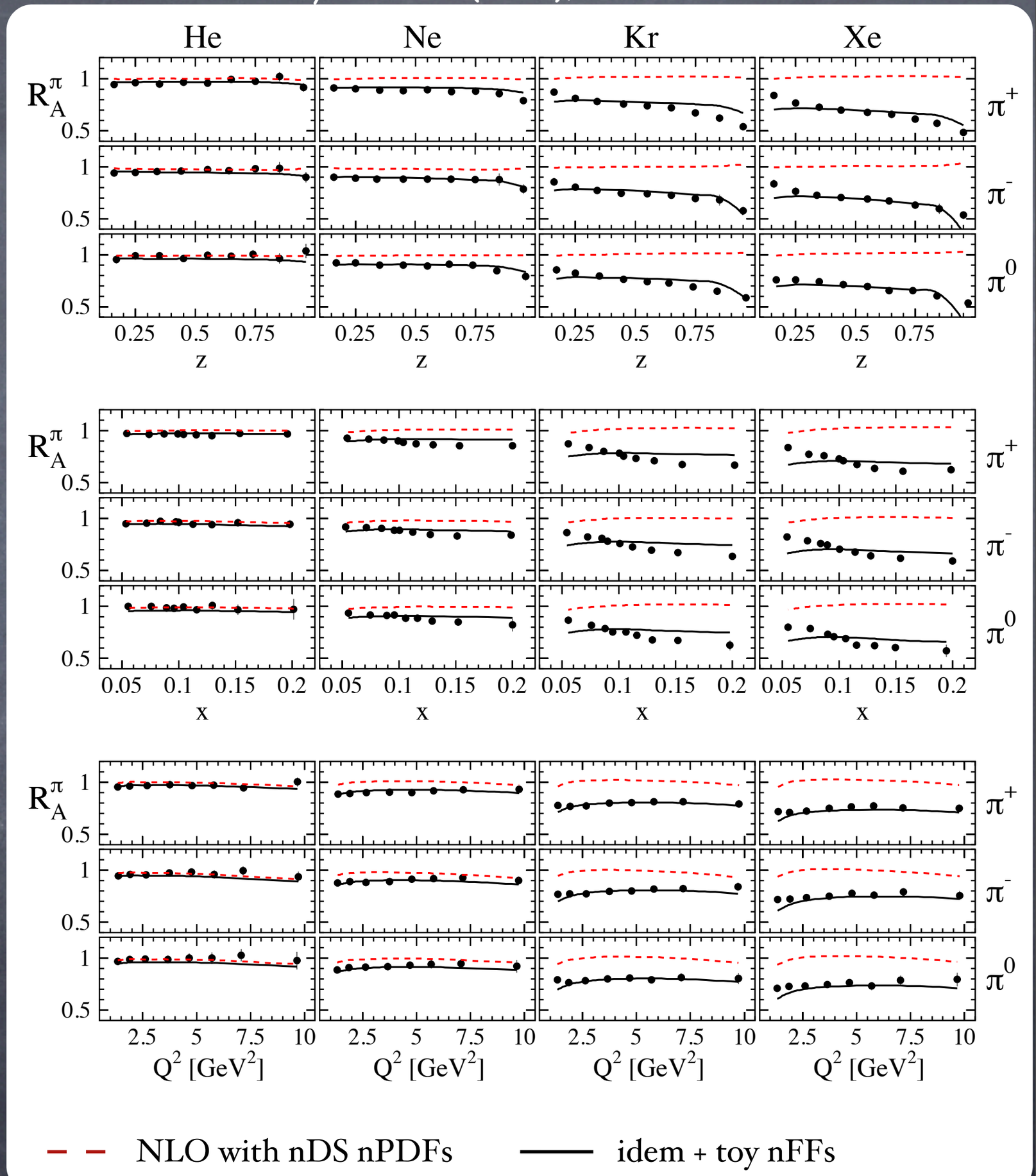


no conflict with standard evolution

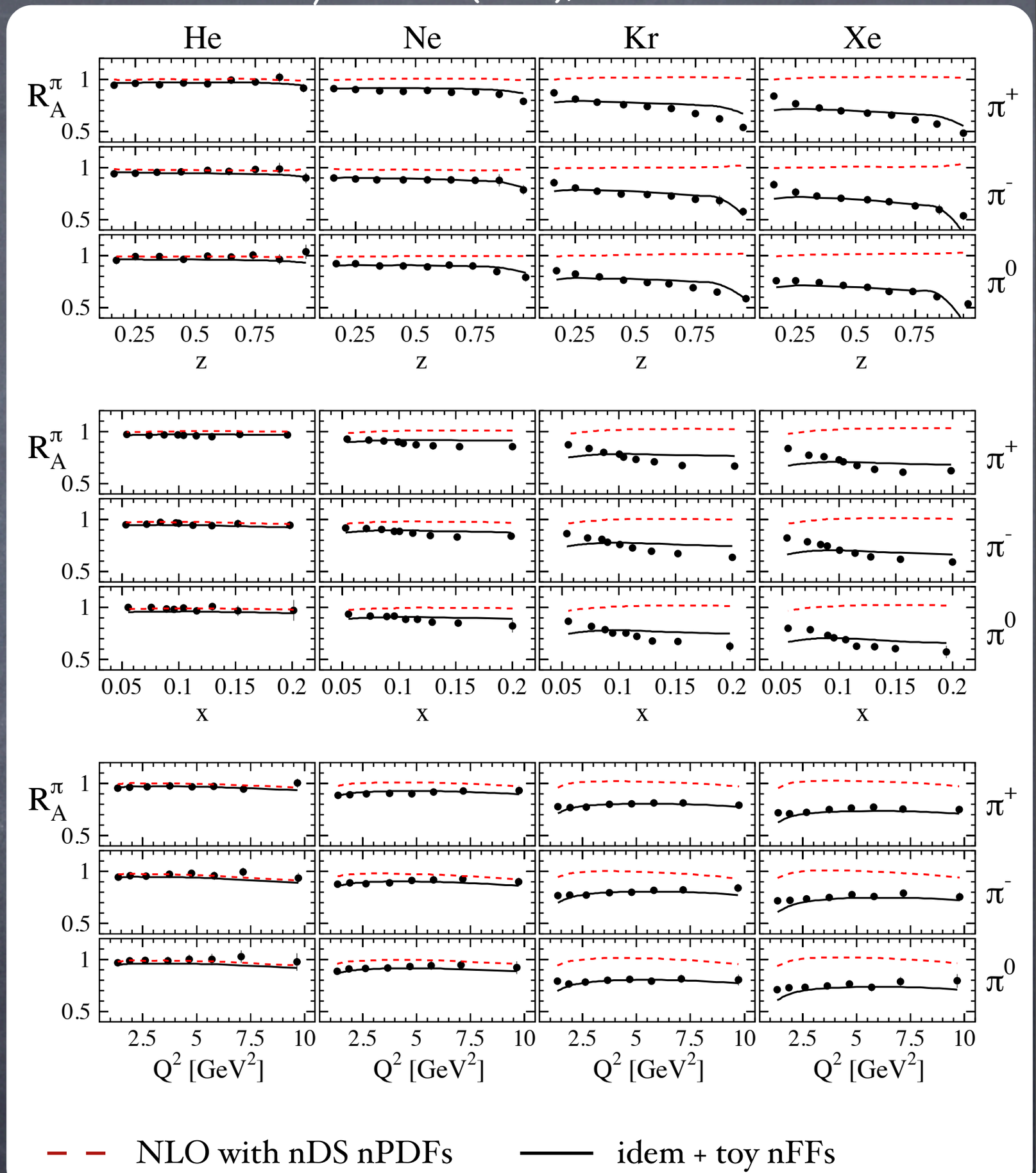
HERMES Nucl. Phys.B 780 1 (2007);

Toy parameterization

normalization & trend

not flexible enough for x-dependence: gluons?

no conflict with standard evolution



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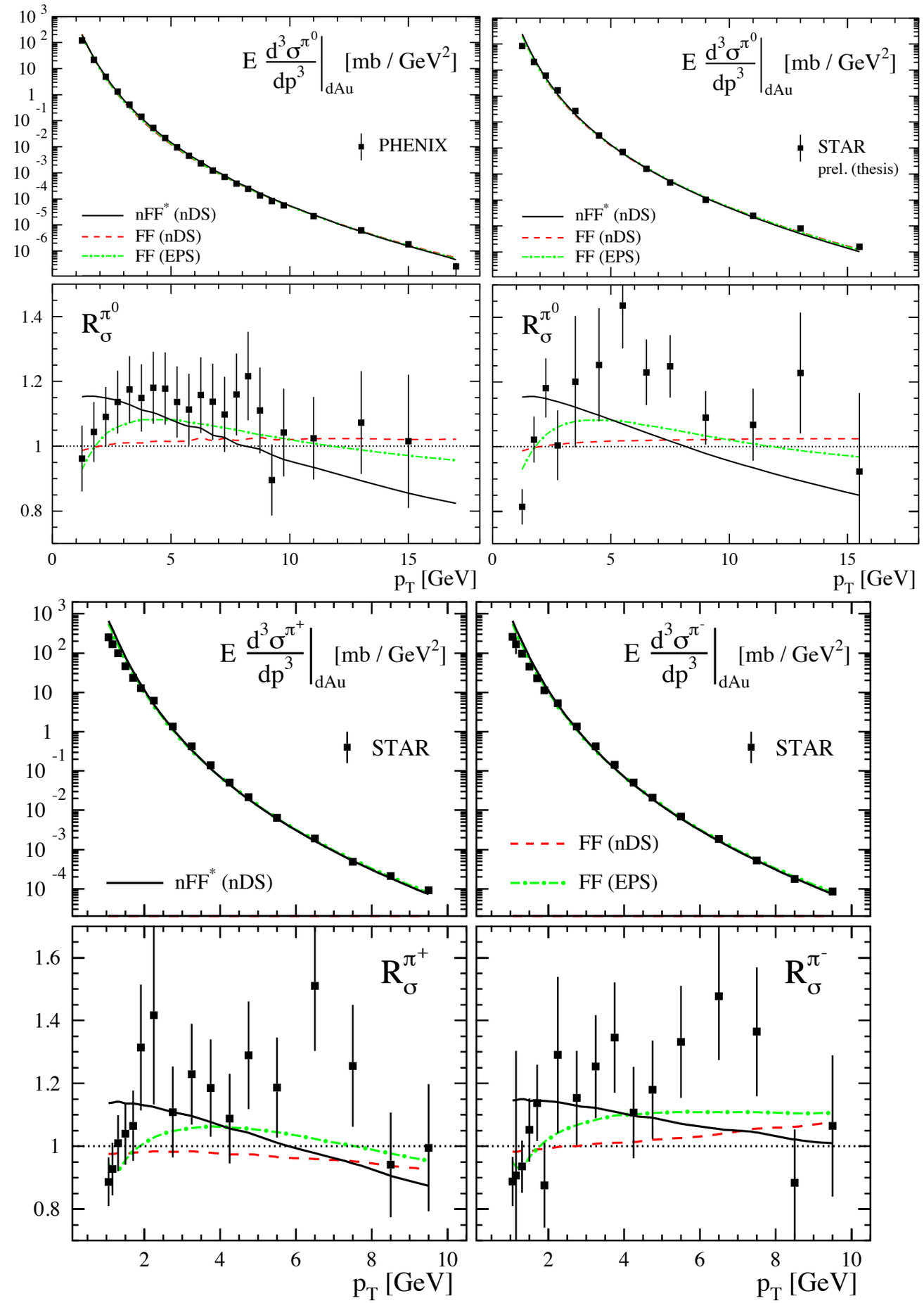
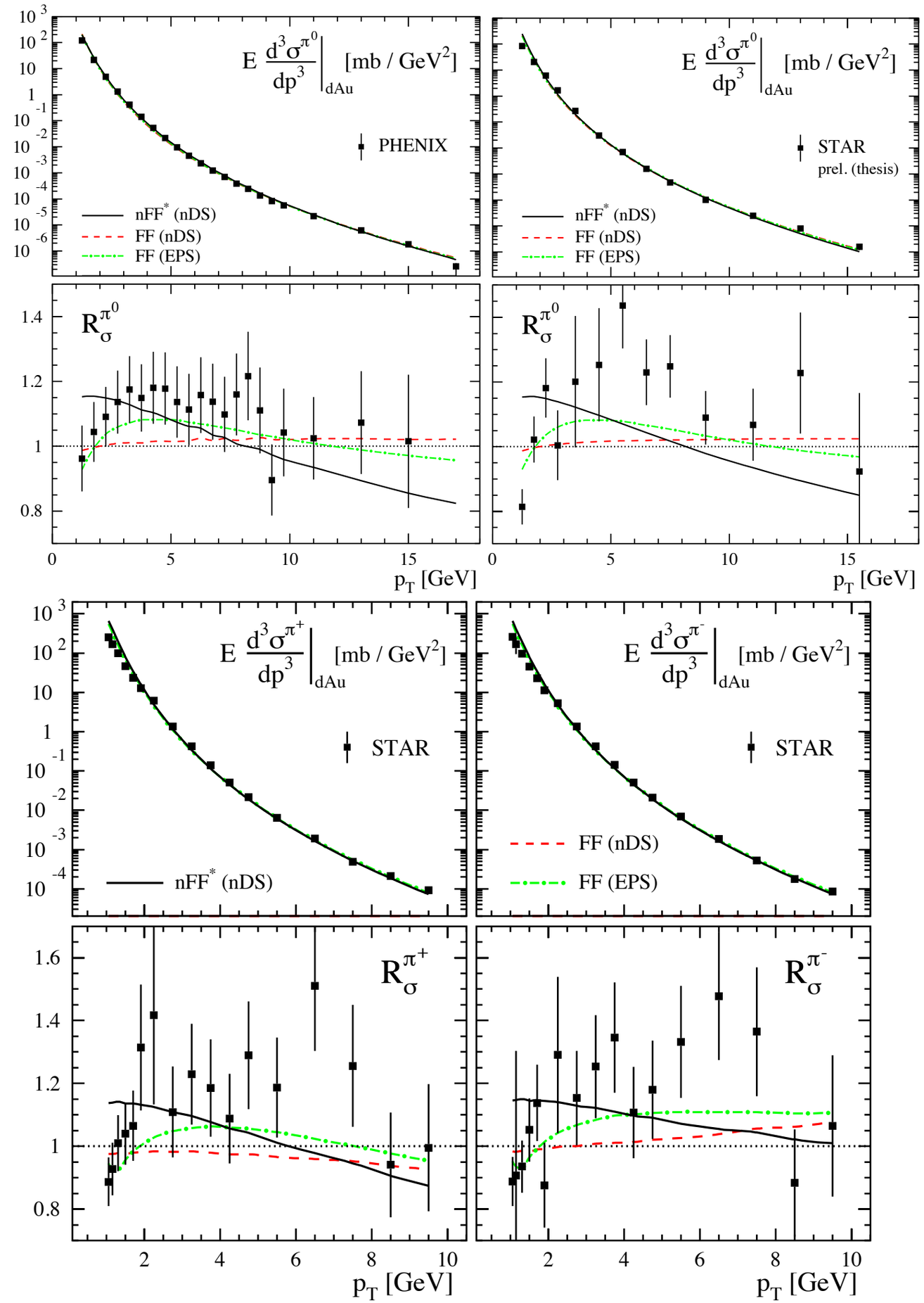


Toy parameterization

pT dependence!

quark/gluon interplay



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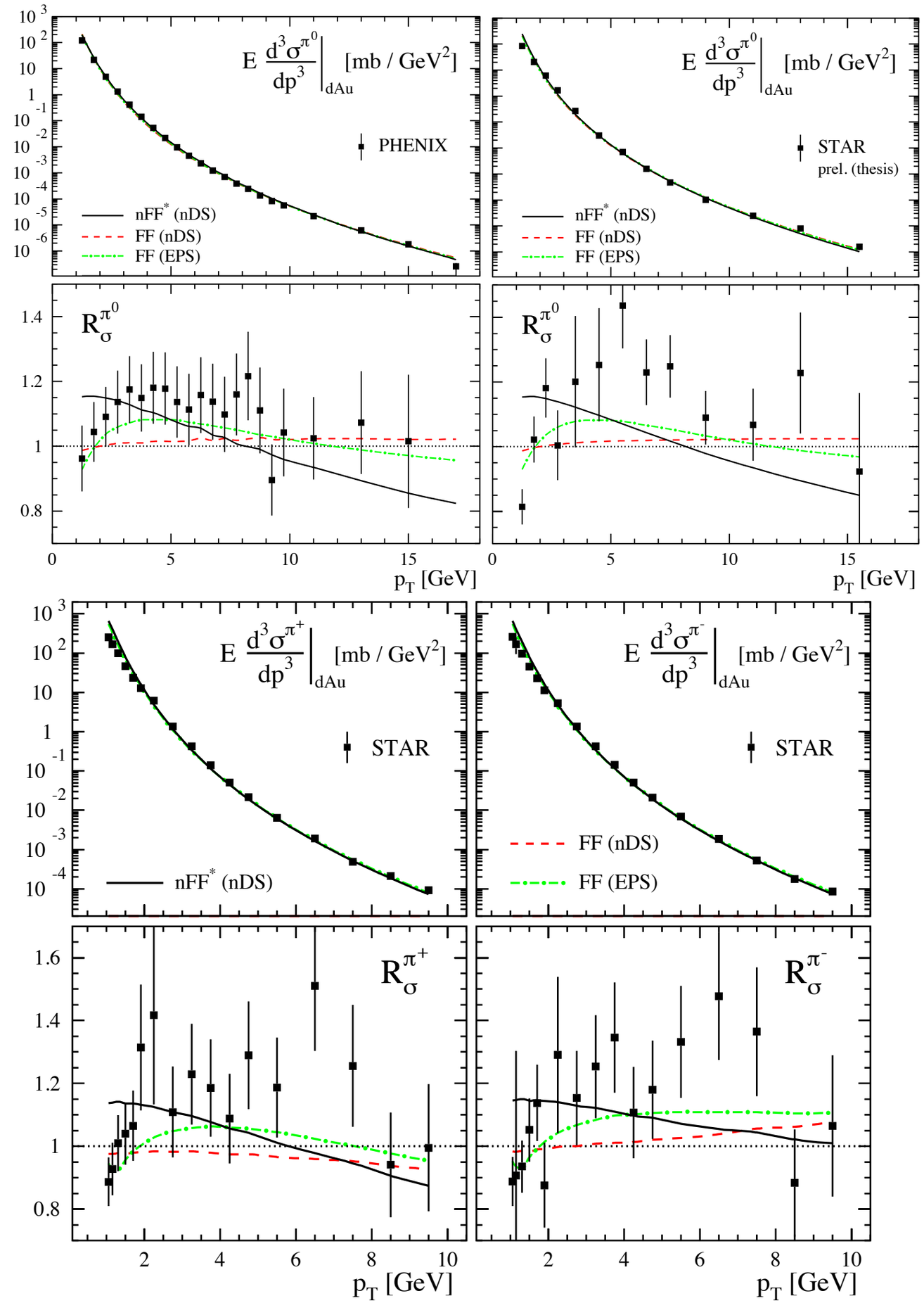
$\chi^2/d.o.f. \sim 2$



Refined parameterization

Refined parameterization

quark fragmentation

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gluon fragmentation

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gluon fragmentation

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

smooth A-dependence

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vanishing effects as $A \longrightarrow 1$

Refined parameterization

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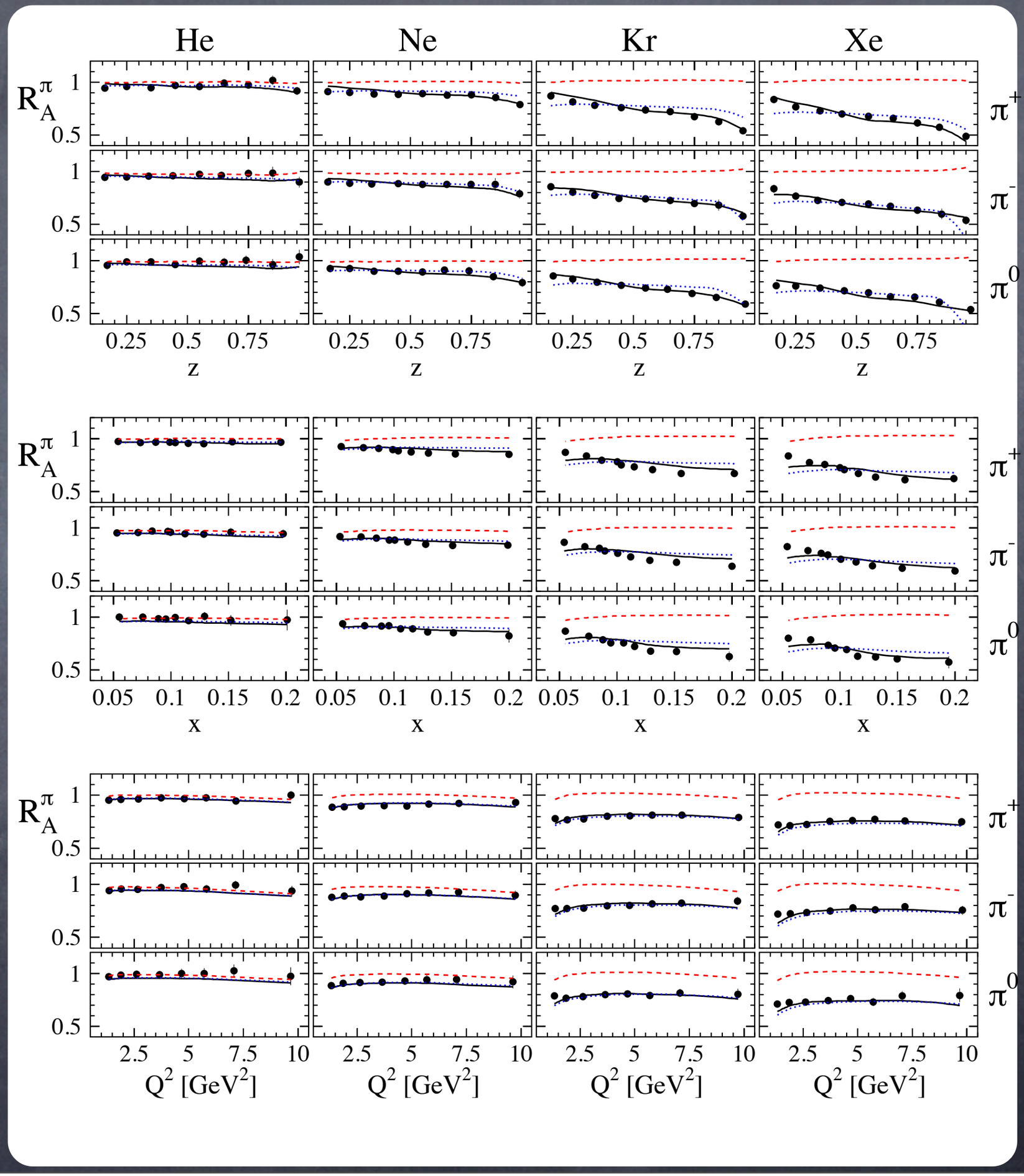
$\sim$ 14 parameters

$\chi^2 = 396.0$

381 data points

14 parameters

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



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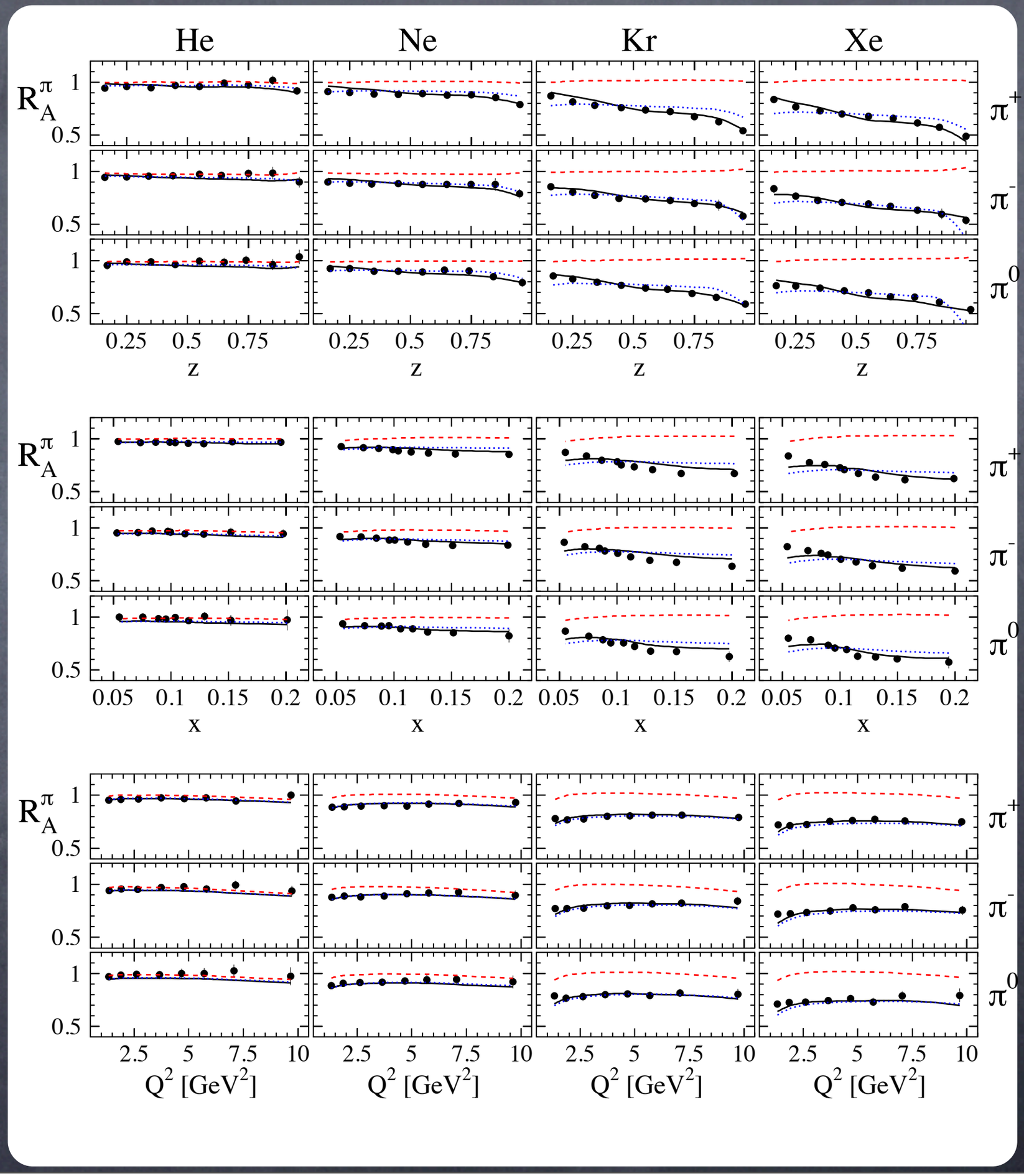

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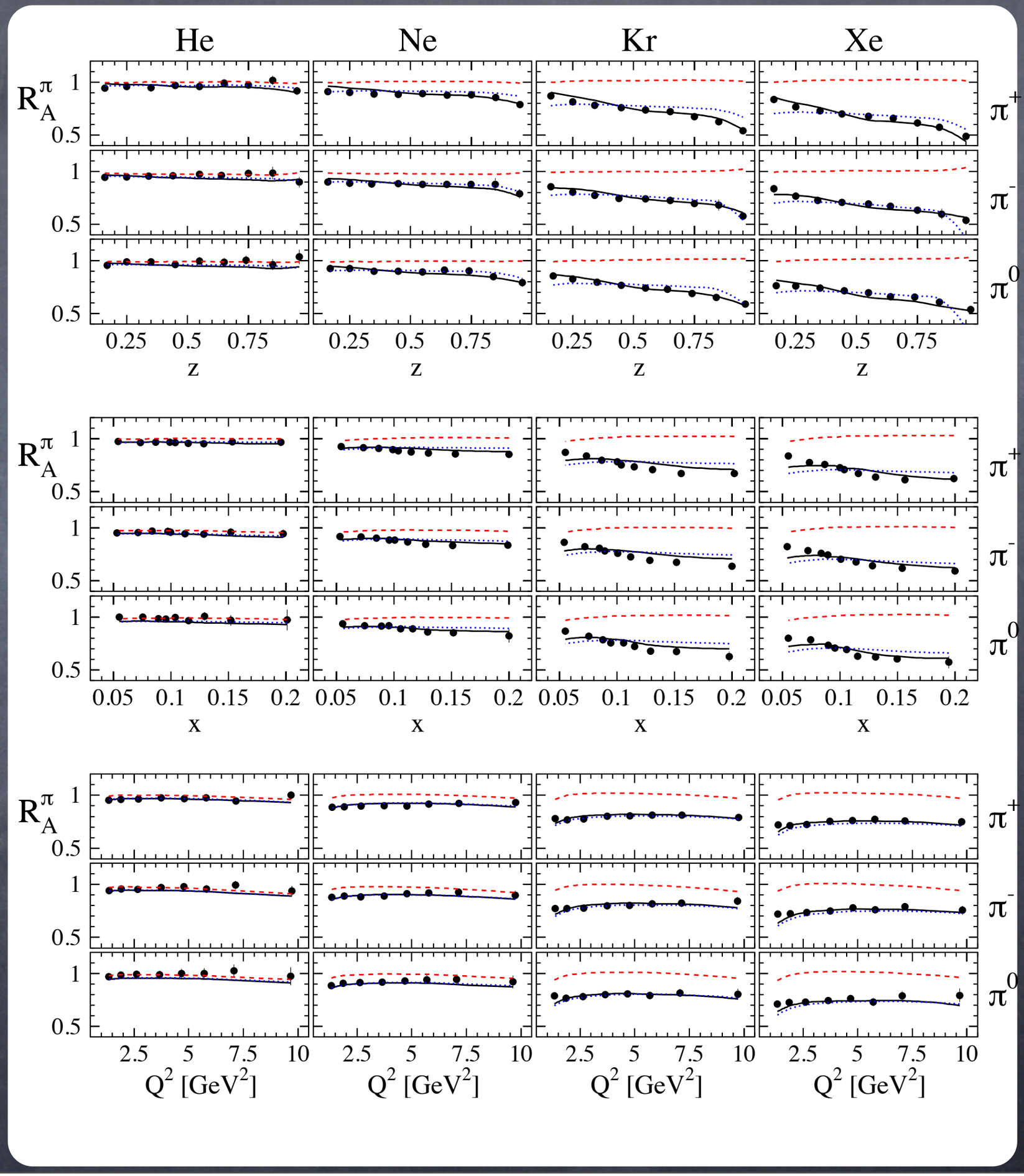

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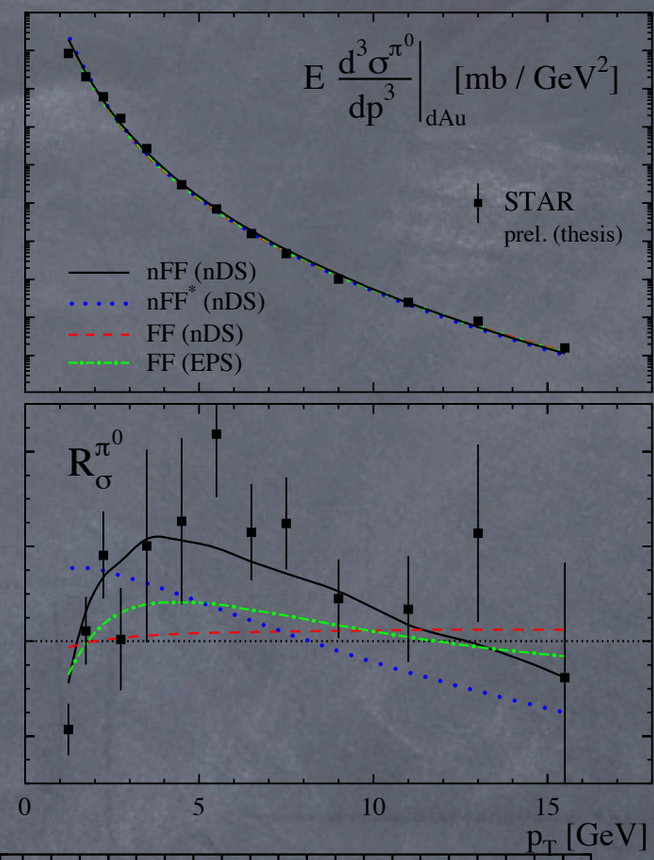

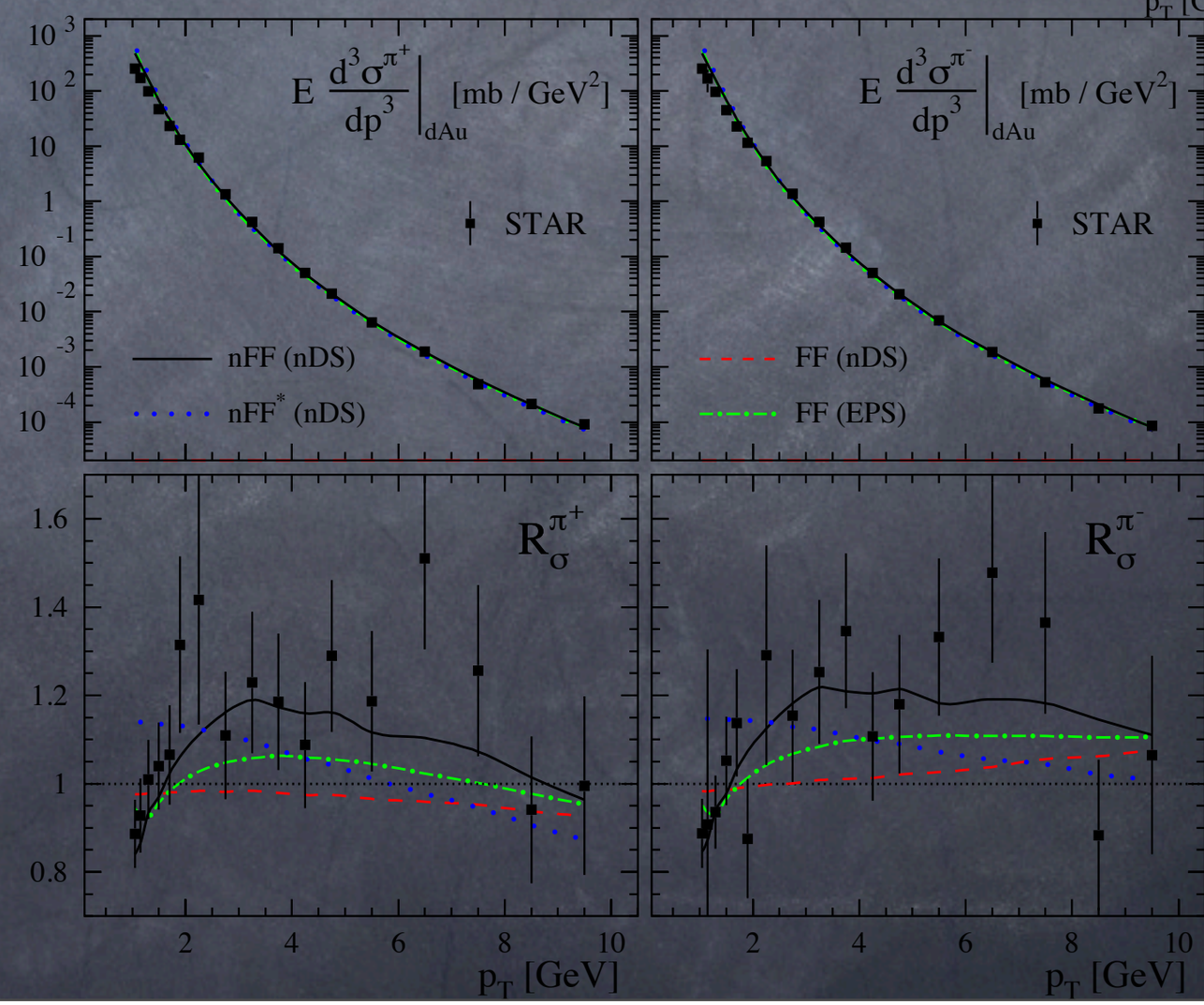

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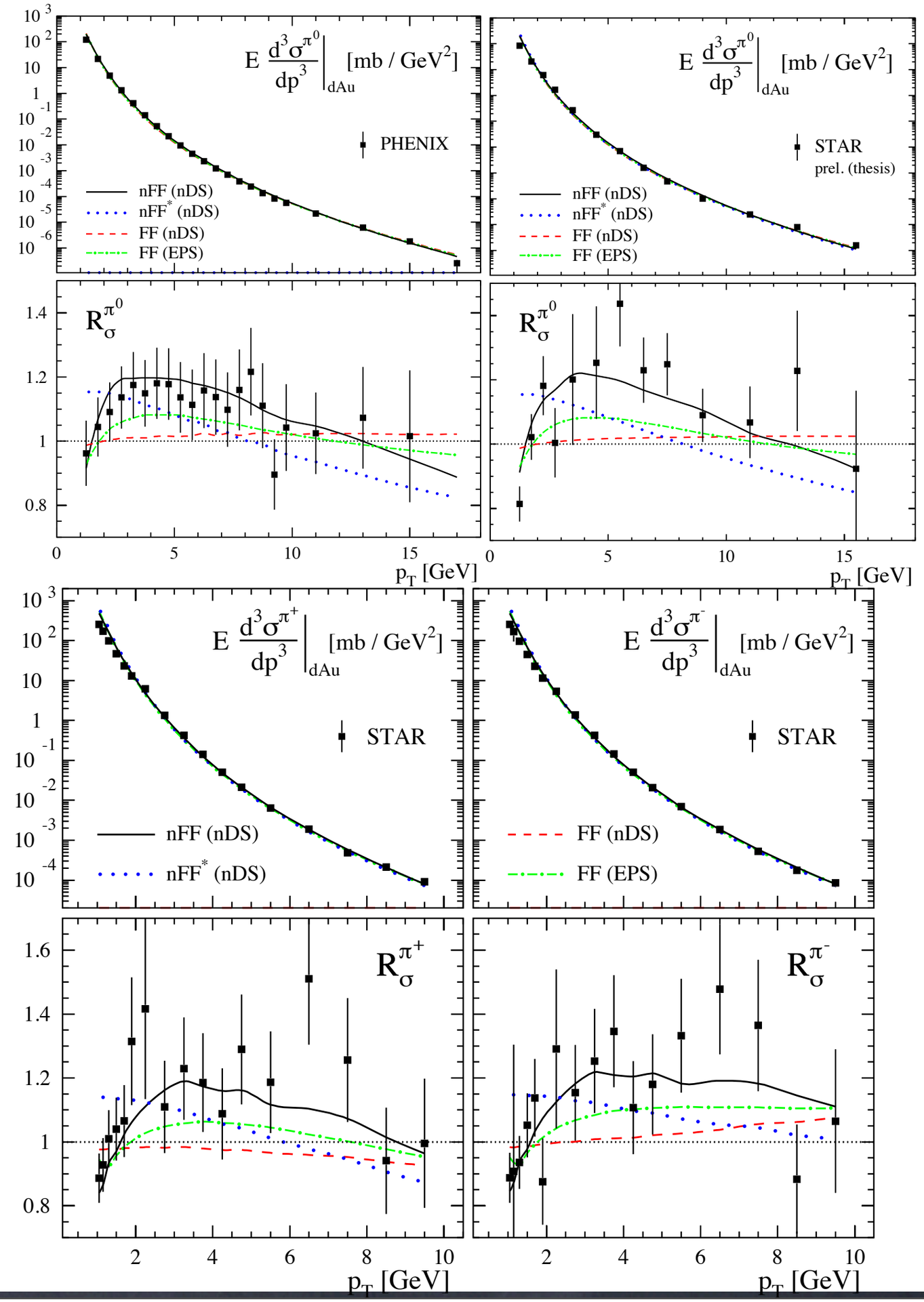

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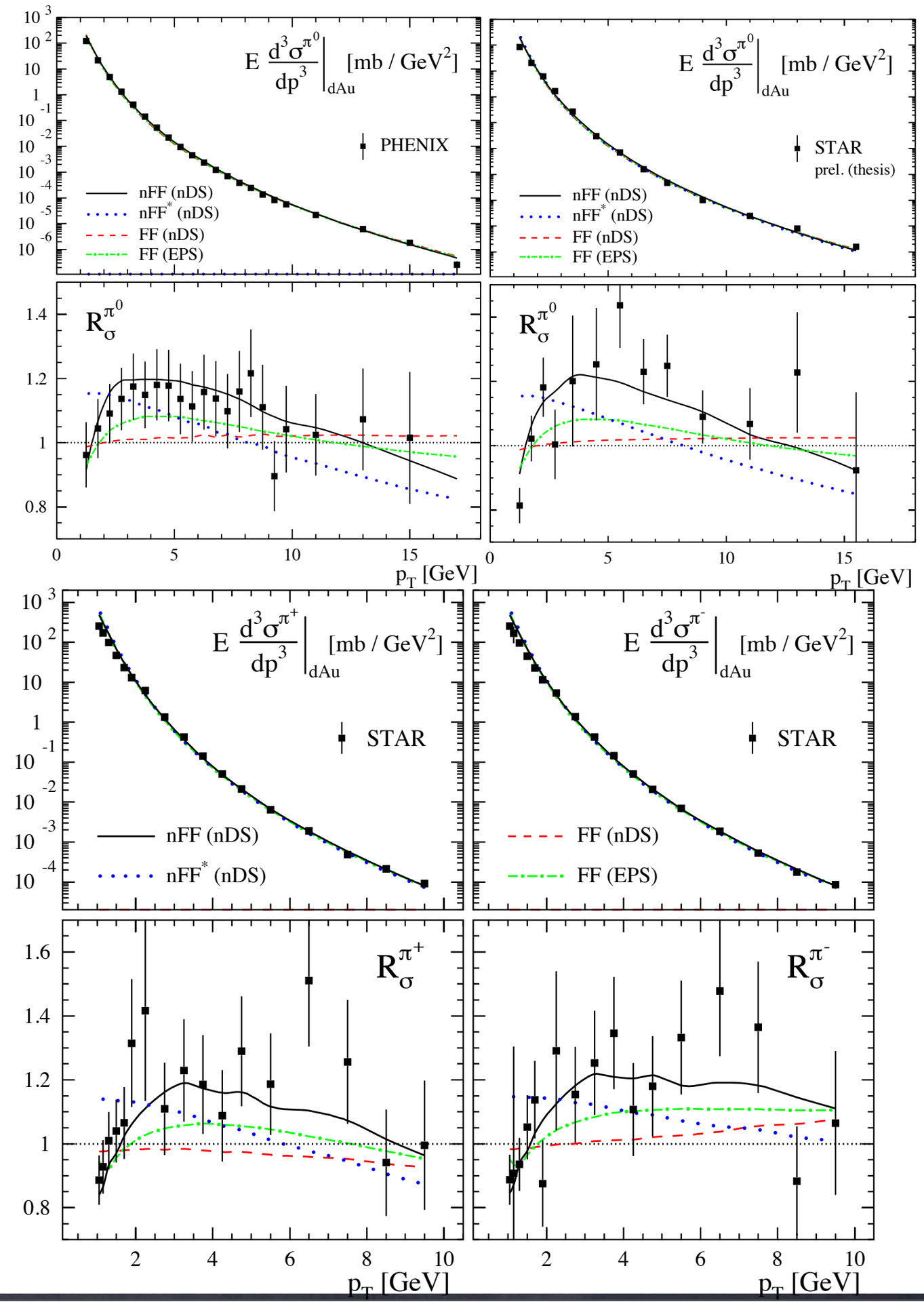
good description:

normalization

pT dependence



R_{dAu} rates are not trivial!

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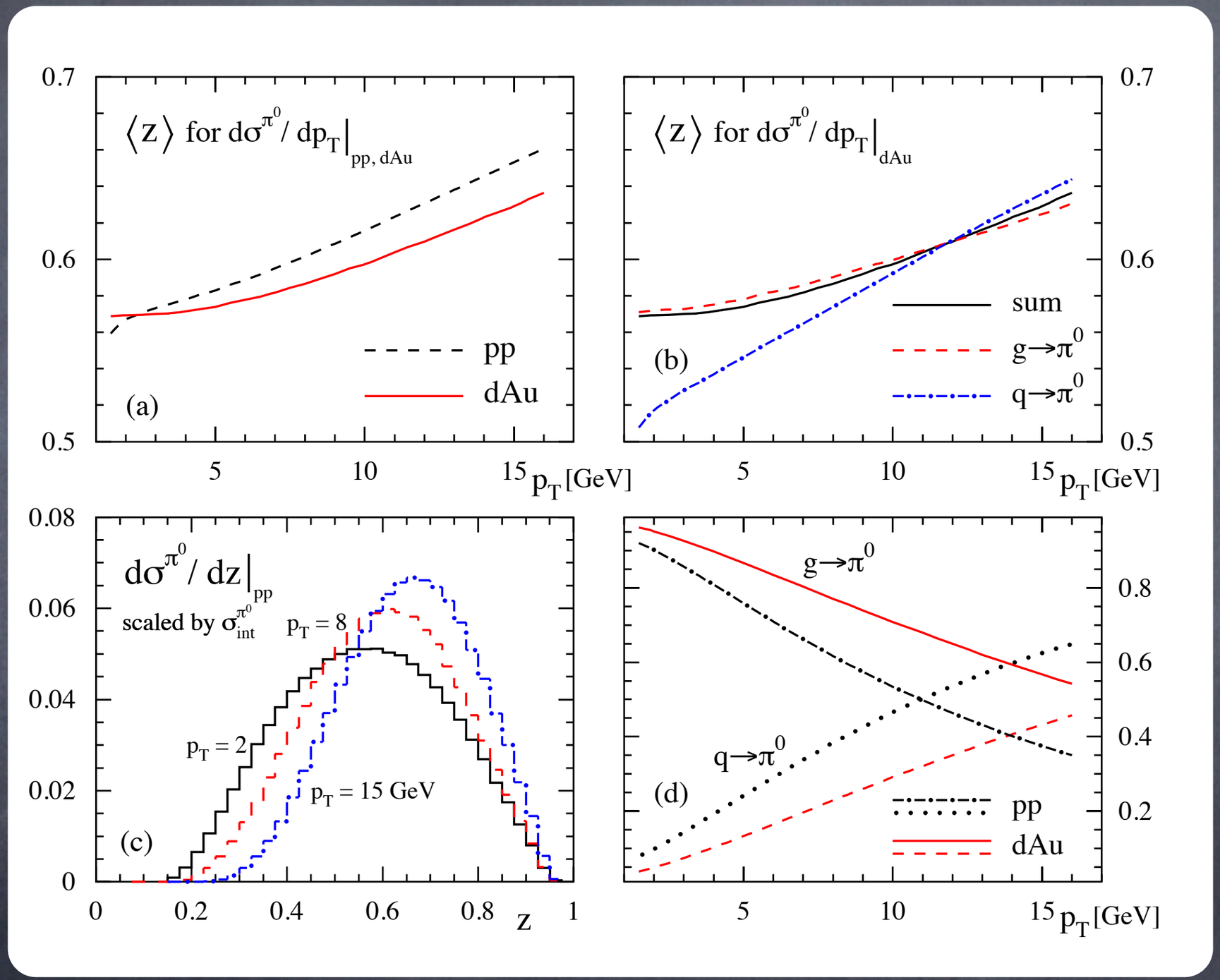
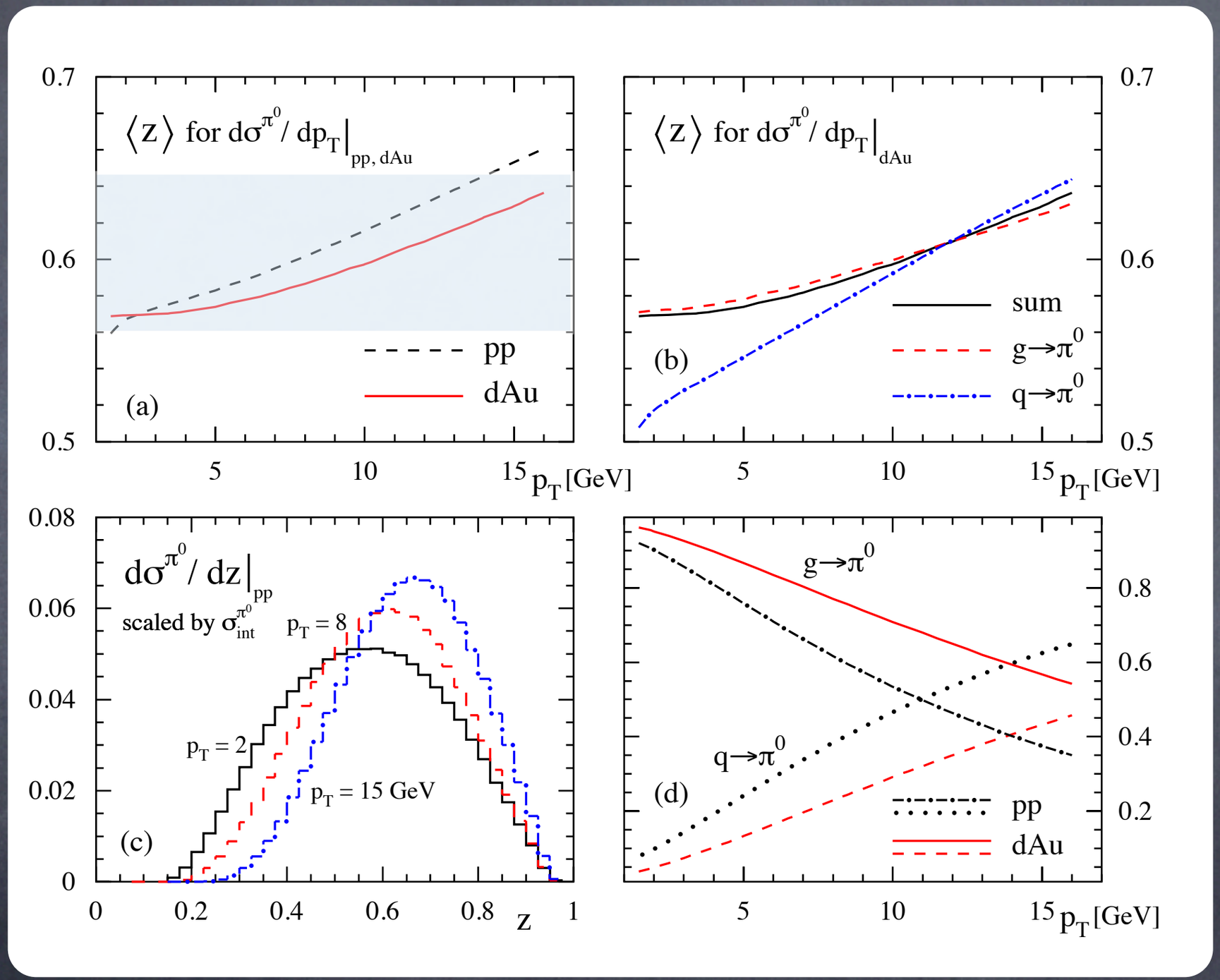


R_{dAu} rates are not trivial!

high-z dominated



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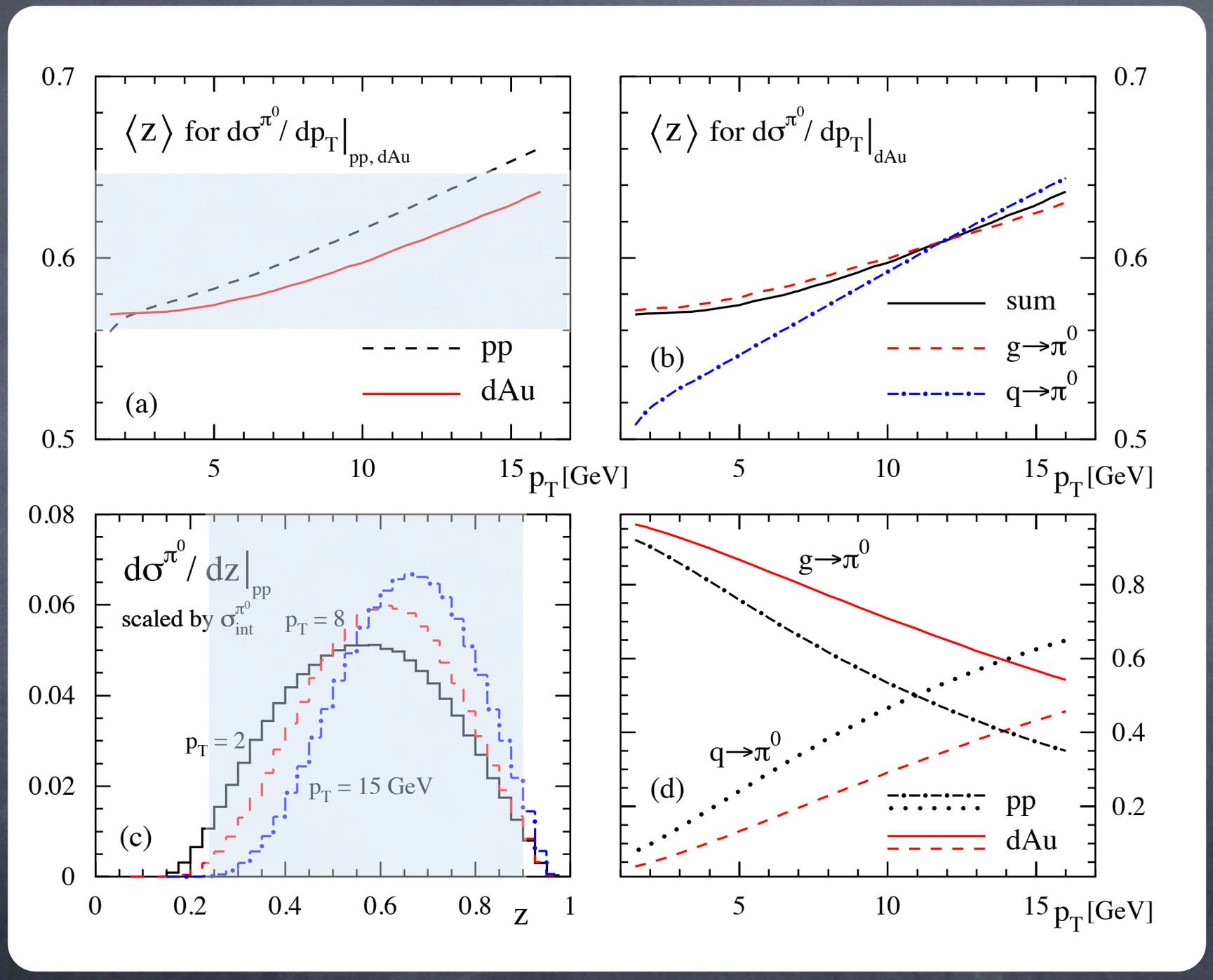

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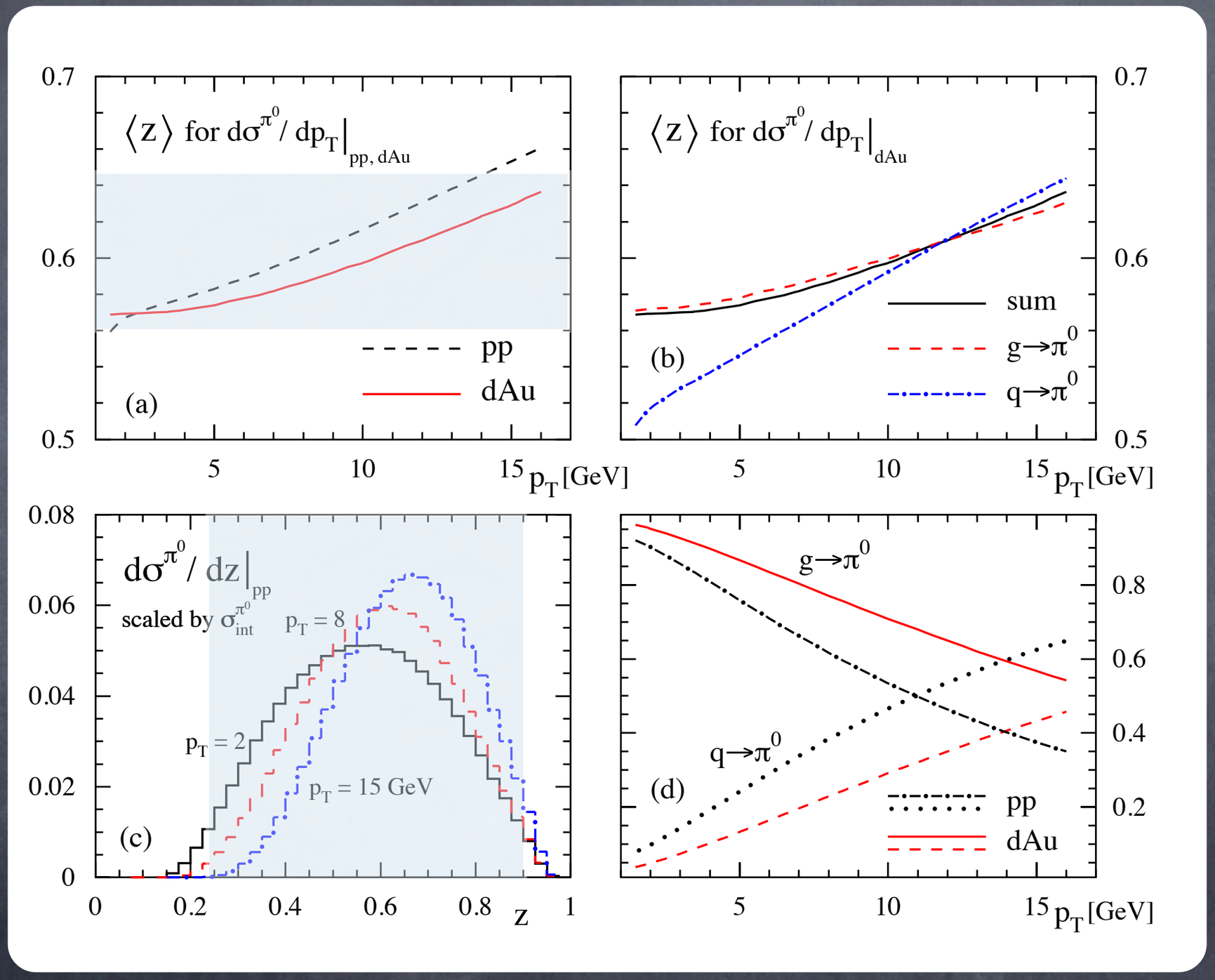
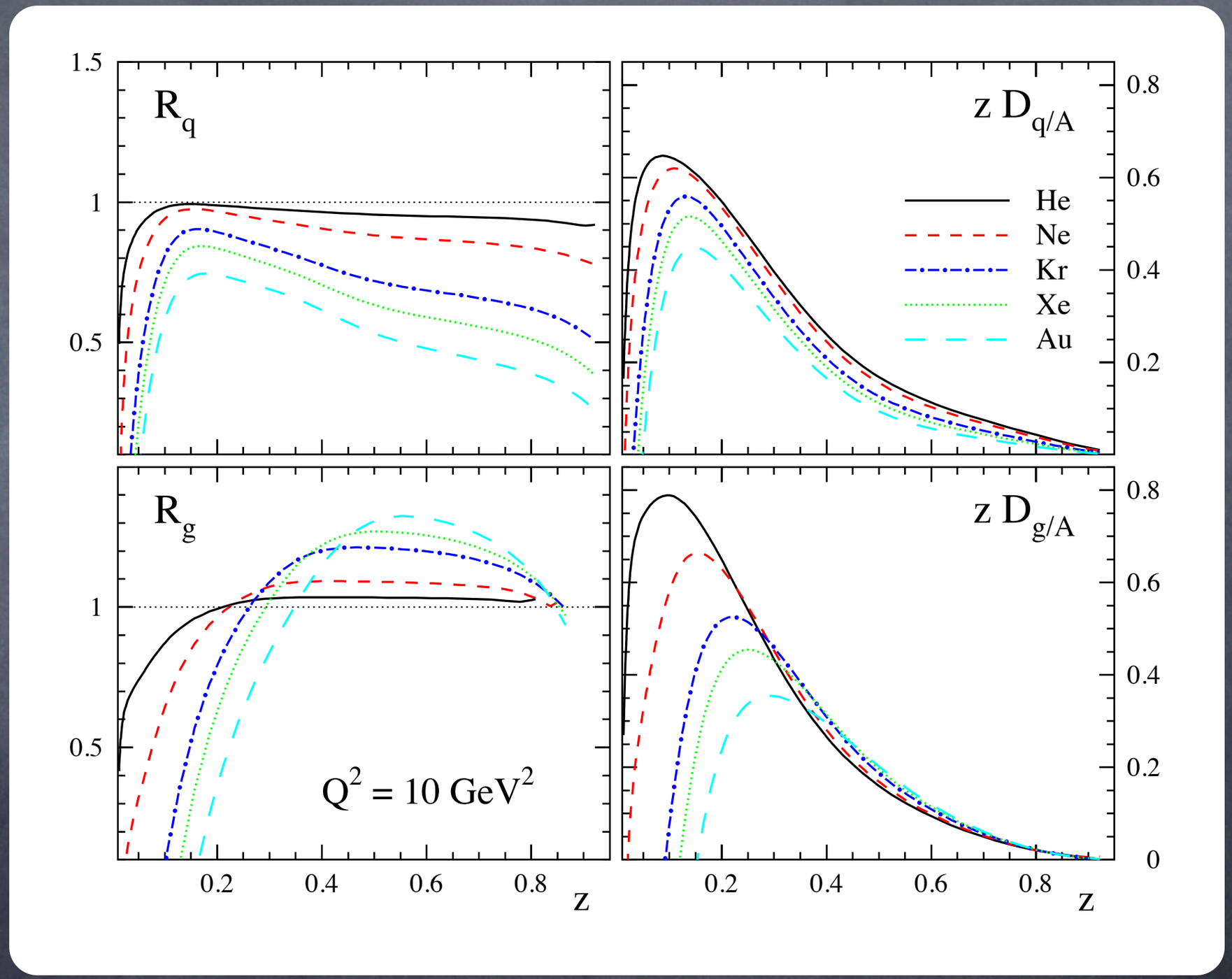


gluon/quark balance

z-dependence

z-dependence

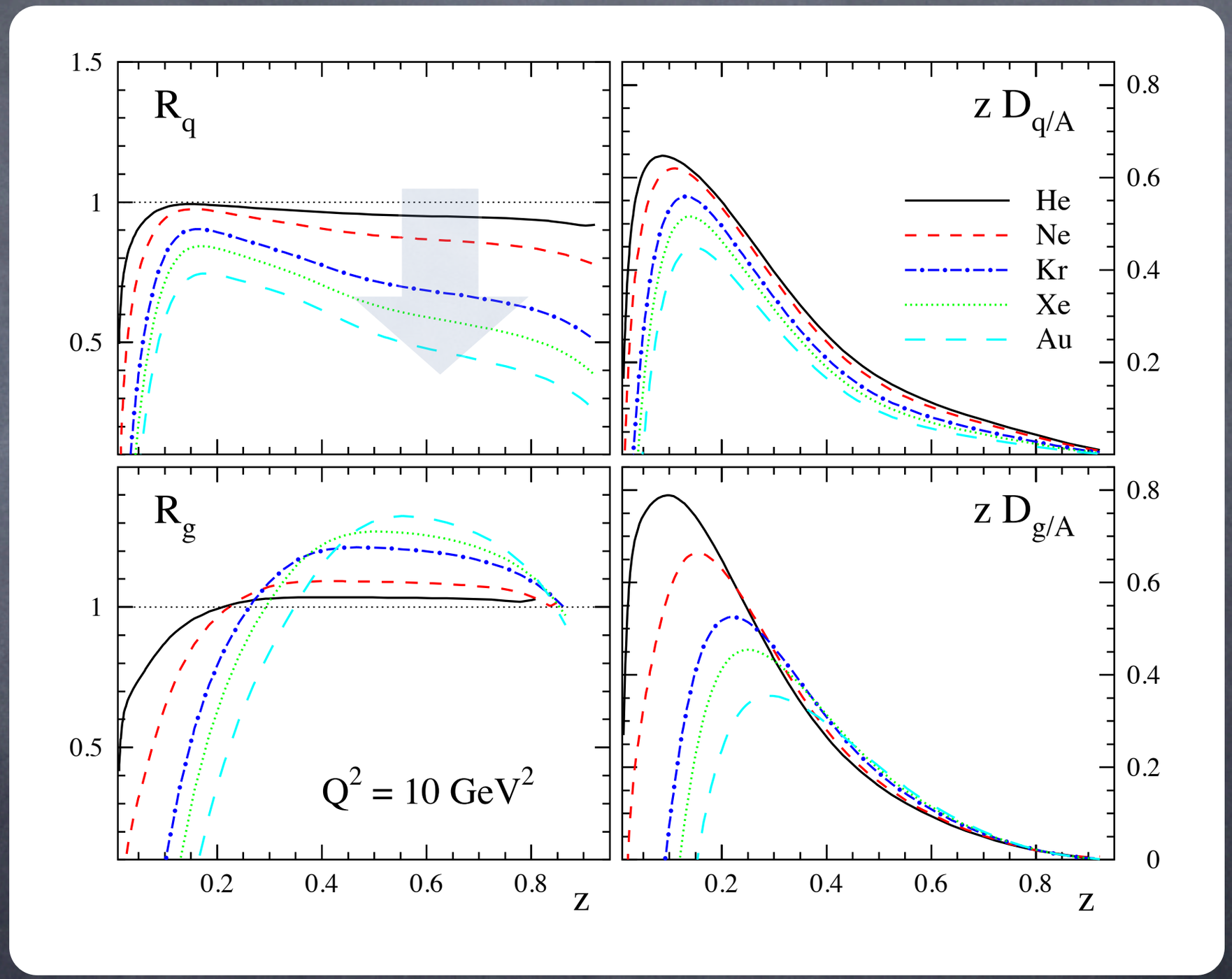
$$R_q = \frac{D_{q/A}(z, Q^2)}{D_{q/p}(z, Q^2)}$$



z-dependence

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

quarks mimic SIDIS



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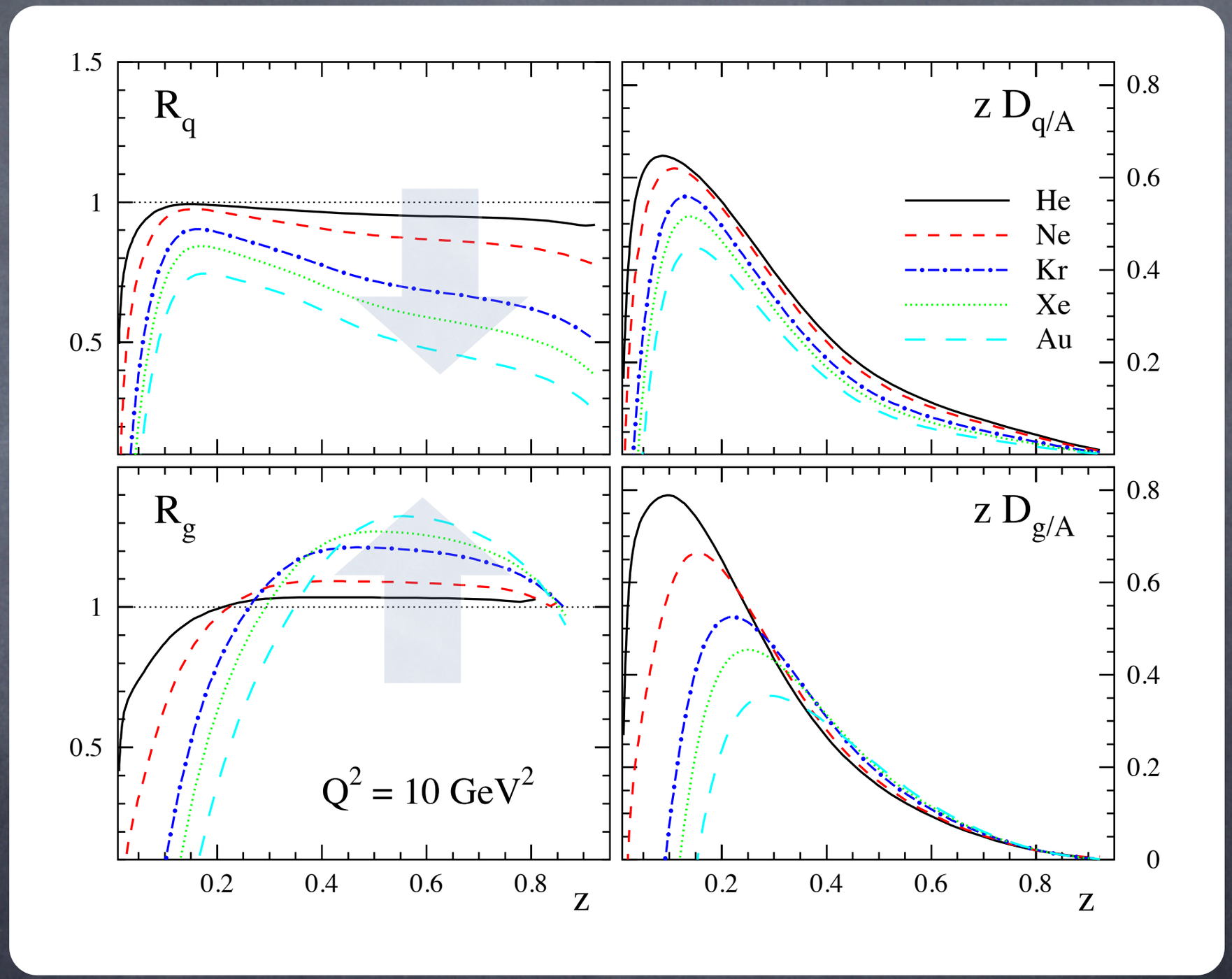
gluons do the opposite



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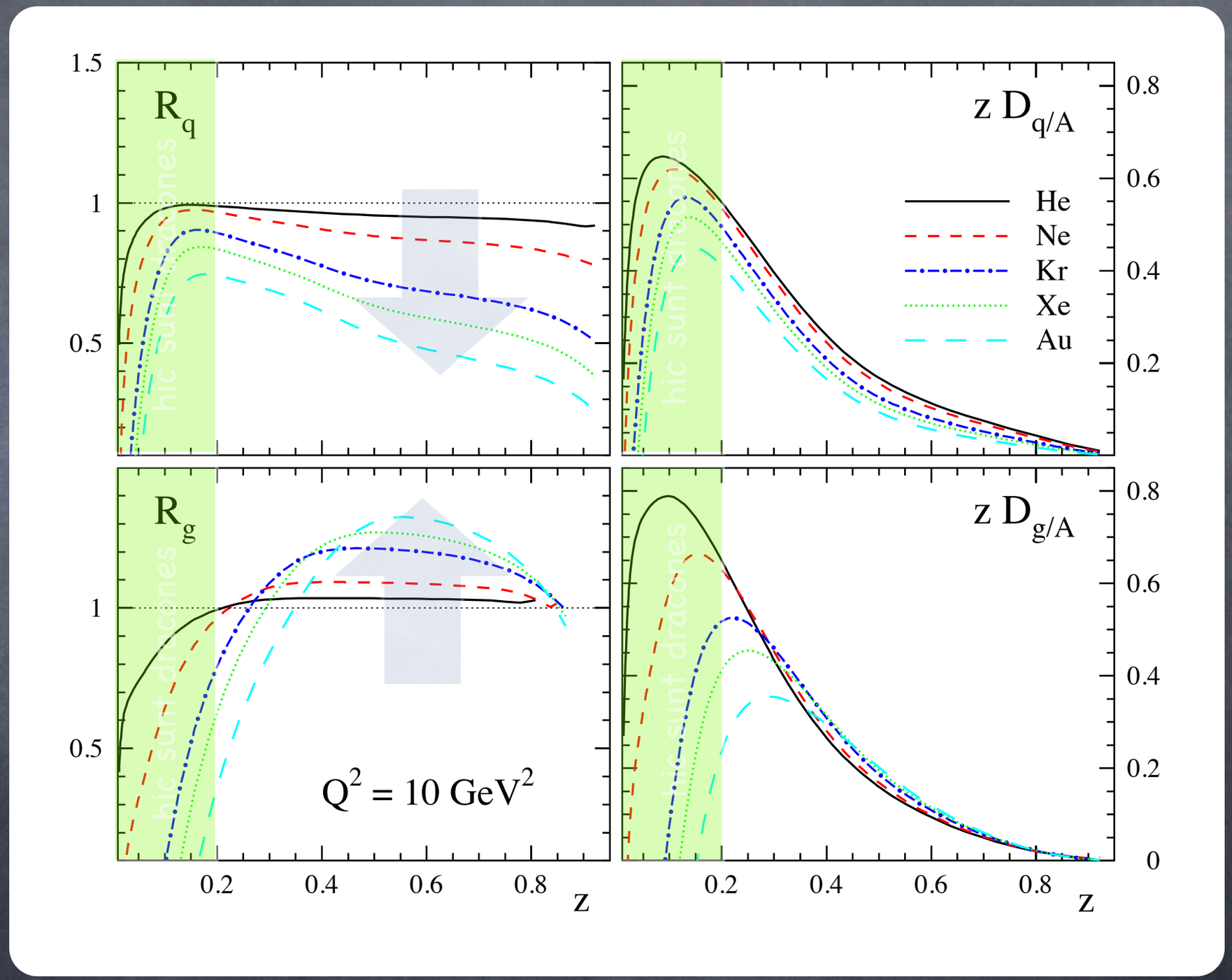
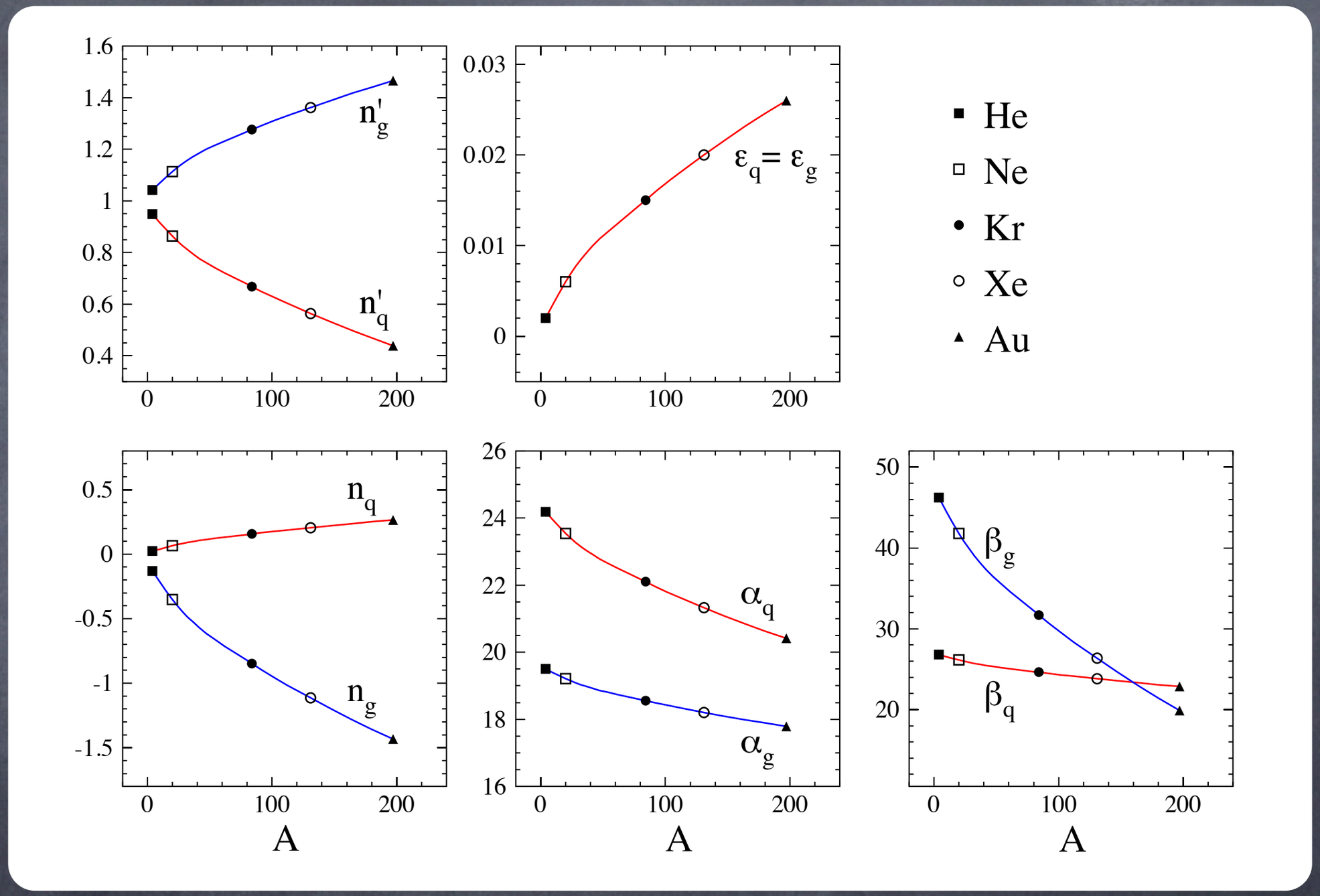


low z behavior not supported by data: artifact?

A-dependence

A-dependence



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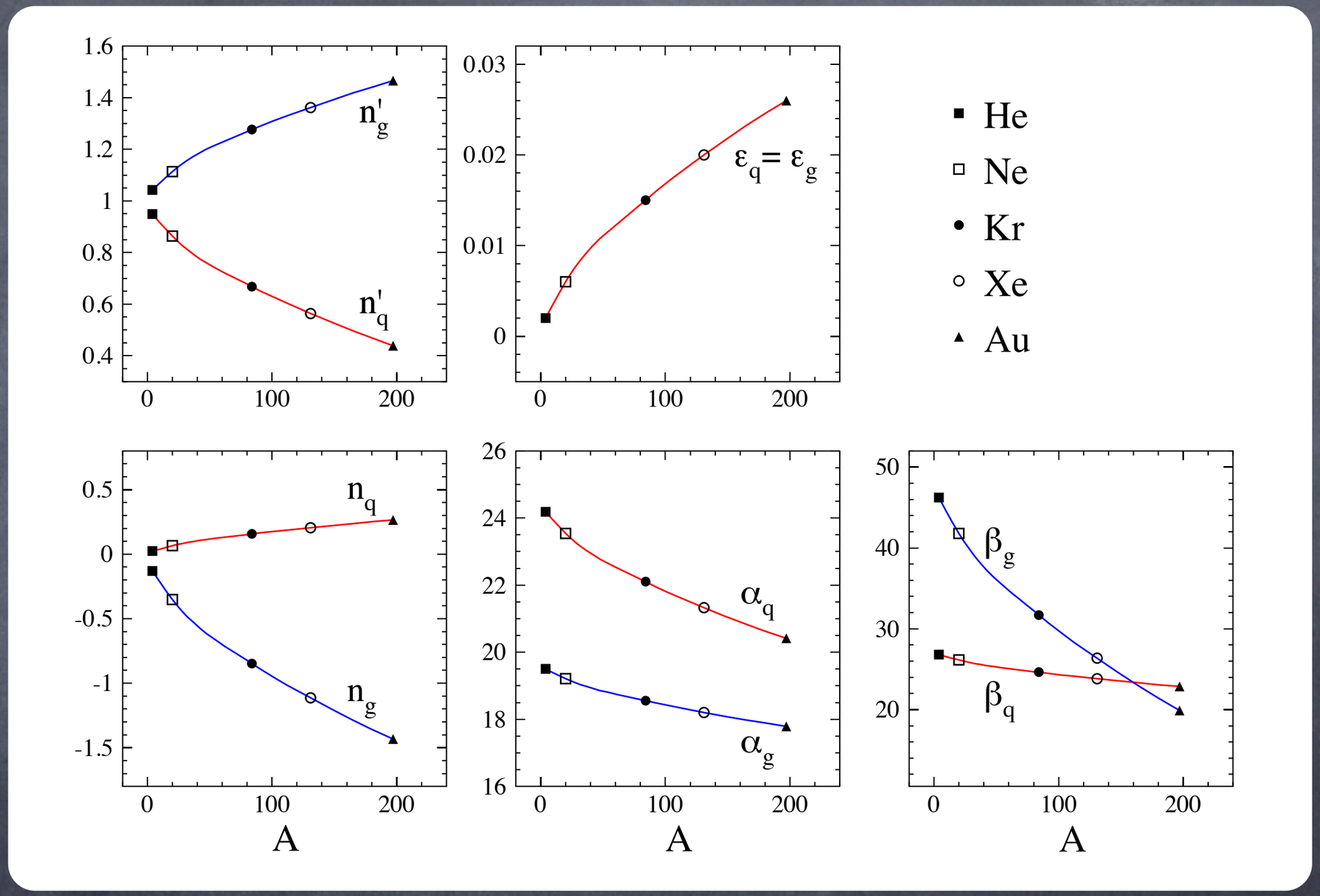
A-dependence



almost linear

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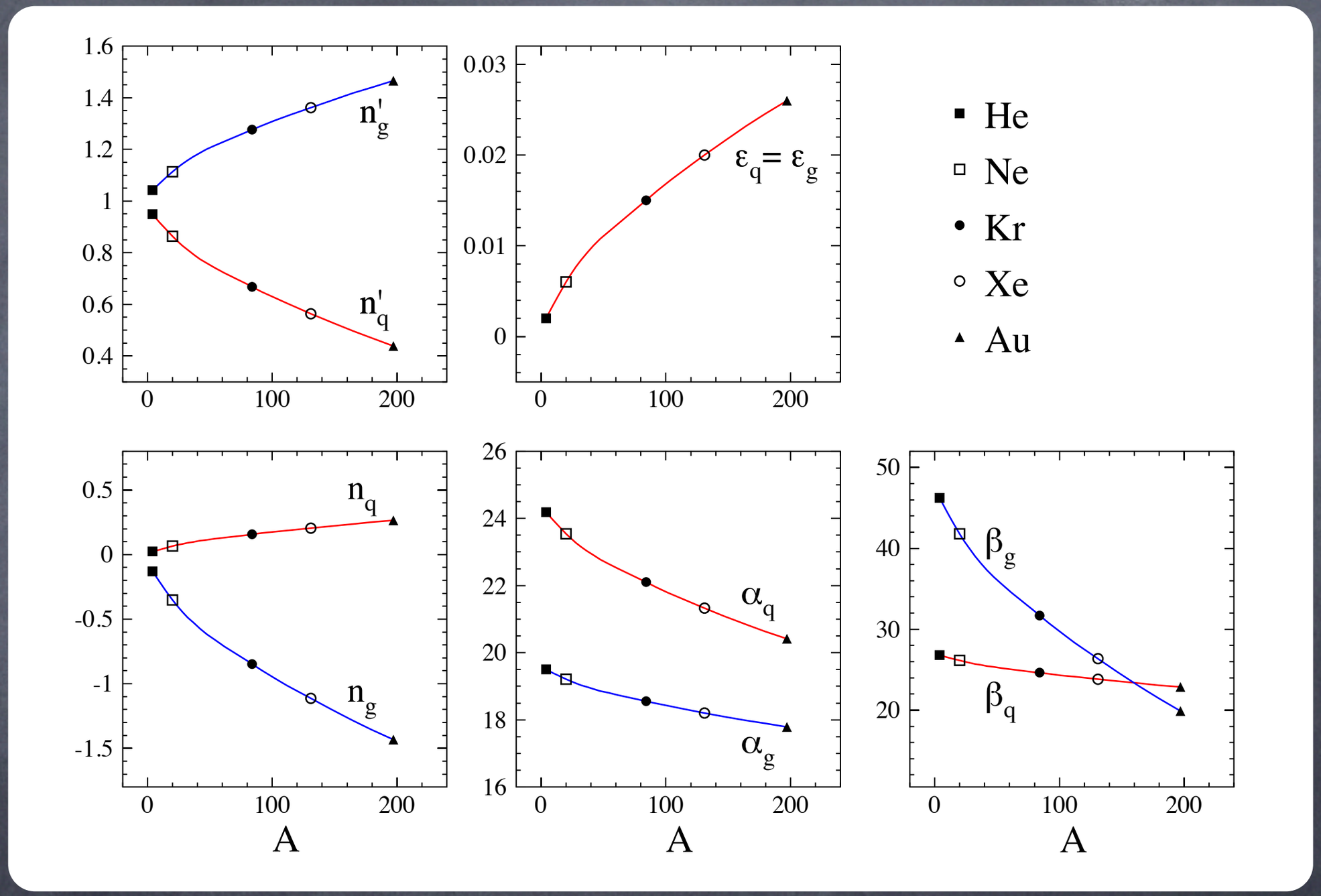
A-dependence

compensation?

almost linear



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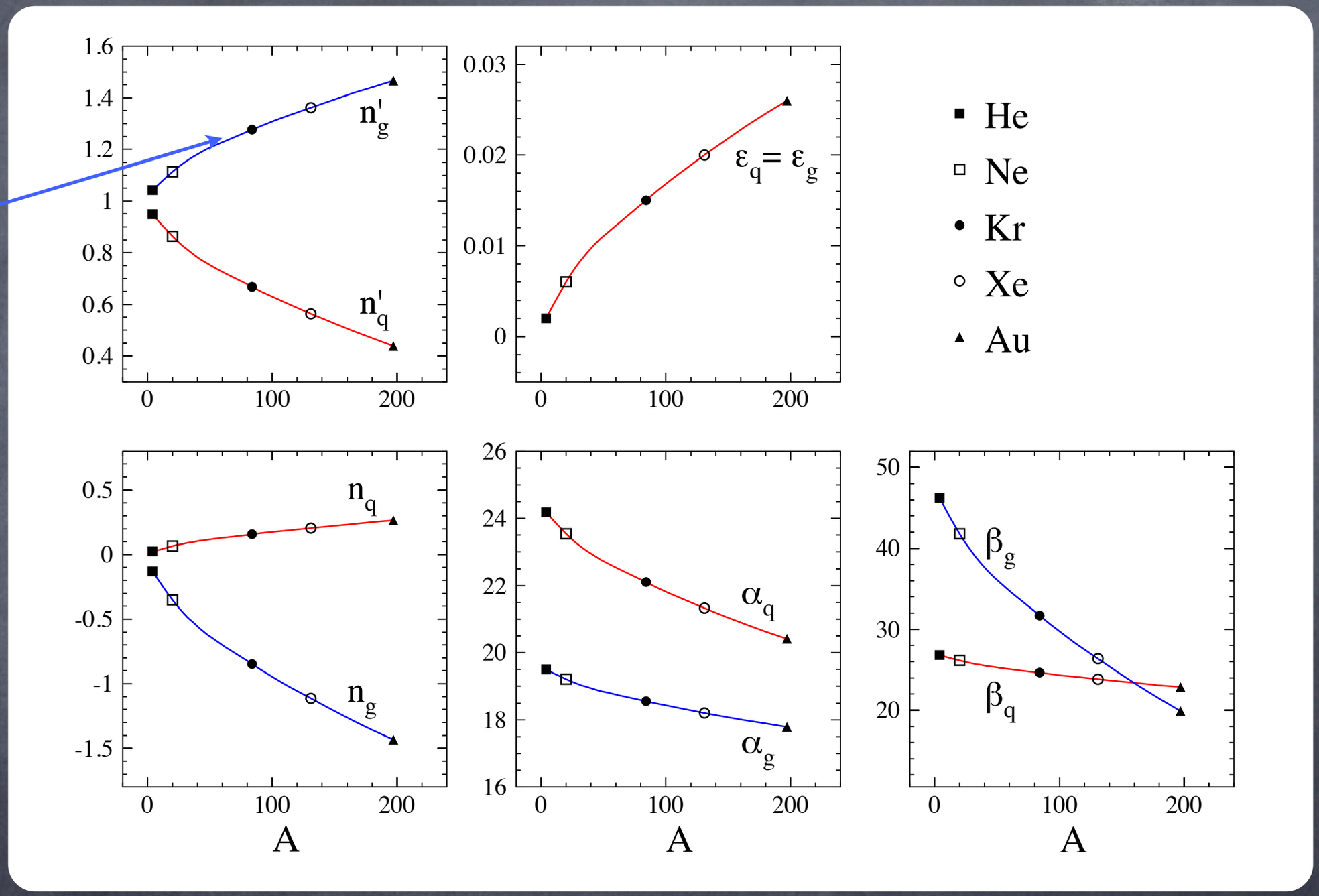

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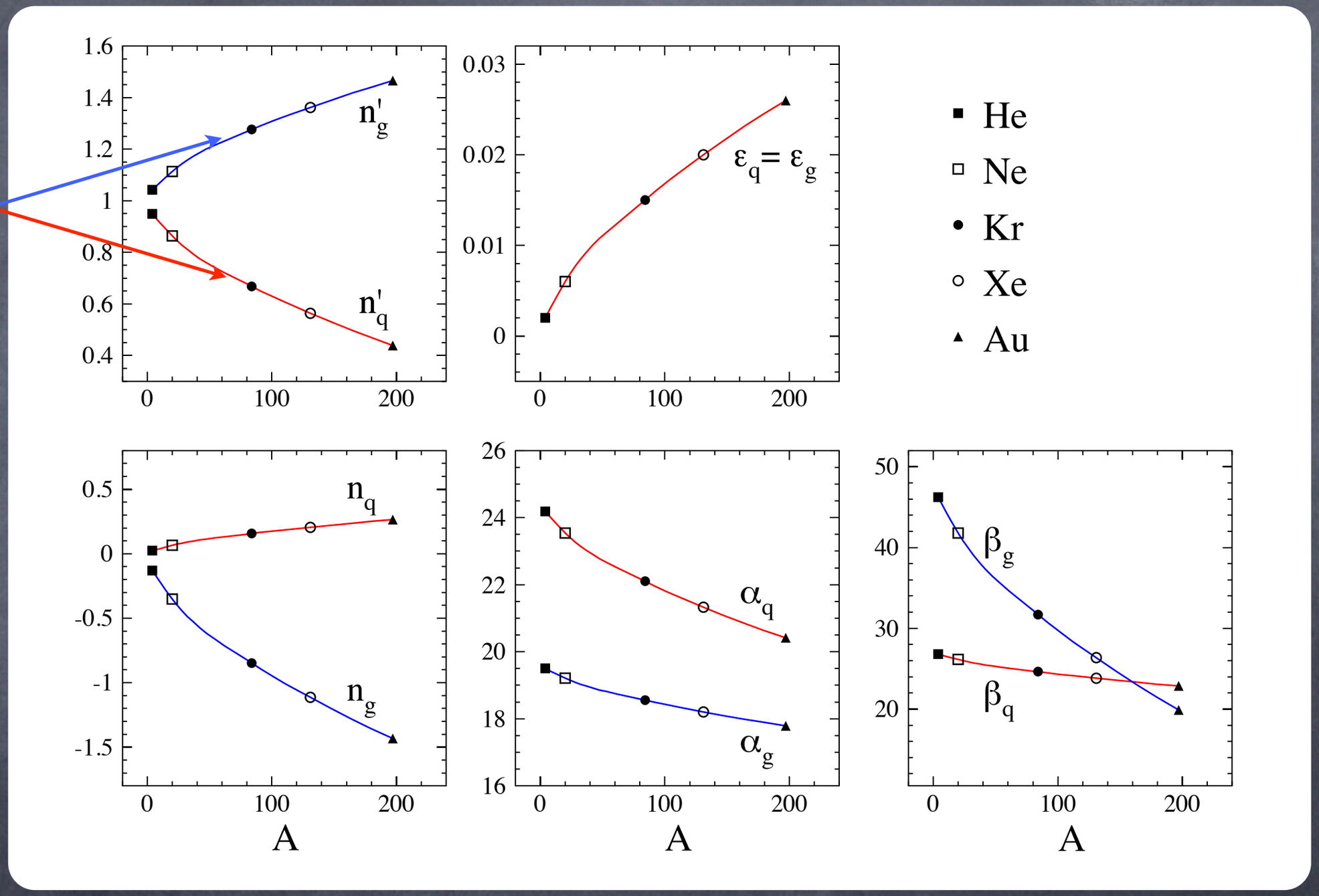

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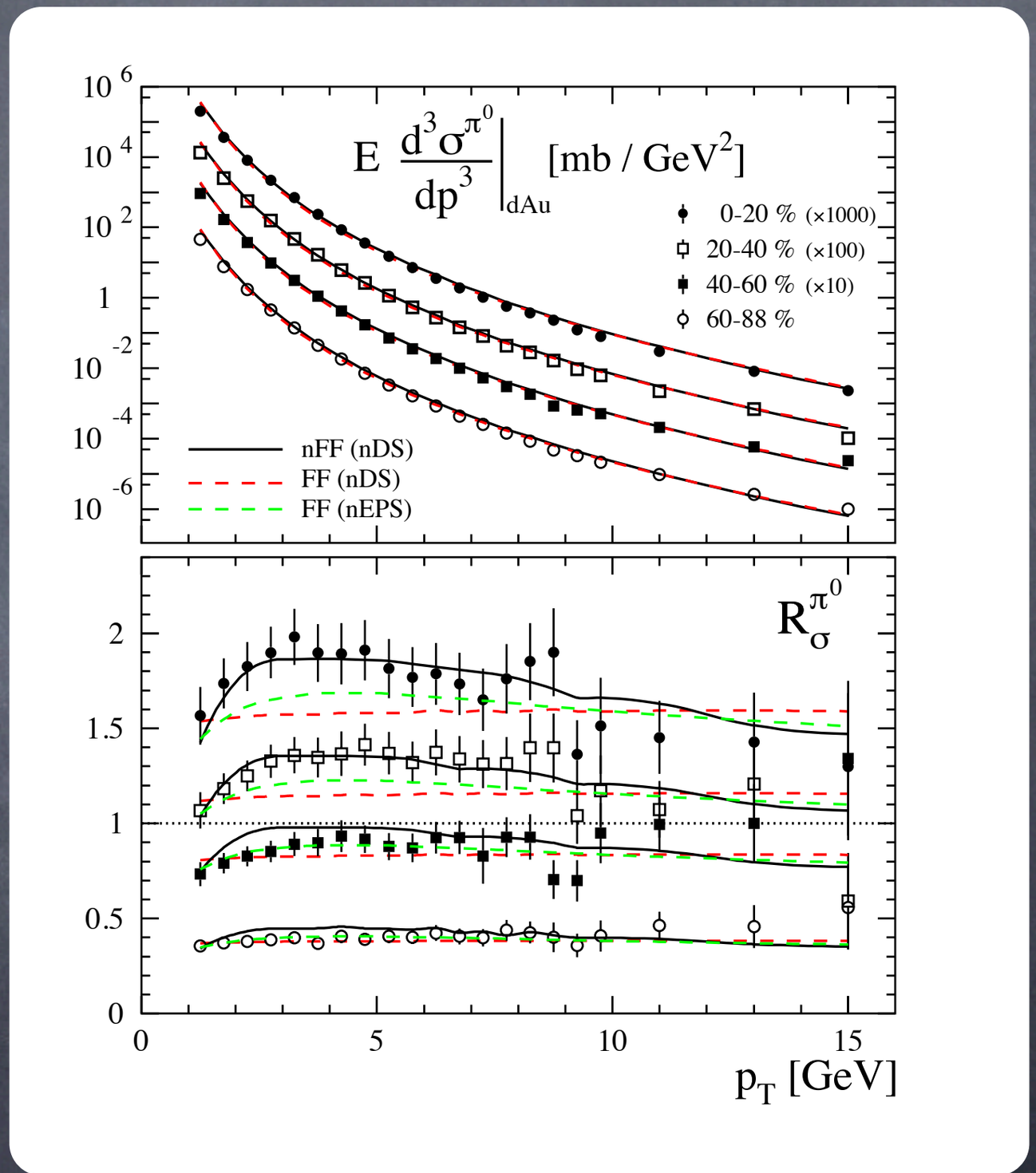

Conclusions

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A NLO pQCD factorizable scheme with effective nFF

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process-independent universal nFF standard evolution equations

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dAu or pA data can help to further constrain nPDFs,

serve the reference for AA data,

provided we have a clear picture of nFF

Backups

A	n'_q	ϵ	n_q	α_q	β_q	n'_g	n_g	α_g	β_g
He	0.949	0.002	0.024	24.183	26.800	1.042	-0.131	19.500	46.241
Ne	0.863	0.006	0.065	23.544	26.131	1.114	-0.351	19.210	41.780
Kr	0.668	0.015	0.157	22.103	24.621	1.276	-0.849	18.557	31.721
Ze	0.564	0.020	0.206	21.331	23.811	1.362	-1.115	18.206	26.331
Au	0.439	0.026	0.265	20.411	22.846	1.466	-1.433	17.789	19.902
λ_i	1	0	0	24.5607	27.1969	1	0	19.6720	48.8825
γ_i	-0.0218	0.0010	0.0103	-0.1613	-0.1691	0.0181	-0.0557	-0.0732	-1.1264
δ_i	0.6147	0.6147	0.6147	0.6147	0.6147	0.6147	0.6147	0.6147	0.6147

$$
\begin{aligned}
W_q^H(y, A, Q_0^2) &= n_q\, y^{\alpha_q}(1-y)^{\beta_q} + n'_q \delta(1-\epsilon_q - y) \\
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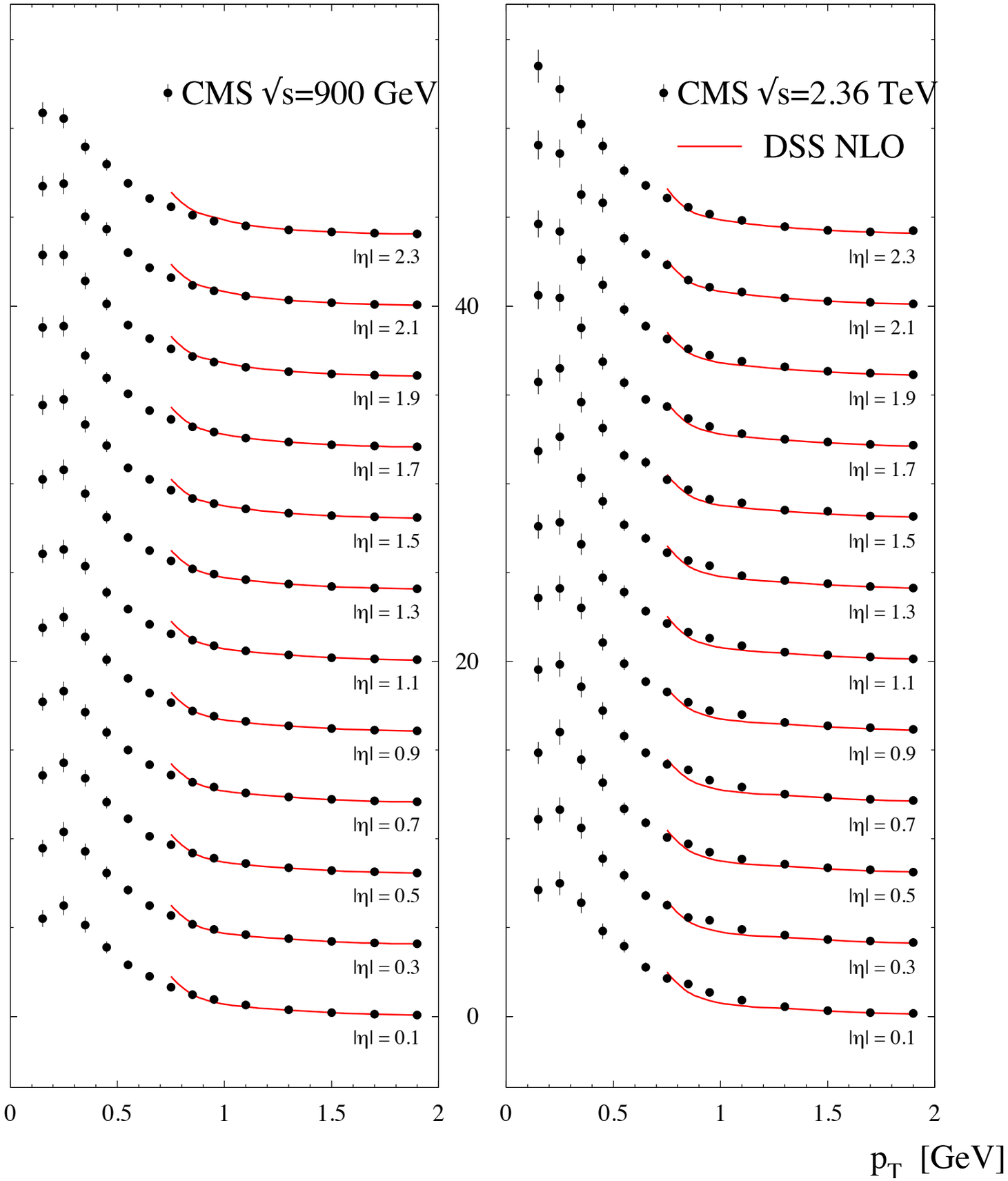
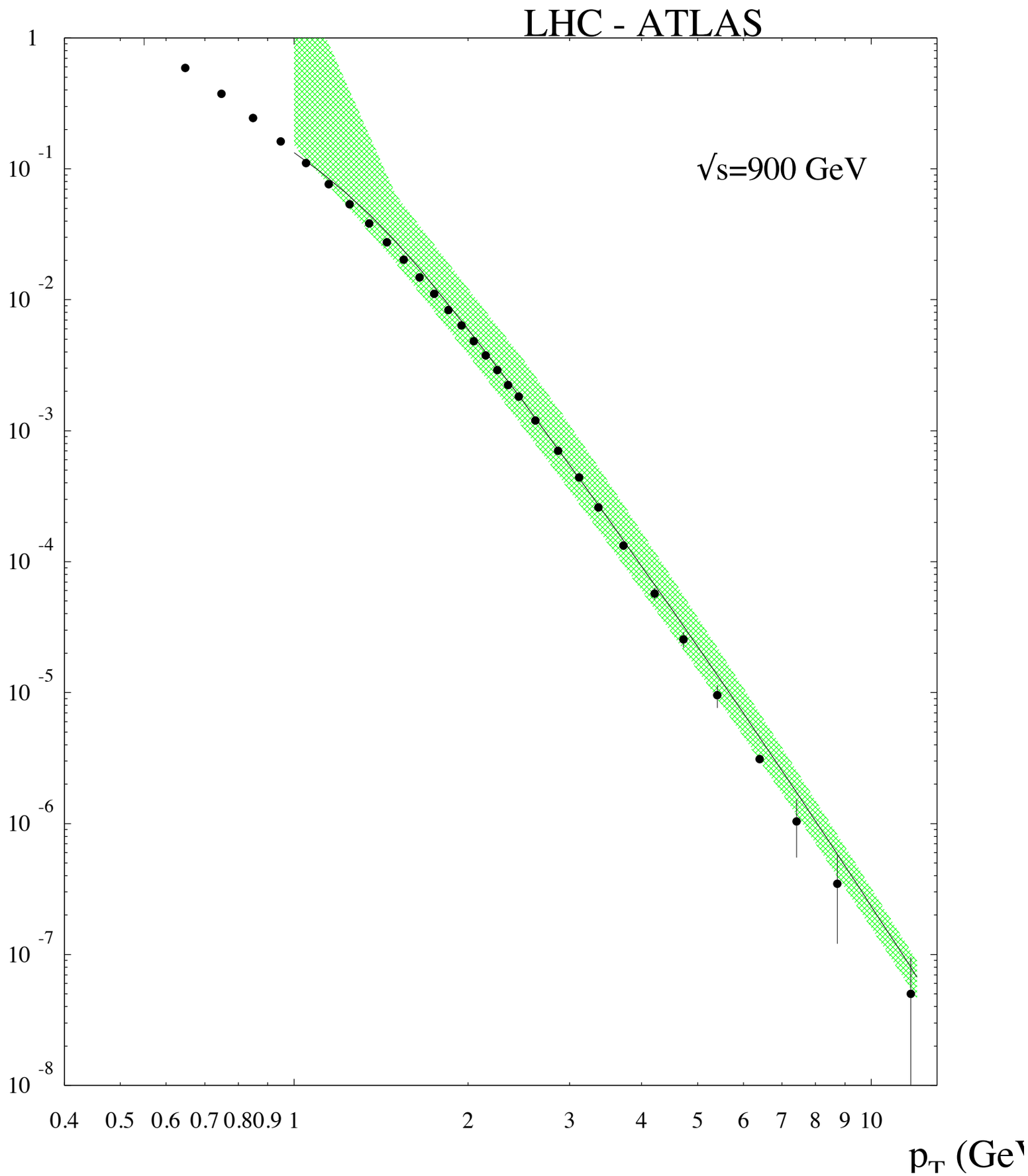
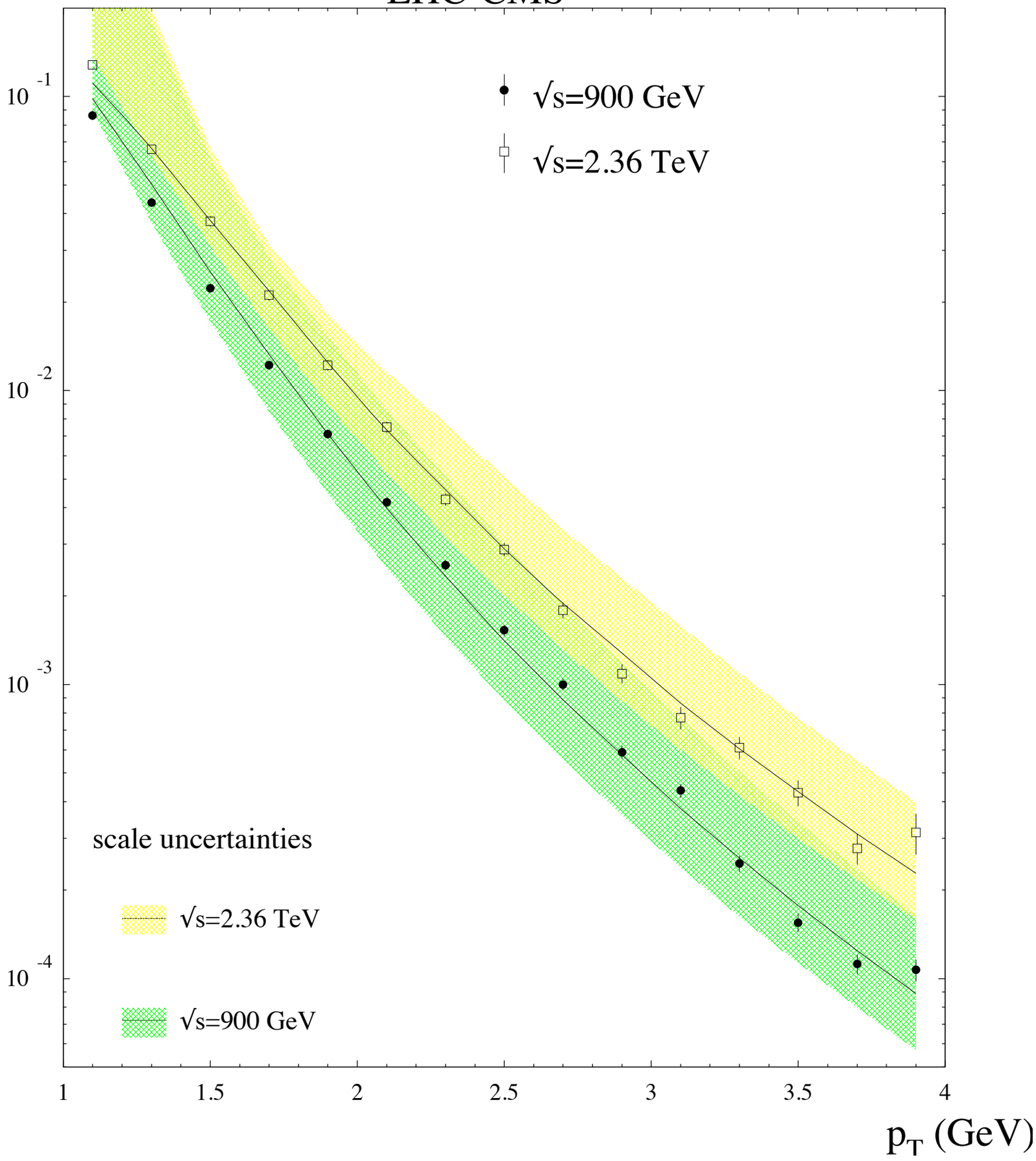
\end{aligned}
$$


CMS √s=900 GeV
CMS √s=2.36 TeV
DSS NLO
|η| = 2.3
|η| = 2.1
|η| = 1.9
|η| = 1.7
|η| = 1.5
|η| = 1.3
|η| = 1.1
|η| = 0.9
|η| = 0.7
|η| = 0.5
|η| = 0.3
|η| = 0.1
40
20
0
0
0.5
1
1.5
2
p_T [GeV]


LHC - ATLAS
√s=900 GeV
1
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
10 -7
10 -8
0.4 0.5 0.6 0.7 0.8 0.9 1 2 3 4 5 6 7 8 9 10
pT (GeV


LHC-CMS
√s=900 GeV
√s=2.36 TeV
scale uncertainties
√s=2.36 TeV
√s=900 GeV
10 -1
10 -2
10 -3
10 -4
1
1.5
2
2.5
3
3.5
4
p_T (GeV)