Consistency of neutrino DIS and the present PDFs

Hannu Paukkunen

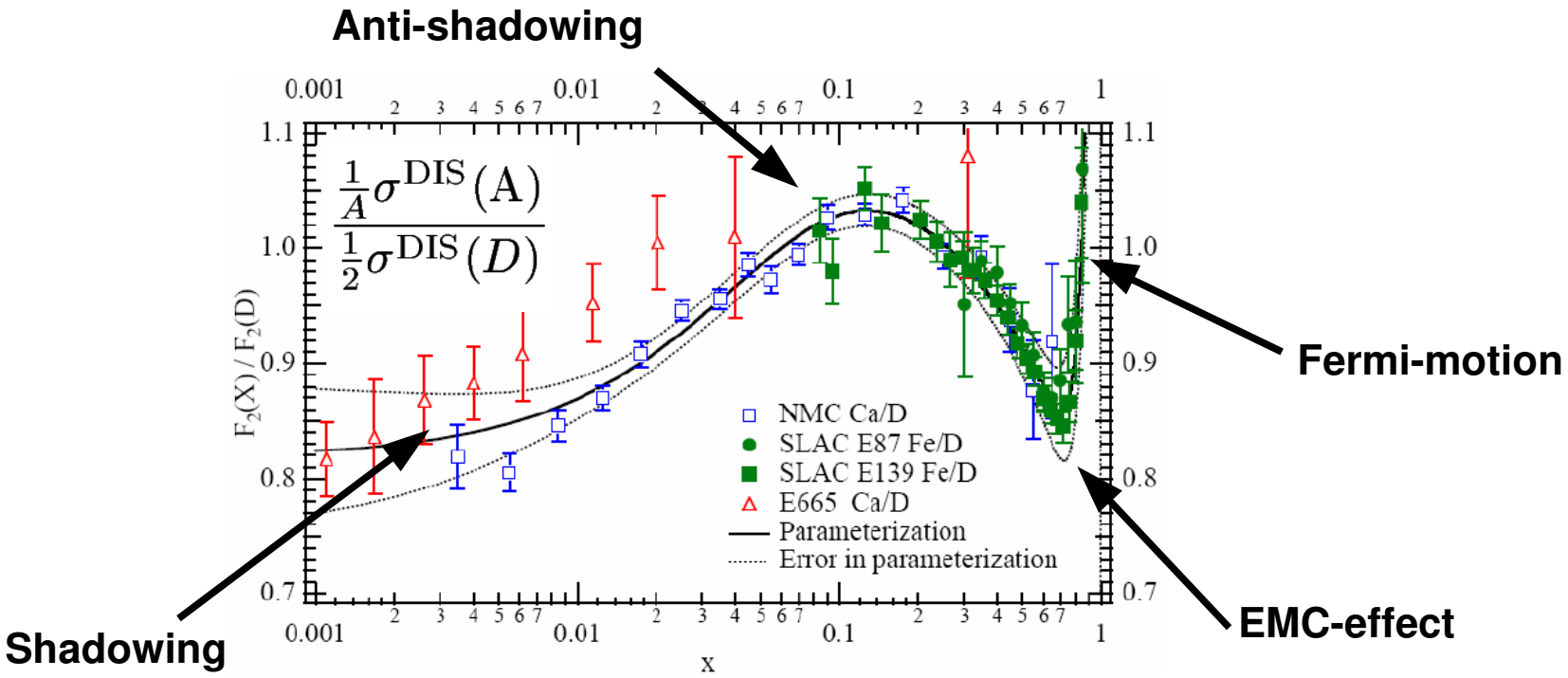
University of Santiago de Compostela

In collaboration with Carlos A. Salgado

JHEP 1007:032,2010

ICHEP, Paris, July 22, 2010

Nuclear modifications in $l^{\pm}$-A DIS



- Such effects can be factorized to the nuclear PDFs: *EPS09, HKN07, nDS, ...*
- Do the same nuclear PDFs also describe the ν-A DIS

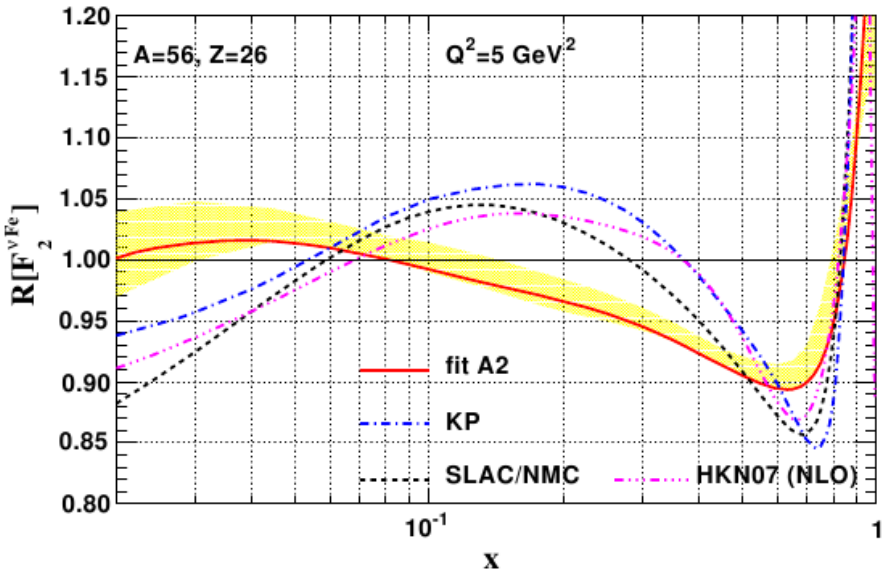
–

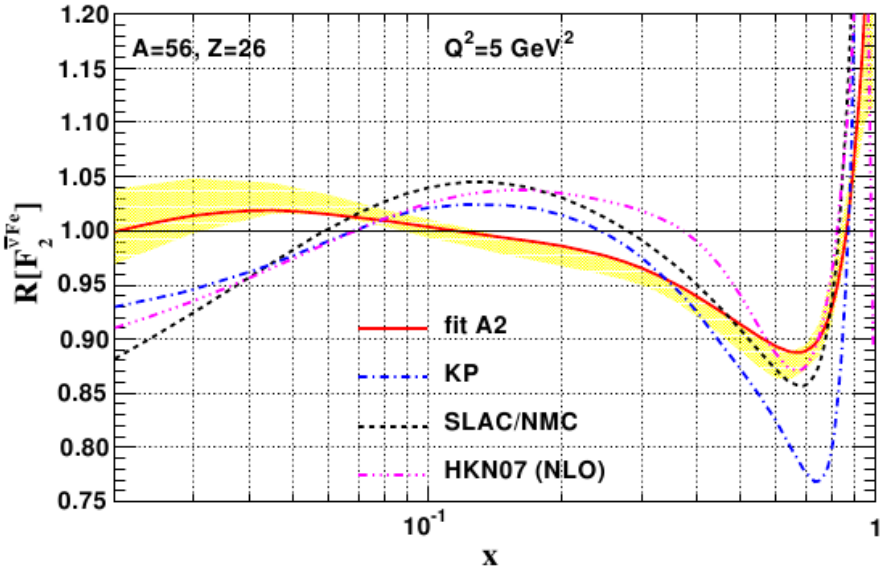
are the nPDFs universal?

From the NuTeV ν-Fe data...

- ...CTEQ-fit suggested different nuclear effects in ν-A DIS than obtained from in charged lepton DIS.

I. Schienbein et.al Phys.ReV. D77:054013,2008





- If true, would make the ν-A data practically useless for constraining e.g. free proton strange quark PDFs.

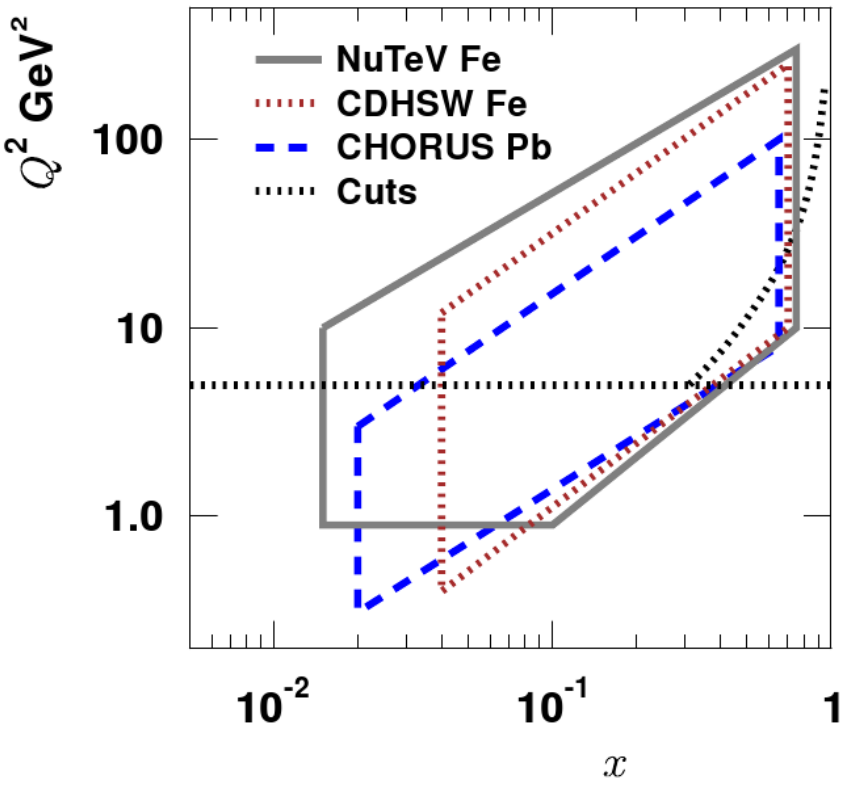
- Exposing the predictions from latest free proton PDFs (CTEQ6.6), and their nuclear modifications (EPS09) to larger data sample, we argue that no problems exist...

Experimental input

- Three ν-A DIS data sets: NuTeV (Fe), CDHSW (Fe), CHORUS (Pb)
- Use the pure cross-section data, not the extracted structure functions.
- Kinematical cuts: $Q^2_{\rm cut} > 5\,{\rm GeV}^2, \qquad W^2_{\rm cut} > 12\,{\rm GeV}^2$

  - NuTeV : 2041 data points
  - CDHSW : 700 data points
  - CHORUS: 768 data points

- Lot of kinematical overlap among the data sets.



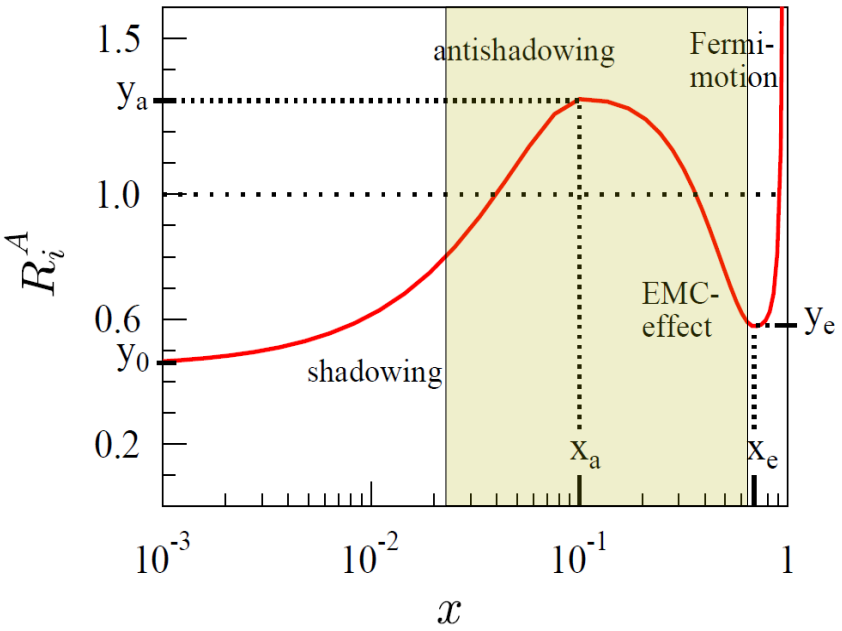
Theoretical Framework

- **Standard NLO, QCD-improved parton model augmented with:**

  - Up-to-date CTEQ6.6 PDFs $f_k^{\text{proton}}(x,Q^2)$

  - Nuclear modifications $R^A(x,Q^2)$ from EPS09

$$f_k^{\text{proton},A}(x,Q^2) = R_k^A(x,Q^2)\, f_k^{\text{proton}}(x,Q^2)$$



Range of ν-data

- SACOT-prescription to account for heavy quark effects

Theoretical Framework

- **Corrections for Target mass & Electroweak radiation:**

1. Target mass: *Qiu, Accardi, JHEP 0807 (2008) 090*

$$\int_x^1 \frac{dz}{z}\omega_{ik}\left(z\right) f_k^A\left(\frac{x}{z}\right) \rightarrow \int_x^1 \frac{dz}{z}\omega_{ik}\left(z\right) f_k^A\left(\frac{\xi}{z}\right)$$

$$\xi \equiv 2x/(1+\sqrt{1+4x^2M^2/Q^2})$$

2. Electroweak radiation: *Arbuzov, Bardin, Kalinovskaya, JHEP 0506 (2005) 078*

$$F_i^A = \sum_k \left[\omega_{ik}^{\mathrm{LO}}\left(1+\Delta_k^{\mathrm{radiative}}\right)+\omega_{ik}^{\mathrm{NLO}}\right]\otimes f_k^A$$

The Results

Incorrubtible measure: The χ^2-values

- The χ^2-values without radiative or target mass corrections:

No RAD + No TM	CTEQ6.6	CTEQ6.6 + EPS09
NuTeV	1.35	1.05
CHORUS	1.23	1.06
CDHSW	0.96	0.85

- The χ^2-values with radiative and target mass corrections:

RAD + TM	CTEQ6.6	CTEQ6.6 + EPS09
NuTeV	1.51	1.05
CHORUS	1.15	0.78
CDHSW	1.10	0.69

Incorrubtible measure: The χ^2-values

- The χ^2-values without radiative or target mass corrections:

No RAD + No TM	CTEQ6.6	CTEQ6.6 + EPS09
NuTeV	1.35	1.05
CHORUS	1.23	1.06
CDHSW	0.96	0.85

- The χ^2-values with radiative and target mass corrections:

RAD + TM	CTEQ6.6	CTEQ6.6 + EPS09
NuTeV	1.51	1.05
CHORUS	1.15	0.78
CDHSW	1.10	0.69

Extremely good χ^2-values!

Incorrubtible measure: The χ^2-values

- The χ^2-values without radiative or target mass corrections:

No RAD + No TM	CTEQ6.6	CTEQ6.6 + EPS09
NuTeV	1.35	1.05
CHORUS	1.23	1.06
CDHSW	0.96	0.85

- The χ^2-values with radiative and target mass corrections:

RAD + TM	CTEQ6.6	CTEQ6.6 + EPS09
NuTeV	1.51	1.05
CHORUS	1.15	0.78
CDHSW	1.10	0.69

Extremely good χ^2-values!

Something strange going on with the NuTeV data?

Figures tell more than 1000 words...

- **The Data/Theory ratios...**

$$R^{\mathrm{CTEQ6.6}} \equiv \frac{\sigma^{\nu,\overline{\nu}}\left(\mathrm{Experimental}\right)}{\sigma^{\nu,\overline{\nu}}\left(\mathrm{CTEQ6.6}\right)}$$

$$R^{\mathrm{CTEQ6.6\times EPS09}} \equiv \frac{\sigma^{\nu,\overline{\nu}}\left(\mathrm{CTEQ6.6}\times\mathrm{EPS09}\right)}{\sigma^{\nu,\overline{\nu}}\left(\mathrm{CTEQ6.6}\right)}$$

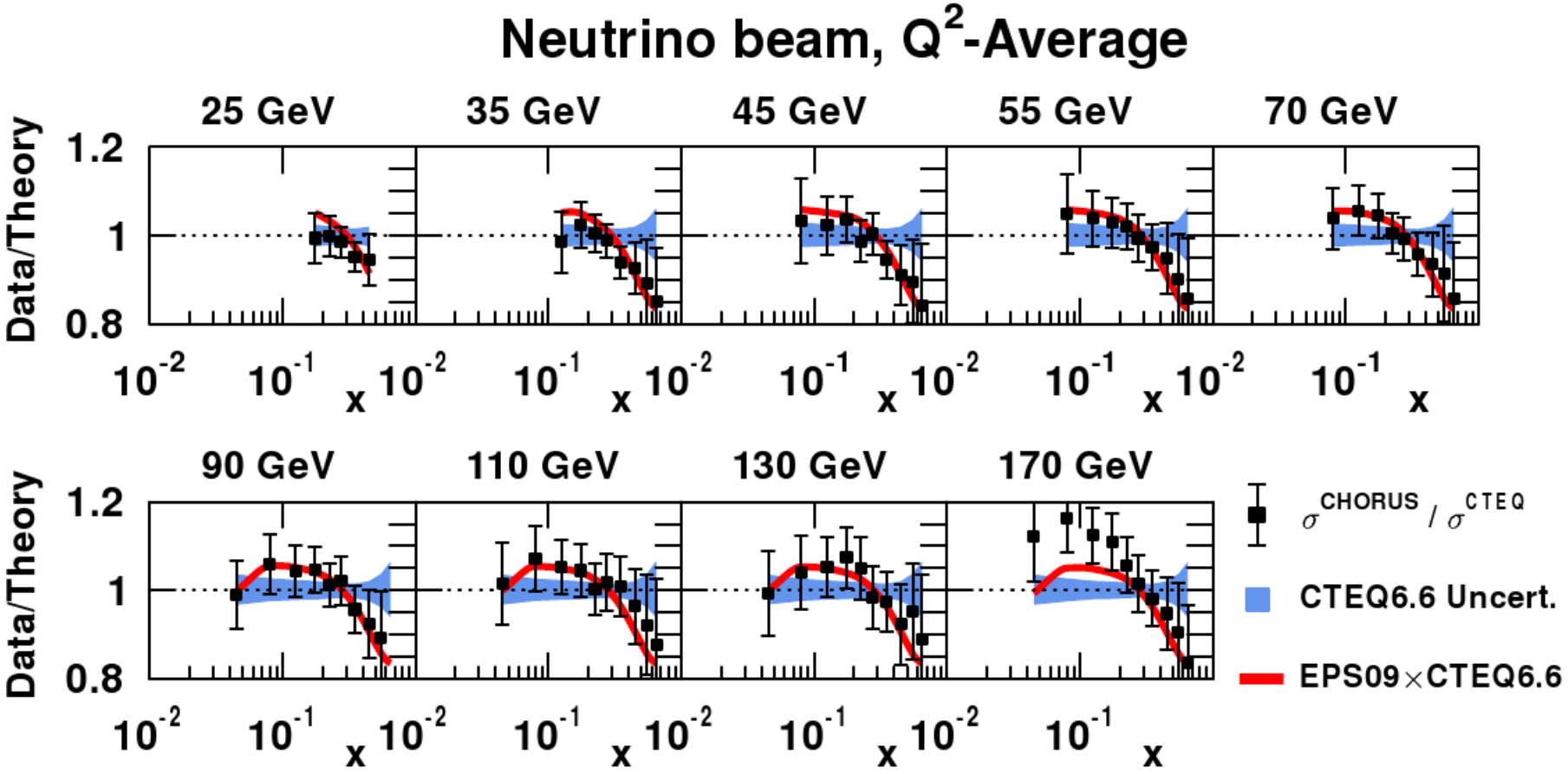
...do not display much Q^2-dependence.

- **Plot the Q^2-averaged Data/Theory ratios instead**

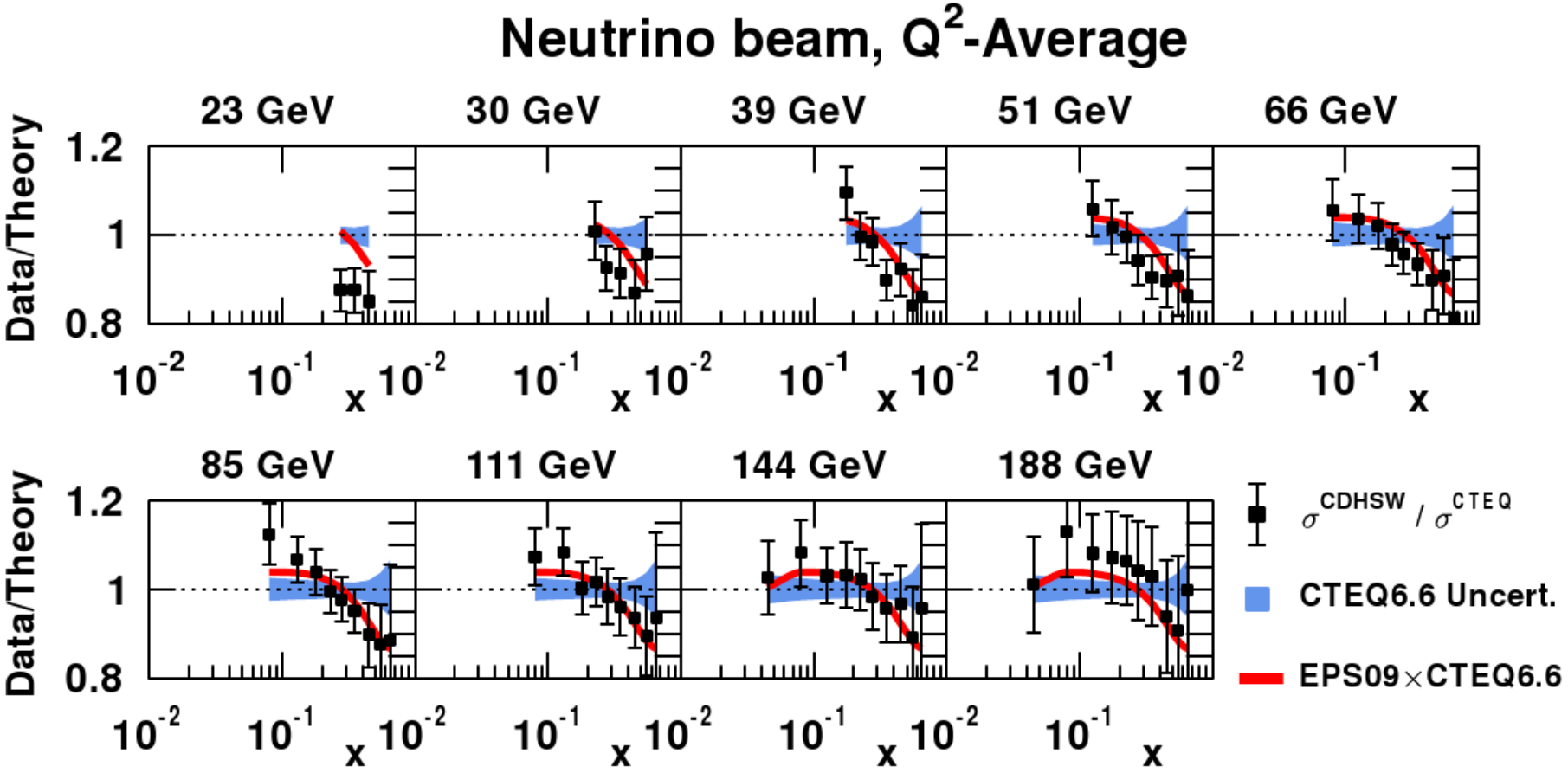
$$R^{\mathrm{CTEQ6.6}}_{\mathrm{Average}} = \left(\sum_{i\in\mathrm{fixed}\,x}^{N}\frac{R_i^{\mathrm{CTEQ6.6}}}{\sigma_i}\right)\left(\sum_{i\in\mathrm{fixed}\,x}^{N}\frac{1}{\sigma_i}\right)^{-1} \pm N\times\left(\sum_{i\in\mathrm{fixed}\,x}^{N}\frac{1}{\sigma_i}\right)^{-1}$$

$$R^{\mathrm{CTEQ6.6\times EPS09}}_{\mathrm{Average}} = \frac{1}{N}\sum_{i\in\mathrm{fixed}\,x}^{N} R_i^{\mathrm{CTEQ6.6\times EPS09}}$$

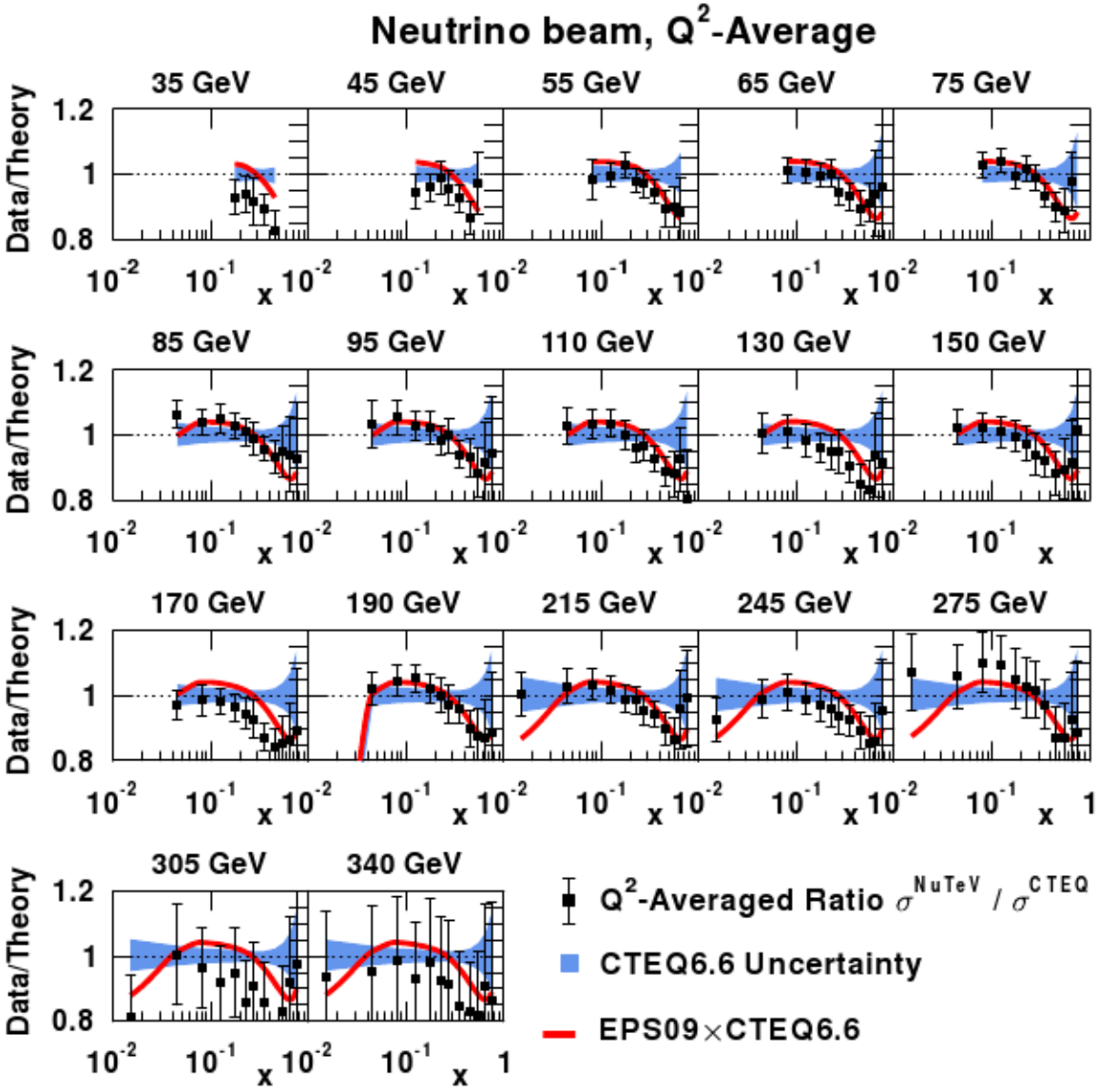
CHORUS (Pb)


Neutrino beam, Q²-Average
25 GeV
35 GeV
45 GeV
55 GeV
70 GeV
90 GeV
110 GeV
130 GeV
170 GeV
Data/Theory
1.2
1
0.8
10⁻²
10⁻¹
x
σ CHORUS / σ CTEQ
CTEQ6.6 Uncert.
EPS09×CTEQ6.6

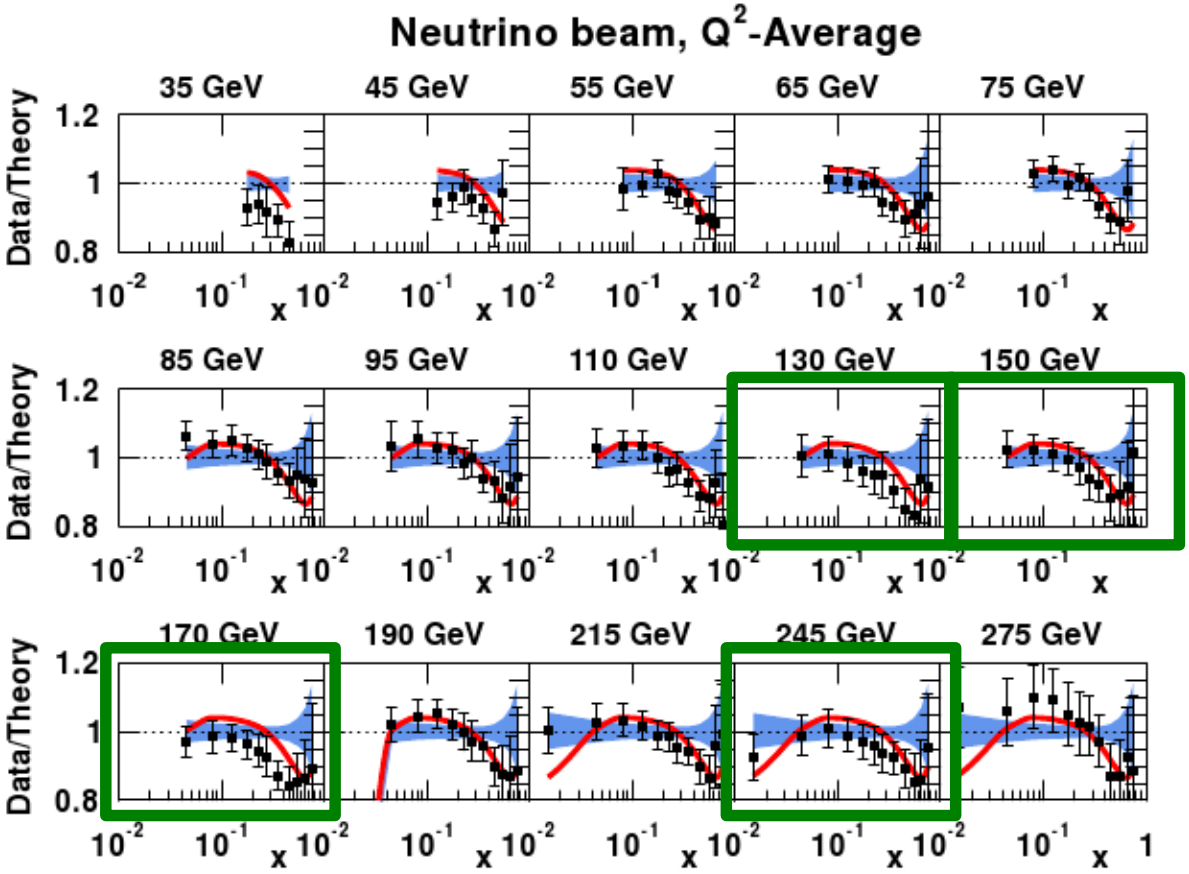
CDHSW (Fe)


Neutrino beam, Q²-Average
23 GeV
30 GeV
39 GeV
51 GeV
66 GeV
85 GeV
111 GeV
144 GeV
188 GeV
Data/Theory
1.2
1
0.8
10⁻²
10⁻¹
x
σ CDHSW / σ CTEQ
CTEQ6.6 Uncert.
EPS09×CTEQ6.6

NuTeV (Fe)

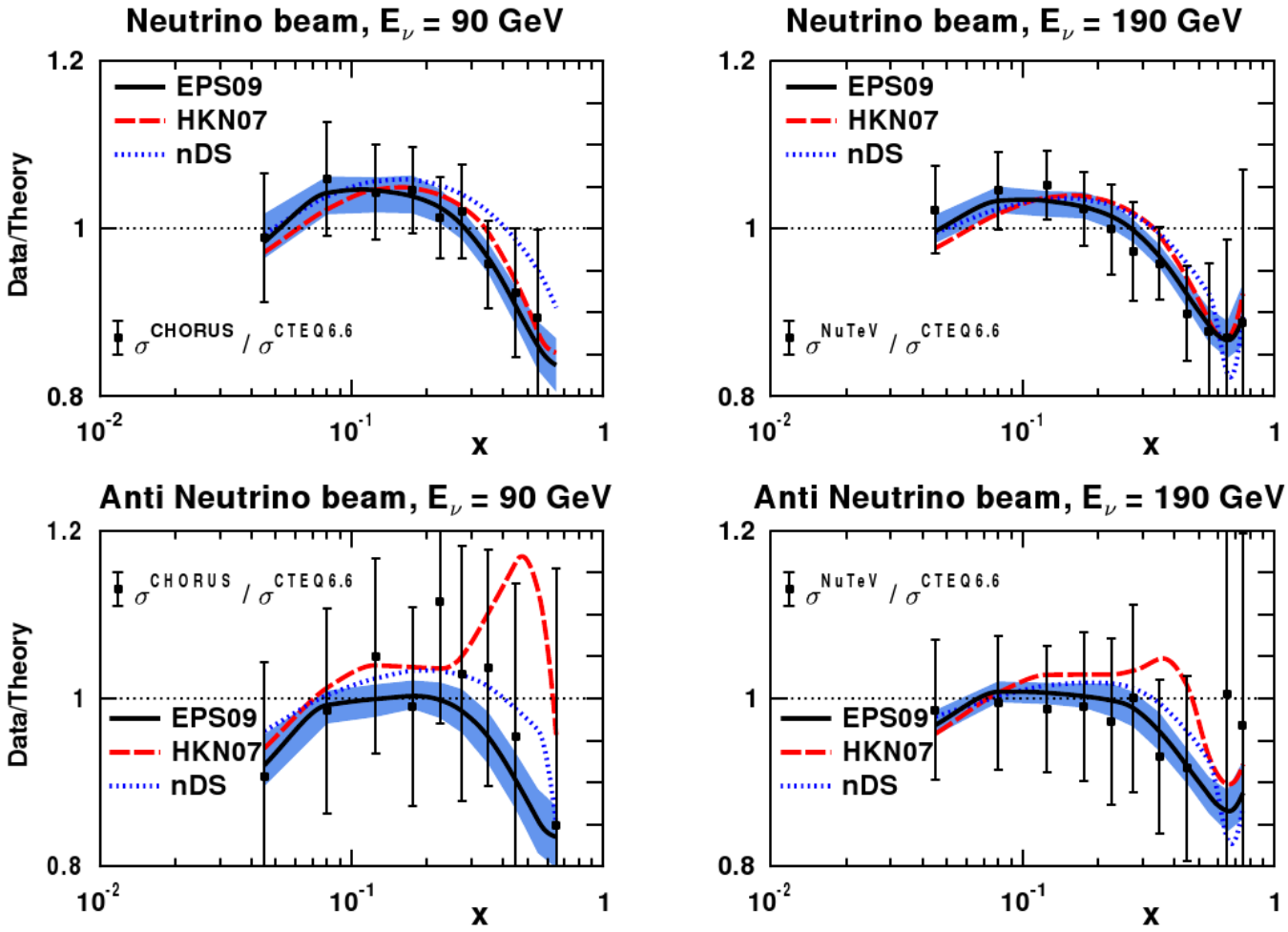

Neutrino beam, Q²-Average
35 GeV
45 GeV
55 GeV
65 GeV
75 GeV
85 GeV
95 GeV
110 GeV
130 GeV
150 GeV
170 GeV
190 GeV
215 GeV
245 GeV
275 GeV
305 GeV
340 GeV
Data/Theory
1.2
1
0.8
10⁻²
10⁻¹
x
1
Q²-Averaged Ratio σ^NuTeV / σ^CTEQ
CTEQ6.6 Uncertainty
EPS09×CTEQ6.6

NuTeV (Fe)



The NuTeV neutrino data in different E_ν bins display some mutual tension!!

Comparison to other sets of nPDFs



- **The evident differences imply that use of neutrino data should be helpful in nPDF fits.**

In short:

- Comparison to CHORUS and CDHSW data display an excellent agreement with the CTE6.6+EPS09 predictions!

- We found evidence of ***internal tension*** within the NuTeV data.
  - This could be the origin of the controversy found by CTEQ.
  - Can't be taken as a discriminative factor for conclusions about the relatively small nuclear effects in PDFs.

- Thus, nuclear effects in ν-A DIS are in line with those extracted from charged lepton DIS and Drell-Yan dilepton production.

The factorization of nPDFs in ν-A DIS seems to be working well!