Global Analyses of Nuclear PDFs

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Introduction

Abstract in brief

- Overview of global DGLAP nPDF analyses (EKS98, HKM, HKN, nDS).
- Results for $R_{F_2}^A$ similar in the large-x region, where data exist.
- New analysis on the nPDFs in progress [EKS05]: Preliminary results similar to EKS98 analysis.

Background

- Nuclear parton distribution functions (nPDFs) are different than those in free protons: $f_i^A(x, Q^2) \neq f_i(x, Q^2)$.
- $f_i^A(x, Q^2)$ taken as non-perturbative input for the QCD calculations.
- Scale evolution: $f_i^A(x, Q_0^2) \overset{DGLAP}{\longrightarrow} f_i^A(x, Q^2)$.

Background

During the years several DGLAP analyses on nPDFs have been published. Among these are for example:

- Qiu Nucl. Phys. **B291** (1987) 746
- Frankfurt, Strikman, Liuti PRL **65** (1990) 1725
- Eskola Nucl. Phys. **B400** (1993) 240
- Indumathi et al. Z. Phys **C74** (1997) 119, Z. Phys **C76** (1997) 91, hep-ph/9609362
- Eskola, Kolhinen, Ruuskanen/ . . . , Salgado [EKS98]

  Nucl. Phys. **B535** (1998) 351, Eur. Phys. J. C **9** (1999) 61
- Hirai, Kumano, Miyama/ . . . , Nagai [HKM/HKN]

  PRD 64 (2001) 034003, PRC 70 (2004) 044905
- de Florian, Sassot [nDS] PRD **D69** (2004) 074028
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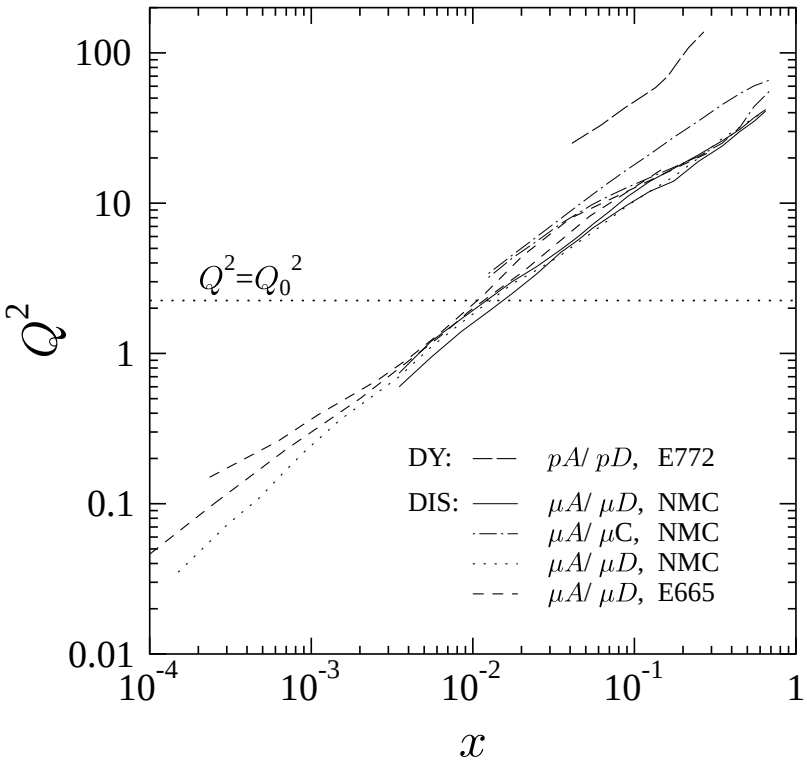
Available Data

nPDFs probed through the DIS and DY cross section ratios.

DIS Data: NMC, SLAC, E665, EMC, . . .
DY Data: E772, E866



Definition of nuclear modifications

HKM, HKN and EKS98:

$$R_i^A(x,Q^2) = \frac{f_i^A(x,Q^2)}{f_i(x,Q^2)} \Rightarrow f_i^A(x,Q^2) = R_i^A(x,Q^2) f_i(x,Q^2). \quad (1)$$

Note: HKM,HKN define ratios for average nucleon in nucleus, EKS for proton

nDS (convolution method):

$$f_i^A(x,Q_0^2) = \int_x^A \frac{dy}{y} w_i(y,A) f_i(\frac{x}{y},Q_0^2). \quad (2)$$

This enables evolution in the Mellin space.

Due to lack of data normally only 3 (EKS98,nDS) or 4 (HKM,HKN) ratios, eg. R_V, R_S and R_g are used at initial scale.

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Details of the analyses

	Q_0^2 [GeV^2]	Ref. PDF	other
HKM	1.0	MRST-LO (98)	no DY data f_i^A averaged over p,n
HKN	1.0	MRST01	f_i^A averaged over p,n
EKS98	2.25	GRV-LO (92) CTEQ4 LO (97)	no actual χ^2 analysis
nDS	0.4	GRV98	NLO, evolution in moment space
EKS05	1.69	CTEQ6 (02)	

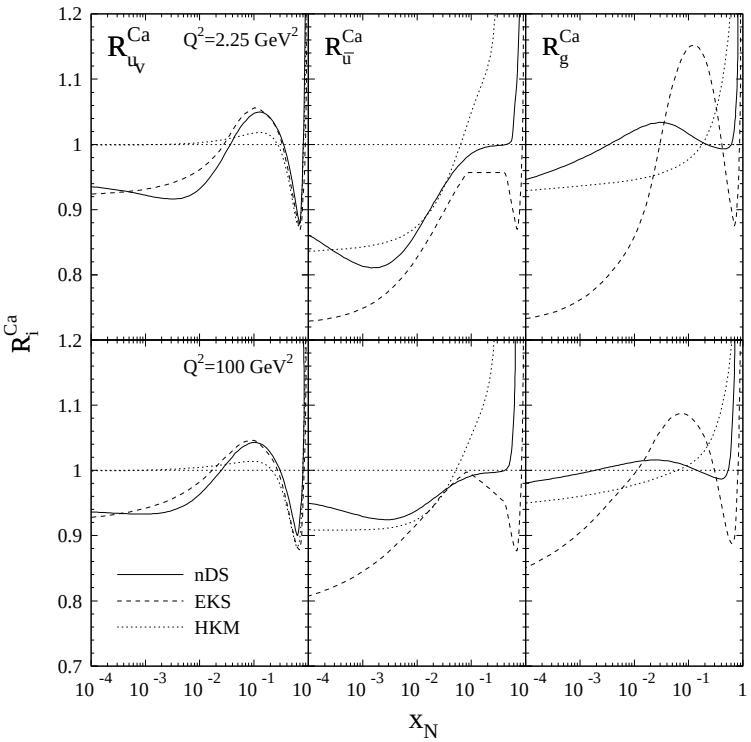
Details of the analyses

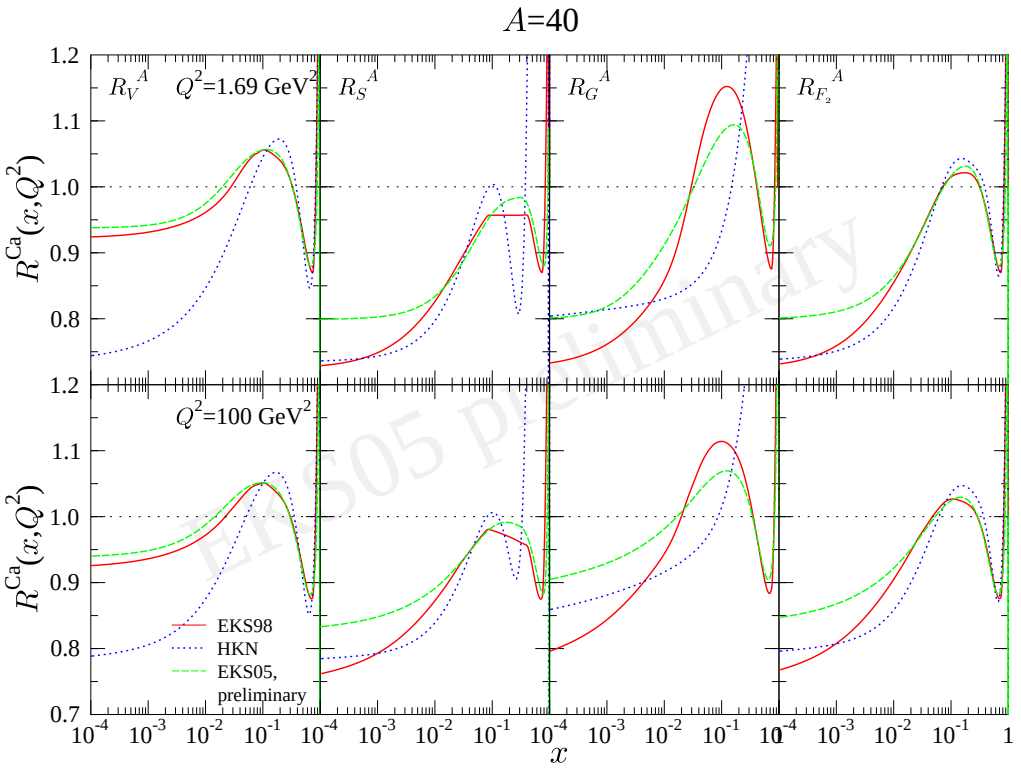
	χ^2	#Data pts.	$\chi^2/d.o.f$
HKM	$\approx$ 546-584	309	$\approx$ 1.83-1.93
HKN	1489.0	951	
EKS98	$\approx$ 400-450	420	N/A
nDS	$\approx$ 300-315 (NLO/LO)	420	$\approx$ 0.76-0.80
EKS05	$\approx$ 390	518	$\approx$ 0.8

EKS05 results very preliminary.

Nuclear modifications compared

Distributions compared





Left Fig: de Florian & Sassot PRD **D69** (2004) 074028

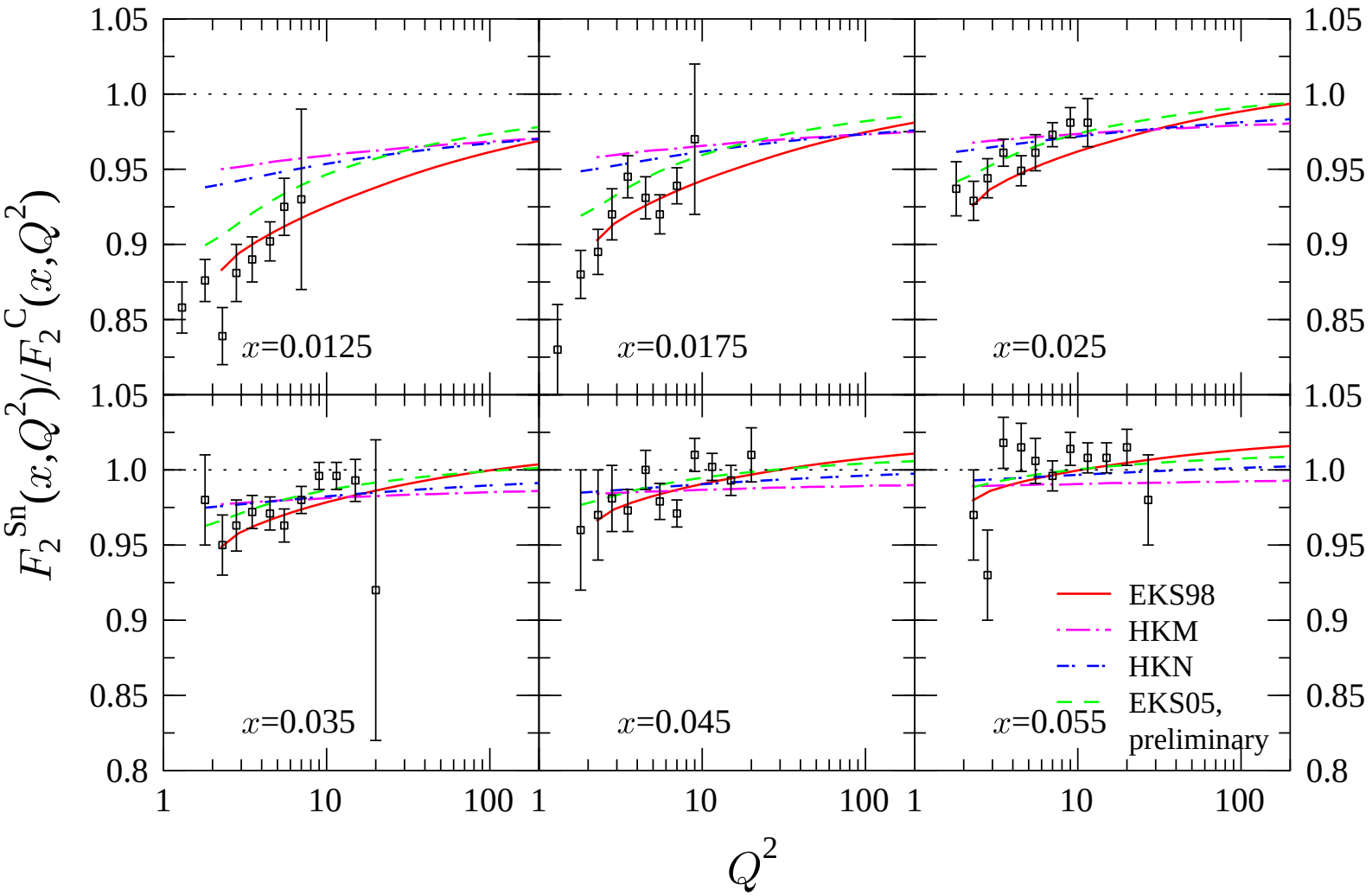
This and the following figs: nDS NLO results used

Nuclear modifications compared

Observations of the comparison

- dNS and EKS98 (and EKS05) valence are rather similar.
- HKM valence has no shadowing, HKN does.
- HKN sea now assumes EMC effect at the initial scale.
- EKS98 gluon has strong shadowing and high antishadowing peak.
- EKS98 and EKS05 (though preliminary) rather similar.
- $R_{F_2}^A$'s coincide well at large x where data exist.

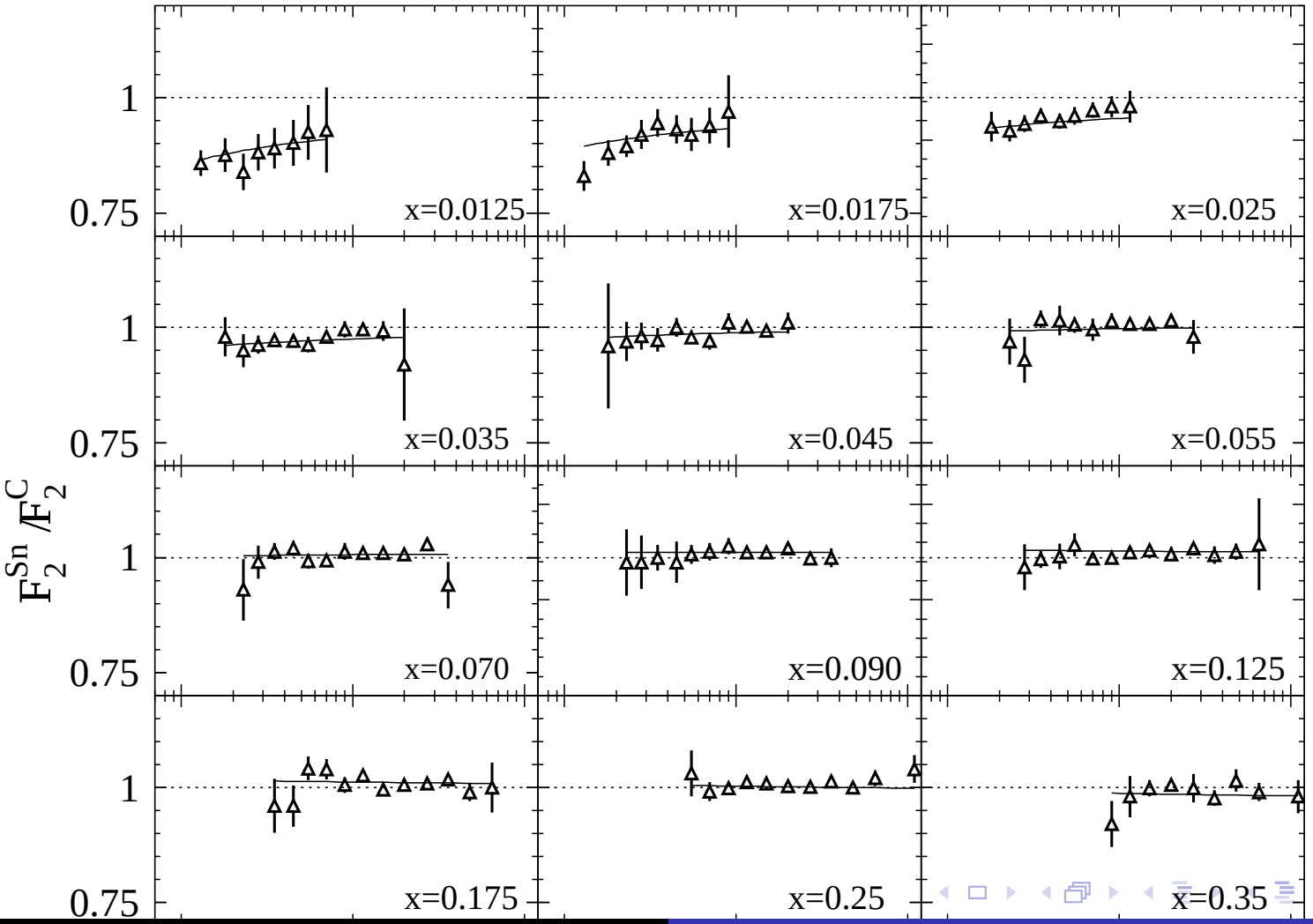
NMC data of $F_2^{\mathrm{Sn}}/F_2^{\mathrm{C}}$



$$\frac{\partial R_{F_2}^A(x,Q^2)}{\partial \log Q^2} \approx \frac{10\alpha_s}{27\pi}\frac{xg(2x,Q^2)}{F_2^D(x,Q^2)}\left\{R_G^A(2x,Q^2) - R_{F_2}^A(x,Q^2)\right\}$$

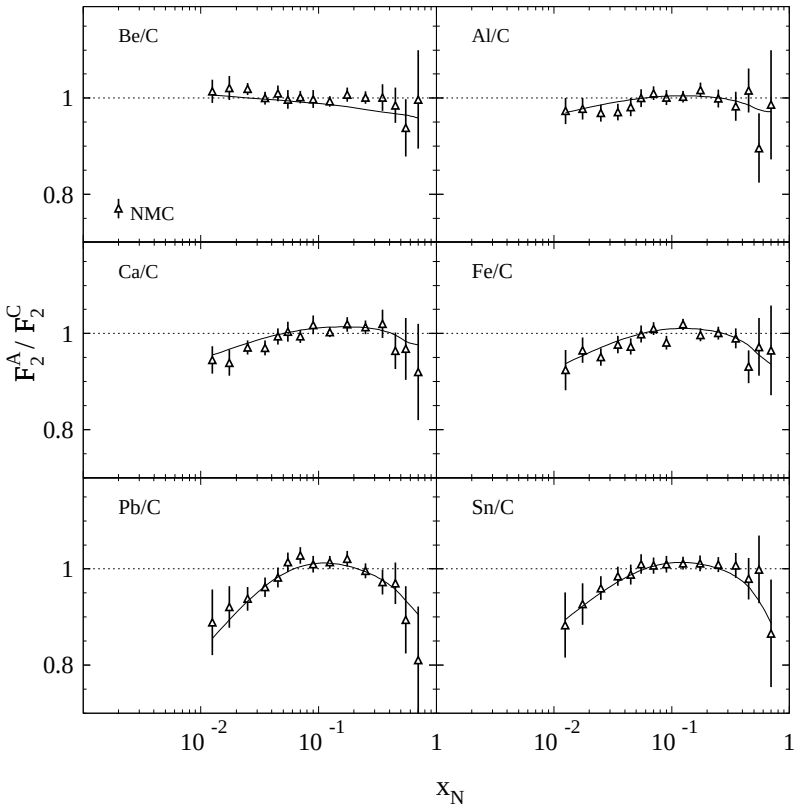
NMC data of F_2^{Sn}/F_2^C

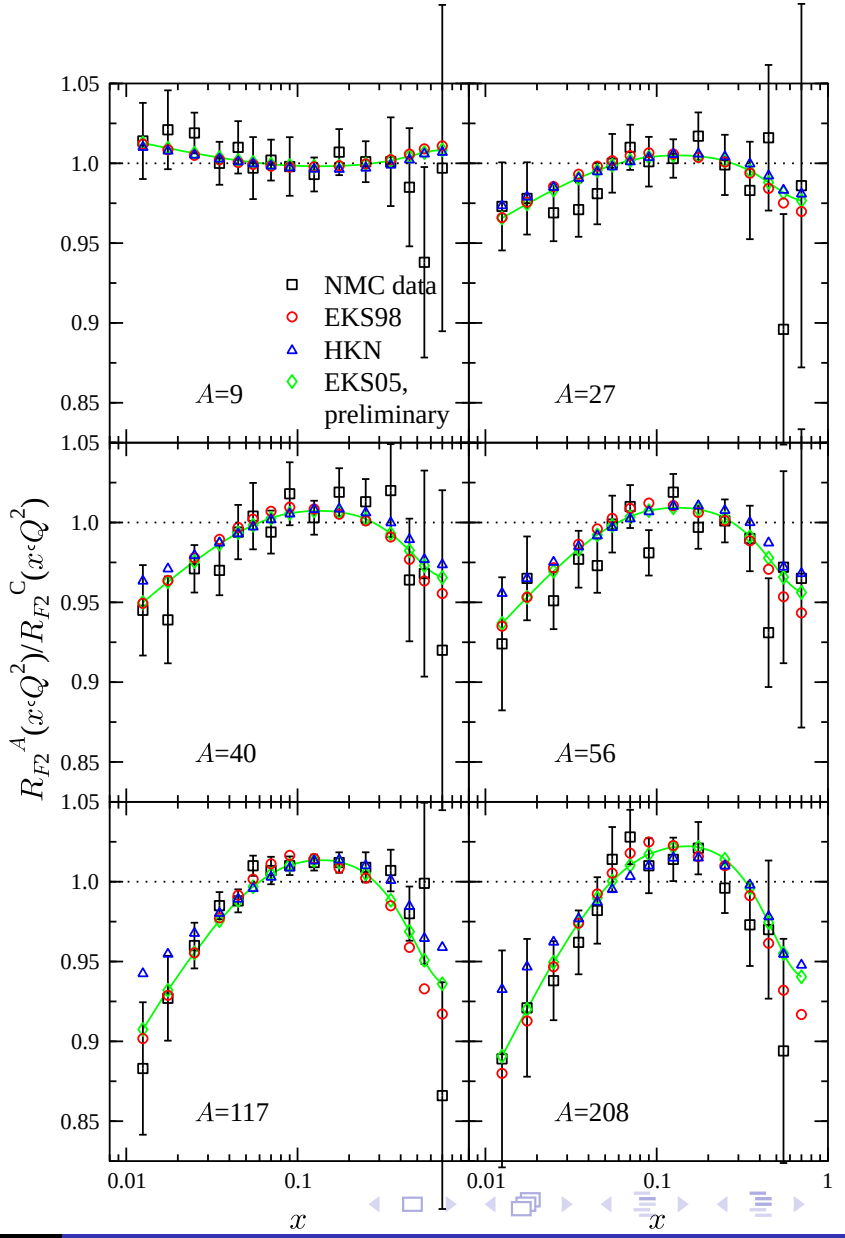
Figure: de Florian & Sassot PRD **D69** (2004) 074028



NMC F_2^A/F_2^C Data

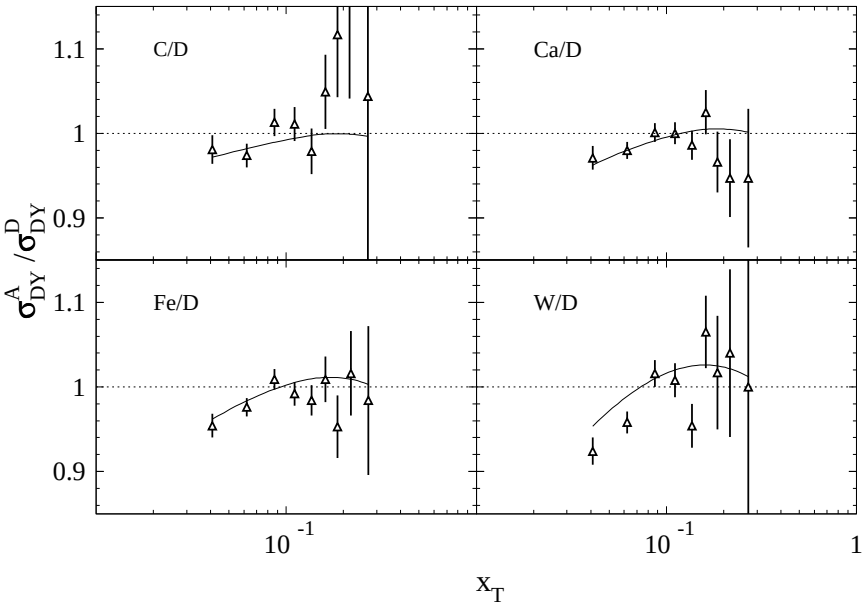
Left Fig: de Florian & Sassot PRD **D69** (2004) 074028

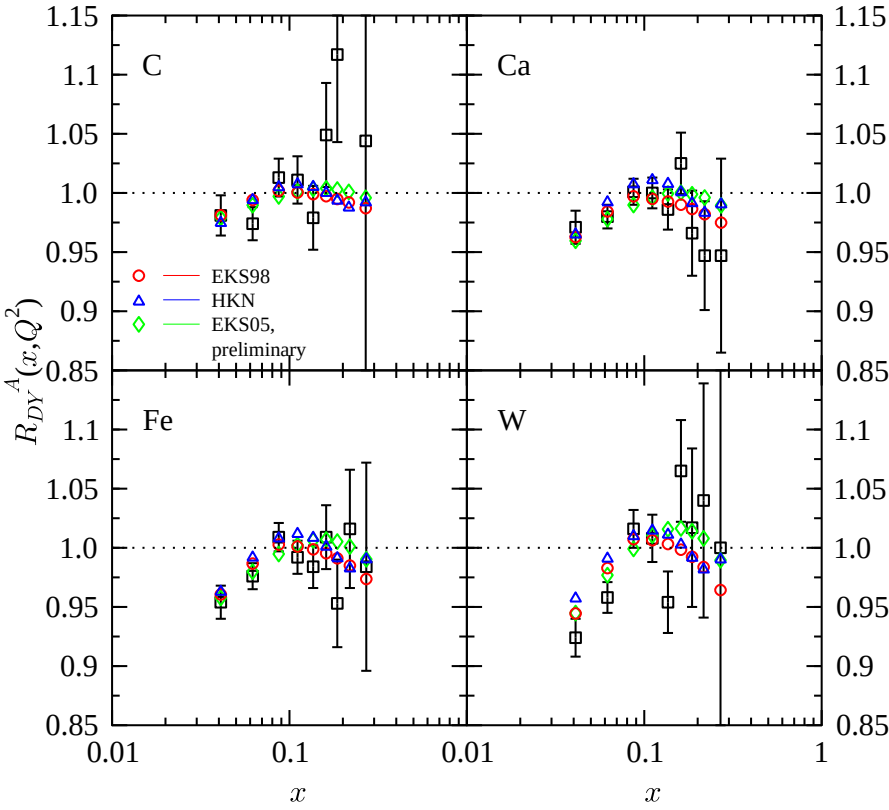




E722 DY Data

Left Fig: de Florian & Sassot PRD **D69** (2004) 074028





Constraints from the data

- $x > 0.3$: DIS data only, valence dominate F_2, only R_V^A constrained
- $0.04 < x < 0.3$: Both DIS and DY data available, constrain R_V^A and R_S^A.
  Baryon number conservation constrains R_V^A
- $5 \cdot 10^{-3} < x < 0.04$: DIS data, baryon number conservation
- $x < 5 \cdot 10^{-3}$: Indirect constraints only. Gluon constraints from the slopes of the NMC $F_2^{\mathrm{Sn}}/F_2^{\mathrm{C}}$ data:

$$\frac{\partial R_{F_2}^A(x,Q^2)}{\partial \log Q^2} \approx \frac{10\alpha_s}{27\pi} \frac{xg(2x,Q^2)}{F_2^D(x,Q^2)} \left\{ R_G^A(2x,Q^2) - R_{F_2}^A(x,Q^2) \right\} \quad (3)$$

Nucl. Phys. **B535** (1998) 351, Phys. Lett. **B311** (1993) 286

- Overall momentum conservation.

Summary

Comparison of nPDF analyses:

- Several global analyses, based on data and DGLAP, have been presented.
- Currently only nDS is in NLO.
- They all fit the data well in the regions the data exist.
- More data would be needed at low x to reduce the error limits especially for gluons.

Ongoing EKS05 analysis:

- Preliminary results rather similar to EKS98.
- Error analysis under way.
- Future: NLO analysis.

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