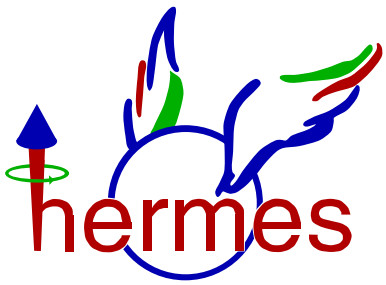
Nuclear Effects on $R = \sigma_L/\sigma_T$ in Deep-Inelastic Scattering

G. van der Steenhoven (NIKHEF)



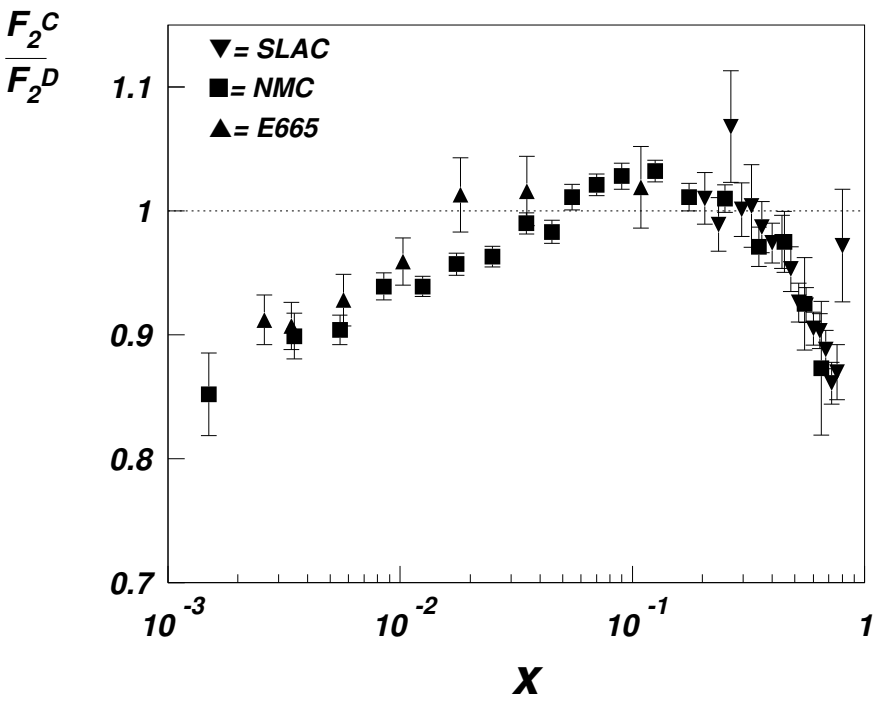
- Introduction
- The extraction of R_A/R_D with $R = \sigma_L/\sigma_T$
- Comparison to existing data
- Interpretation and outlook

Workshop on "Deep-Inelastic Scattering 2000"

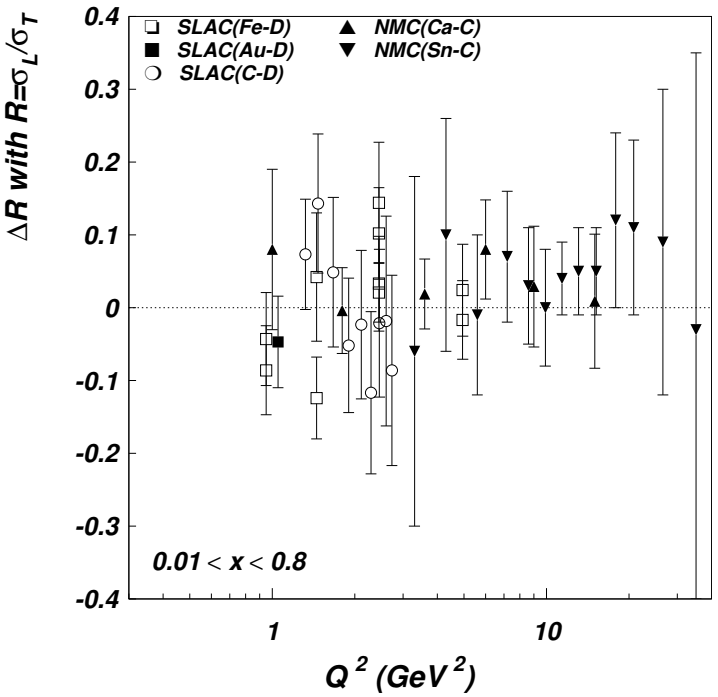
Liverpool, UK, April 25 - 30, 2000

Introduction

- A-dependence of inclusive DIS: $(F_2^A(x)/F_2^D(x))$

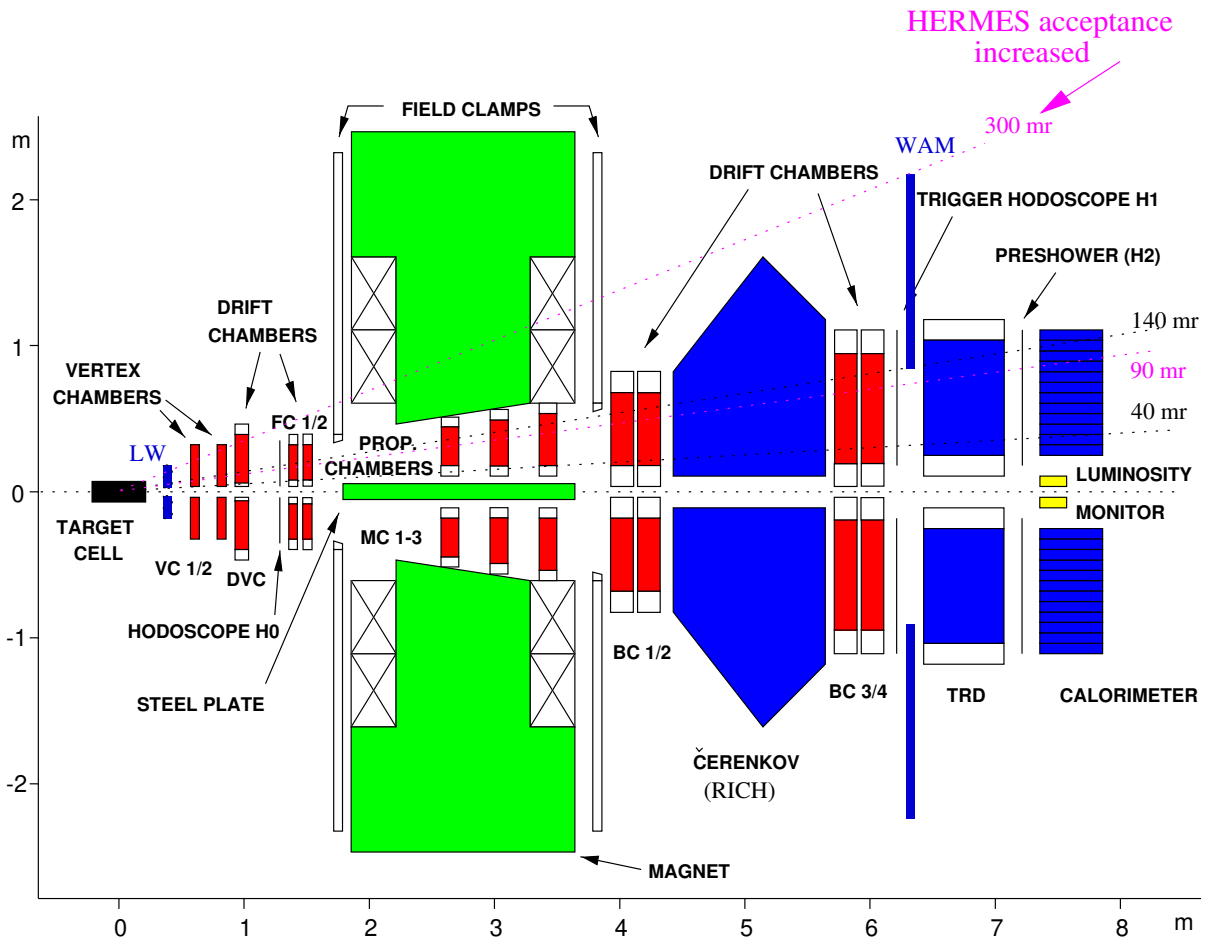


- A-dependence of $R = \sigma_L/\sigma_T$: $(\Delta R = R_A - R_D)$



The HERMES experiment

- Sideview:



- Data collection:
  - 27.5 GeV positron beam: $8 < I_b < 44$ mA
  - Unpolarized gas targets: ^{1,2}H, ^{3}He, ^{14}N, ^{84}Kr
  - Luminosities: 0.02 - 2 $\times$ 10^{33} N/cm^2/s
  - Deadtimes: < 10 %

Data analysis

- Kinematic cuts:

  $Q^2 > 0.3$ GeV^2
  $W^2 > 4.0$ GeV^2
  $y < 0.85$

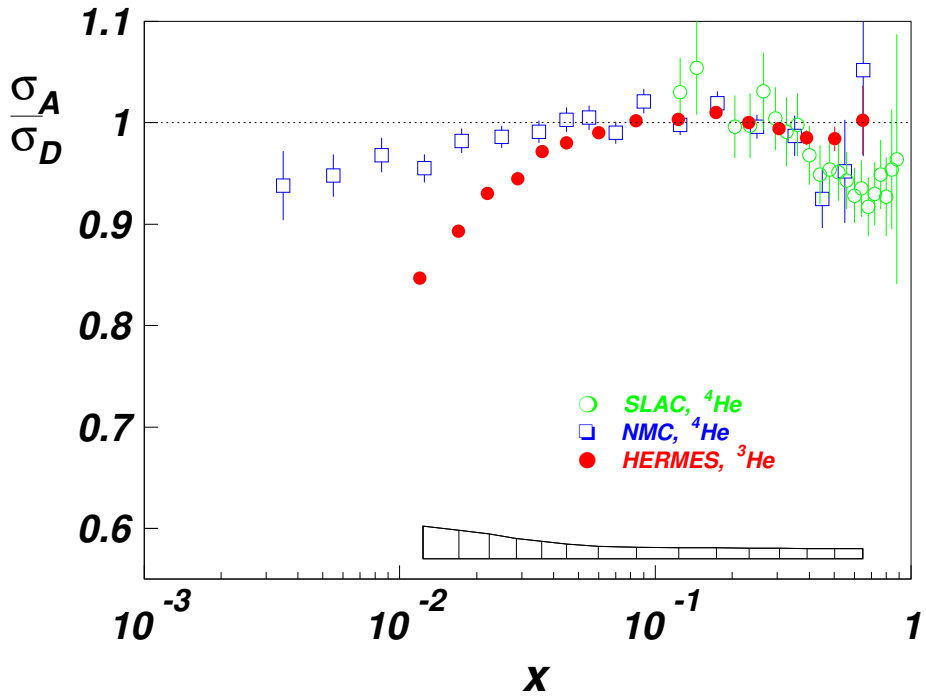
- Radiative corrections:
  - TERAD code:
    - check against POLRAD: < 1 %
    - check against FERRAD: < 2 %
    - NMC check: hadron tag $\approx$ corrected data
    - SLAC codes agrees with HERMES code < 1%
  - Size of the corrections on σ_A/σ_D: < 32 %
    (similar to corrections of the NMC data at lowest x)
  - Input: form factors, QE-suppr., $F_2^A(x)$, $R_A(x)$

  Iterative procedure required

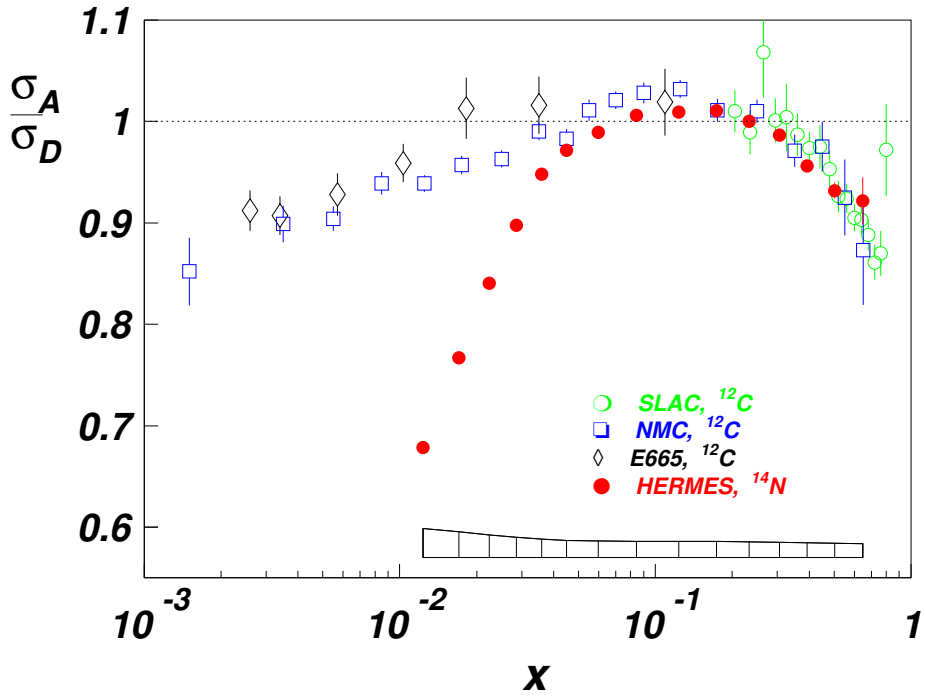
- Stability, reproducebility:
  - Varied I_{beam}, t_{target}, fill-type,..
  - Independent analyses on different targets
  - Three data taking periods: $\Delta(\sigma_A/\sigma_D) < 1.5$ %

Deep-Inelastic Scattering

- The ratio of DIS cross sections on ^{3}He and ^{2}D:



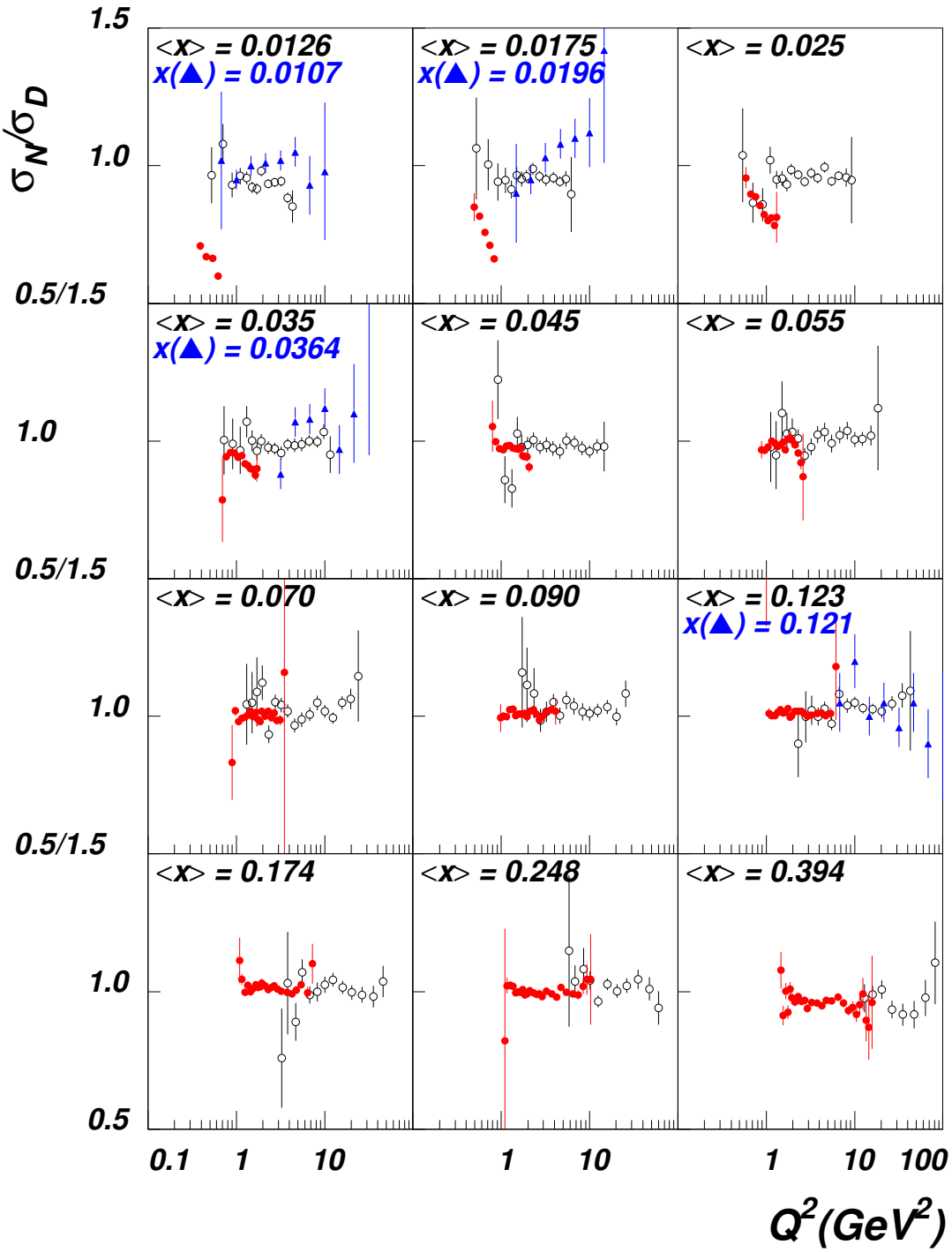
- The ratio of DIS cross sections on ^{14}N and ^{2}D:



Large differences between HERMES and NMC.

Q^2 dependence – ^{14}N

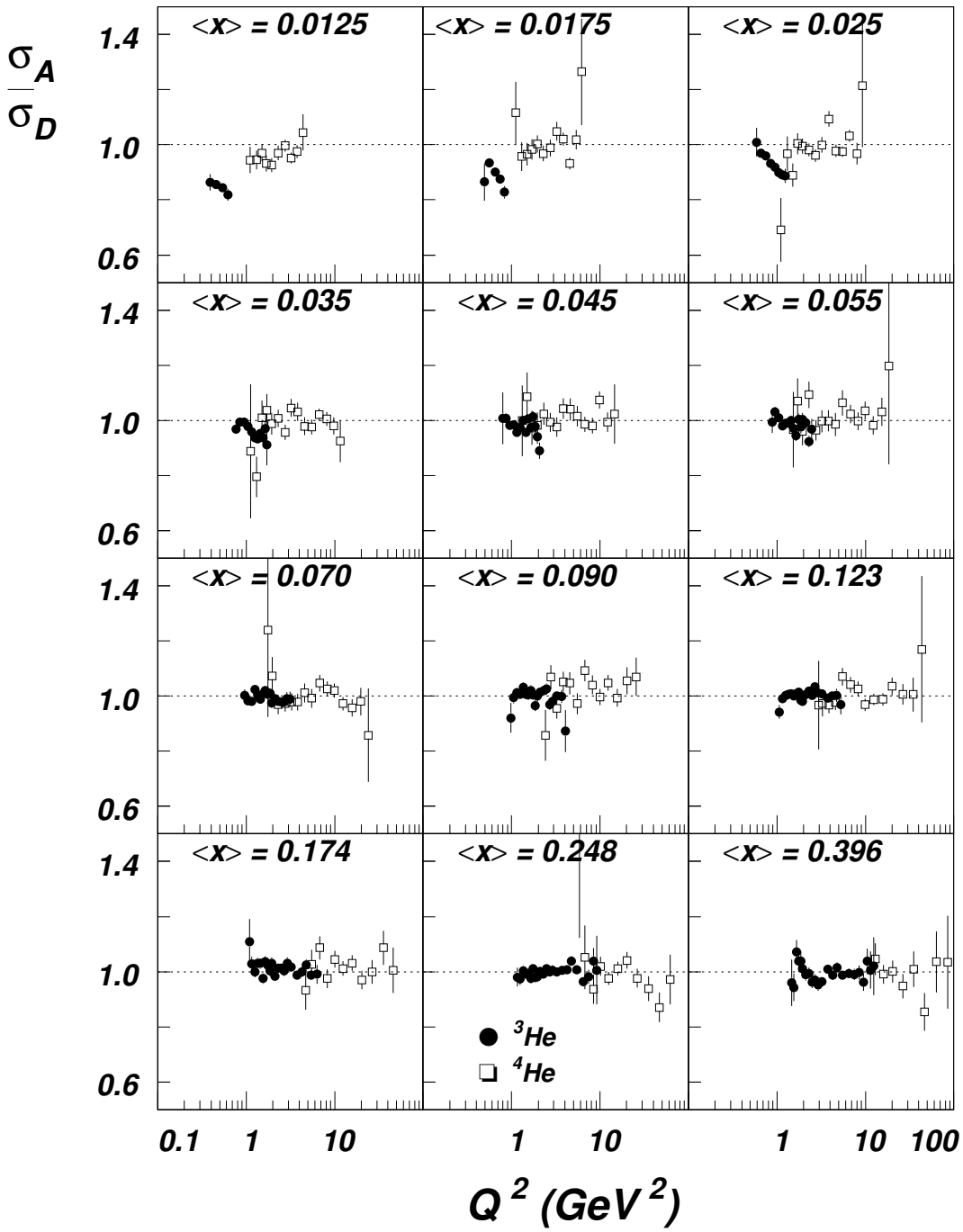
- Q^2-dependence of $\sigma_{^{14}N}/\sigma_{^2H}$:



Differences at low x increase with Q^2

Q^2 dependence - ^{3}He

- Q^2-dependence of $\sigma_{^3He}/\sigma_{^2H}$:



Difference at low x increases with Q^2

DIS Formalism

- The inclusive DIS cross section:

$$\frac{d\sigma(x,Q^2,\epsilon)}{dE'd\Omega} = \sigma_{Mott}\frac{2MxF_2(x,Q^2)}{\epsilon Q^2}[\frac{1+\epsilon R(x,Q^2)}{1+R(x,Q^2)}]$$

  with

$$\epsilon = \frac{4(1-y)-\frac{Q^2}{E^2}}{4(1-y)+2y^2+\frac{Q^2}{E^2}}$$

- The ratio of DIS cross sections on nuclei A and D:

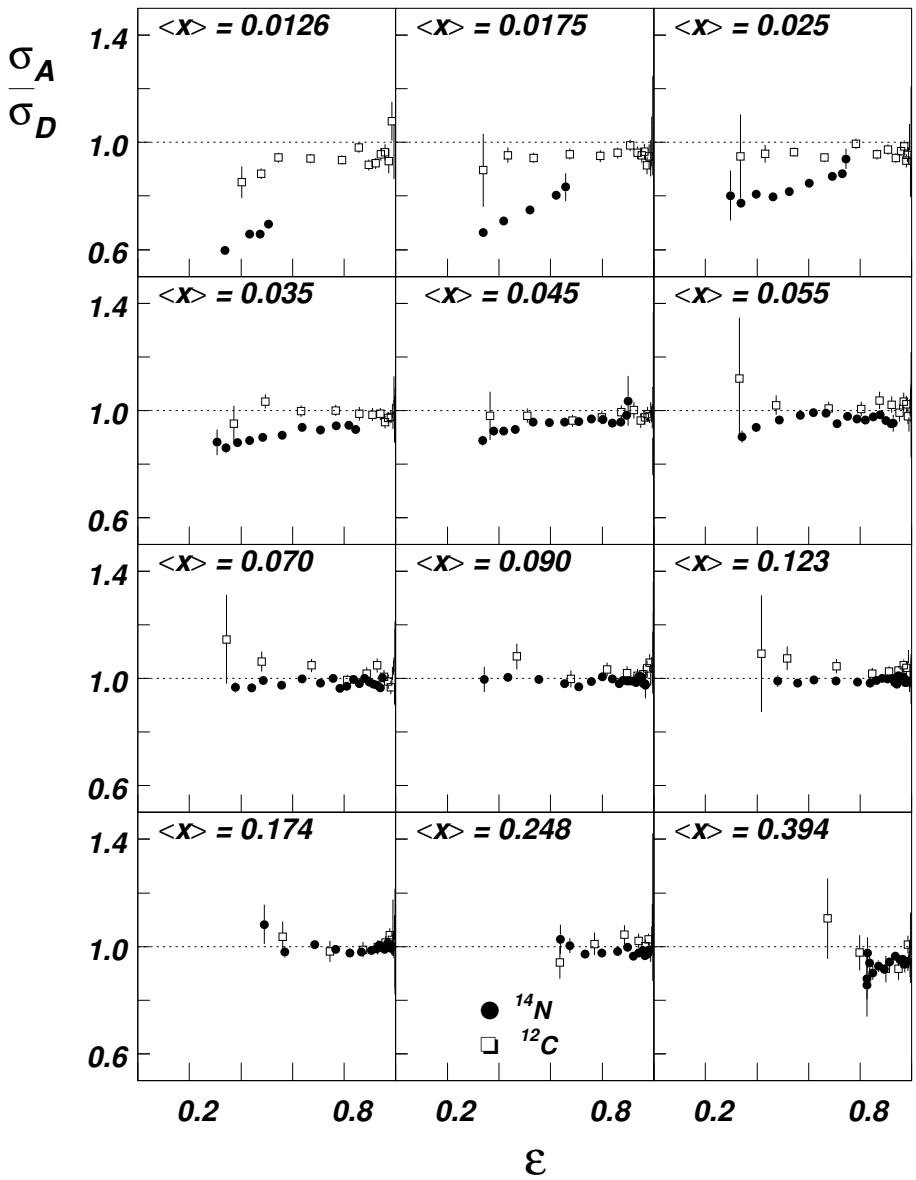
$$\frac{\sigma_A}{\sigma_D} = \frac{F_2^A}{F_2^D}\frac{(1+\epsilon R_A)(1+R_D)}{(1+R_A)(1+\epsilon R_D)}$$

- Limiting conditions:
  - If $\epsilon \to 1$ then $\frac{\sigma_A}{\sigma_D} \to \frac{F_2^A}{F_2^D}$
  - If $R_A = R_D$ then $\frac{\sigma_A}{\sigma_D} = \frac{F_2^A}{F_2^D}$
- Fit R_A/R_D against experimental data:

HERMES: evidence for A-dependence of σ_L/σ_T

ϵ dependence

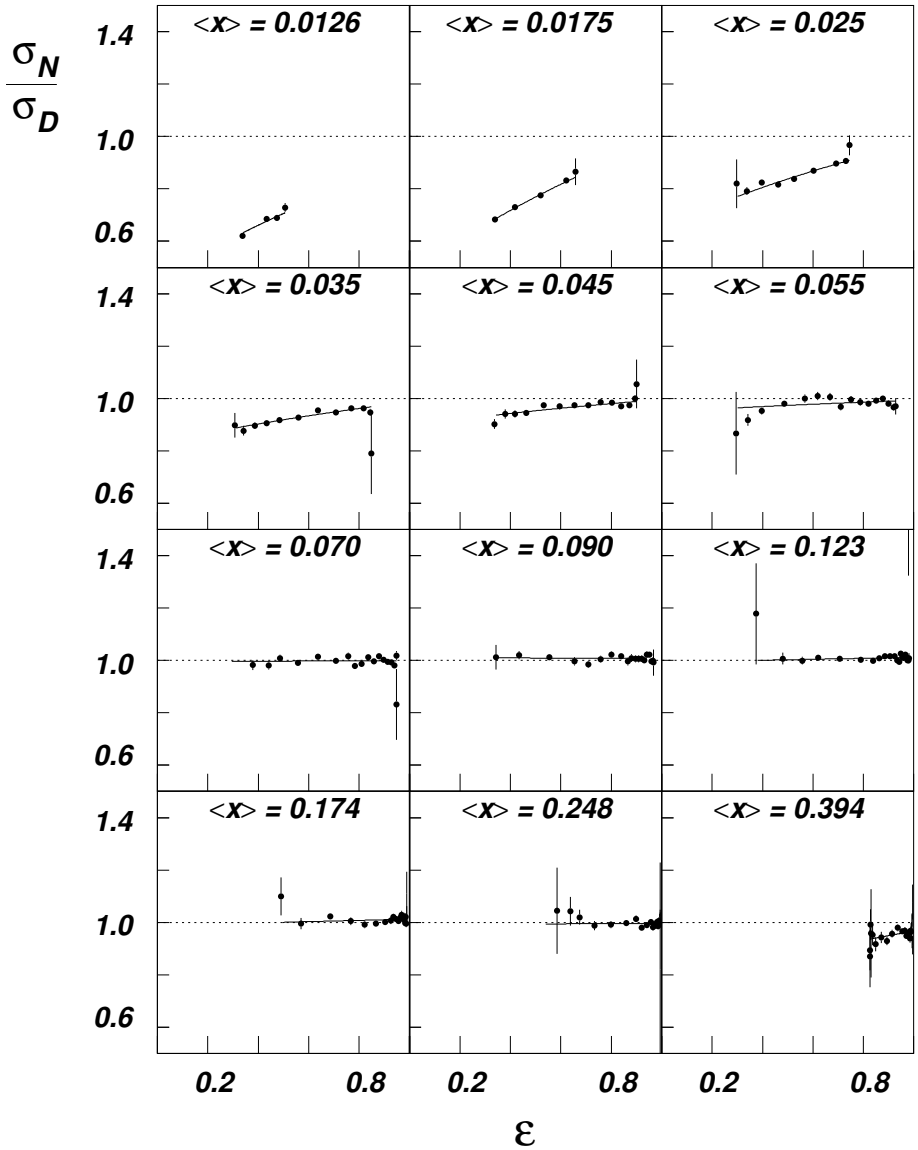
- ϵ-dependence of $\sigma_{^{14}N}/\sigma_{^{2}H}$:



- Fit of the ϵ – dependence with 2 parameters:
  - F_2^A/F_2^D for each x-bin.
  - R_A/R_D for each x-bin.

Fit of ϵ dependence – ^{14}N

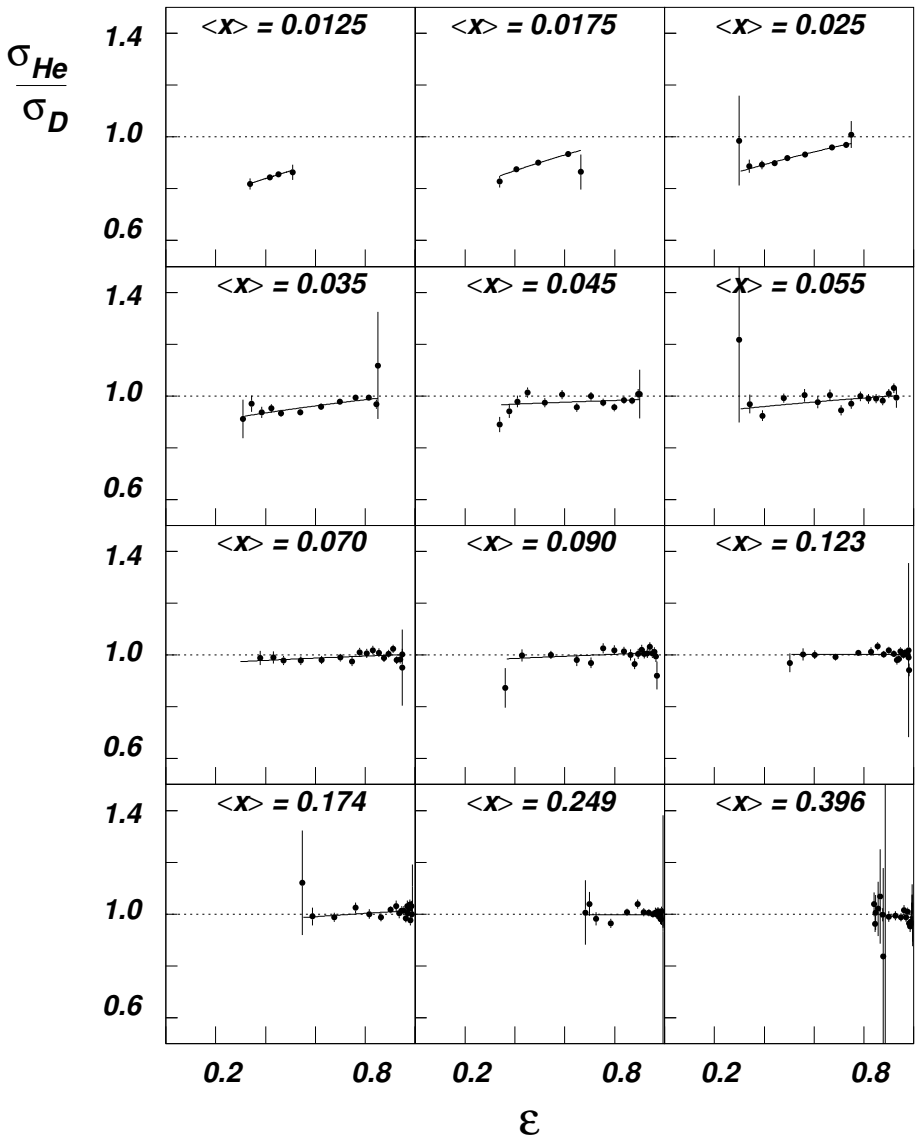
- Fit ϵ-dependence of $\sigma_{^{14}N}/\sigma_{^{2}H}$:



- Sensitivity of the fit:
  - intercept at $\epsilon = 1$: F_2^A/F_2^D .
  - slope with ϵ: R_A/R_D .

Fit of ϵ dependence - ^{3}He

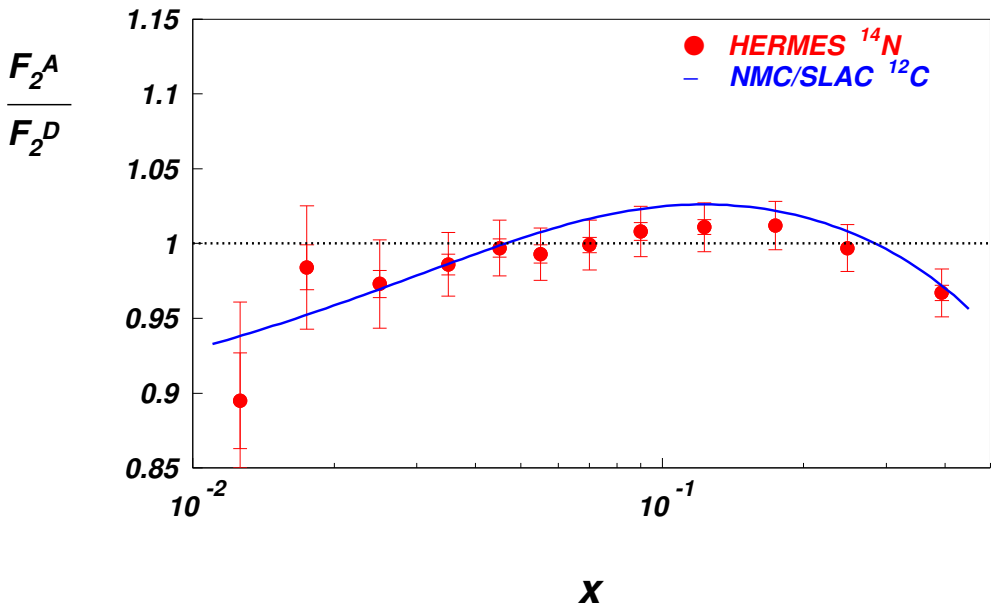
- Fit ϵ-dependence of $\sigma_{^3He}/\sigma_{^2H}$:



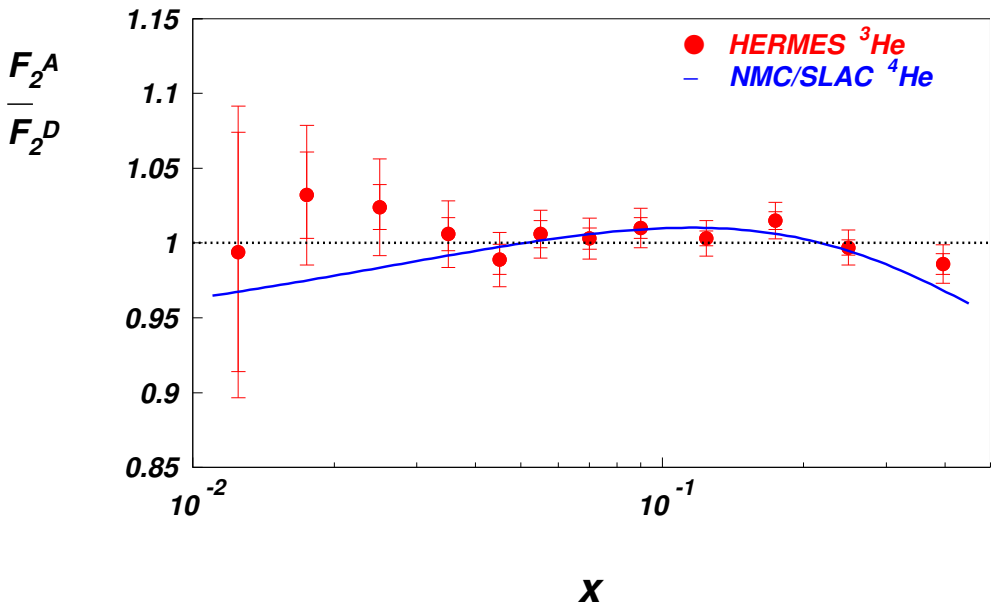
- Verify method by also fitting existing data:
  - NMC/SLAC data on ^{4}He/^{2}H
  - NMC/SLAC data on ^{12}C/^{2}H

A-dependence of $F_2(x)$

- Fitted values of F_2^A/F_2^D for ^{14}N:



- Fitted values of F_2^A/F_2^D for ^{3}He:

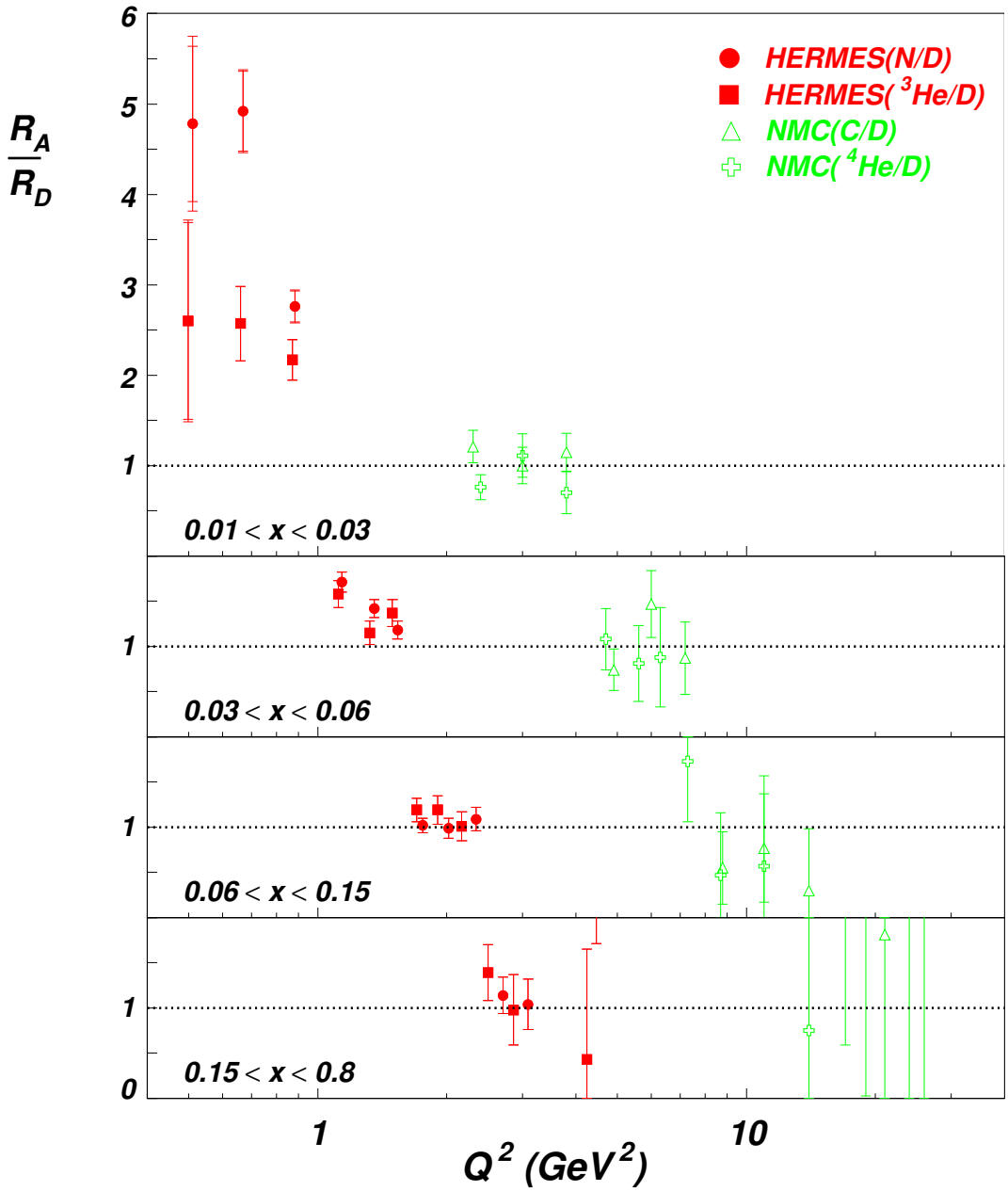


- Conclusion:

Fitted F_2^A/F_2^D values agree with NMC data

A dependence of $R = \sigma_L/\sigma_T$

- Fitted values of R_A/R_D:

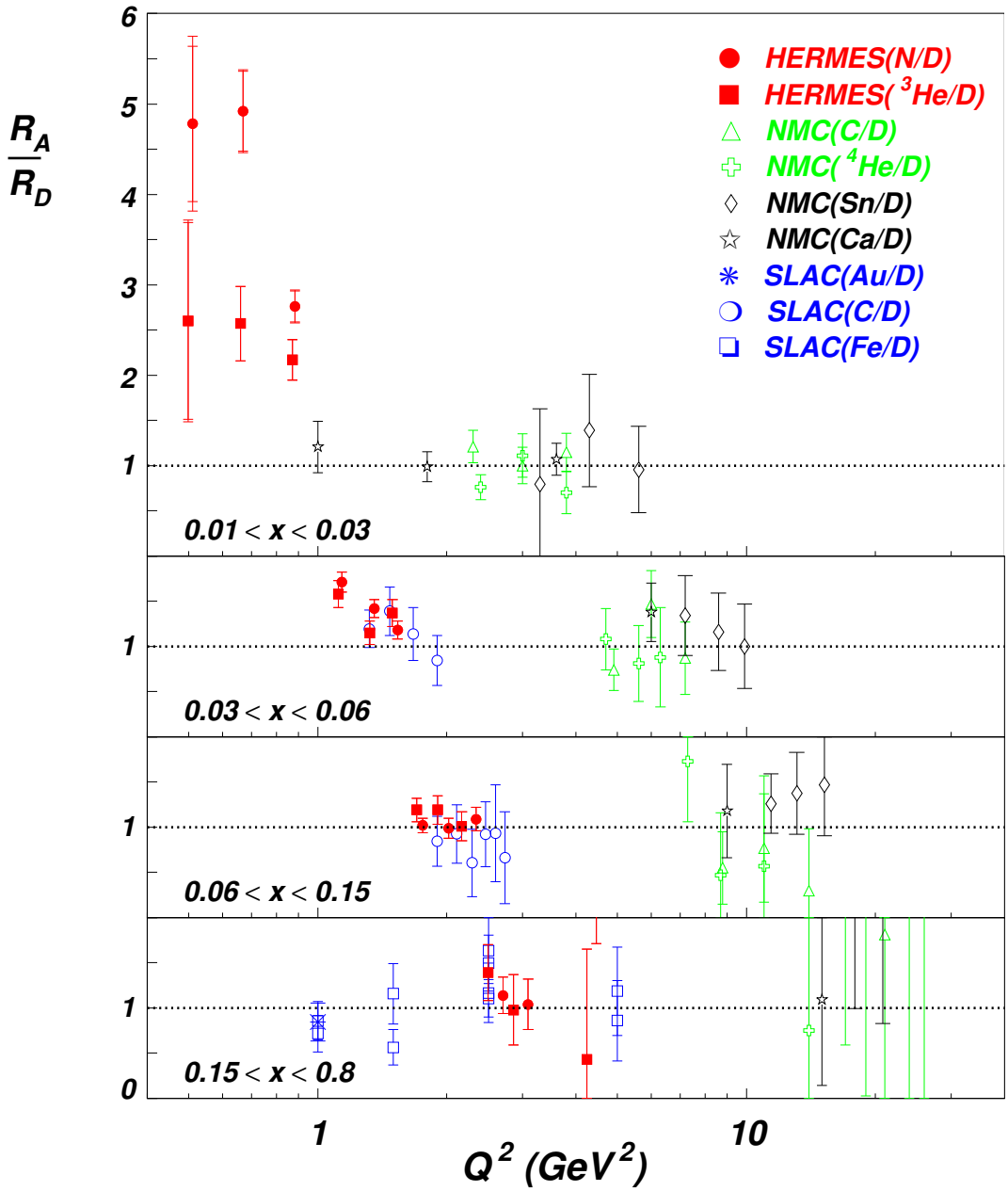


- Conclusion:

$R_A > R_D$ at $x < 0.05$ and $Q^2 < 1.5$ GeV^2

World data on $R_A = \sigma_L/\sigma_T$

- Comparison of HERMES data to existing data:

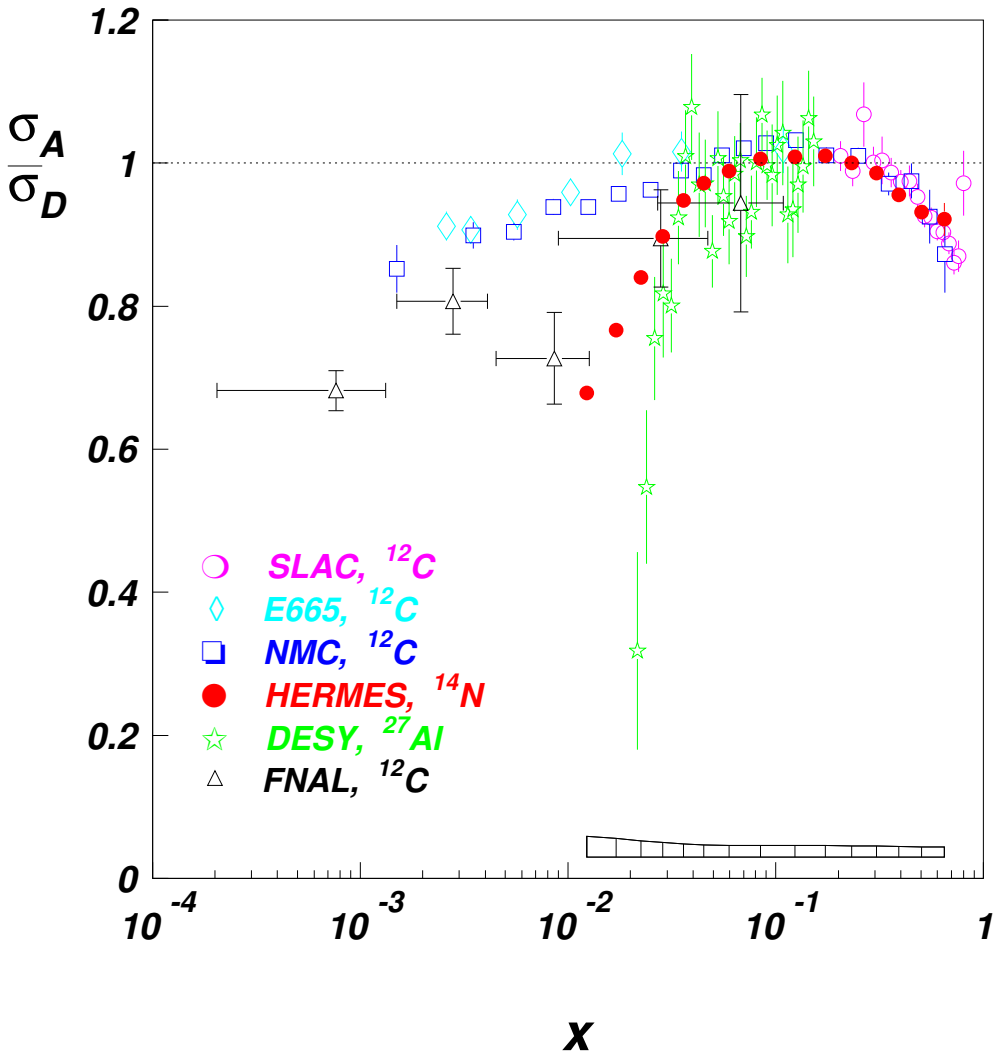


- Conclusion:

No inconsistency with existing data.

Existing data on σ_A/σ_D

- Comparison of HERMES data to existing data:

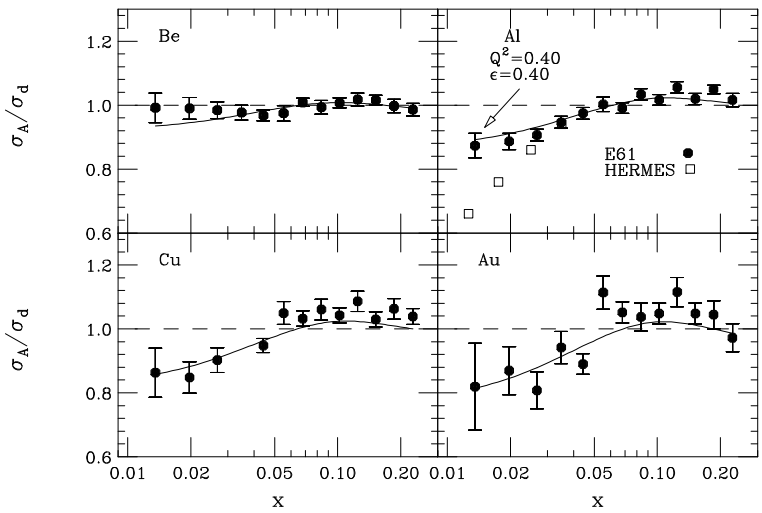


- References:
  - FNAL ^{12}C data: PRL 47 (1981) 293, E = 209 GeV
  - DESY ^{27}Al data: ZPhys C10 (1981) 105; E = 7 GeV

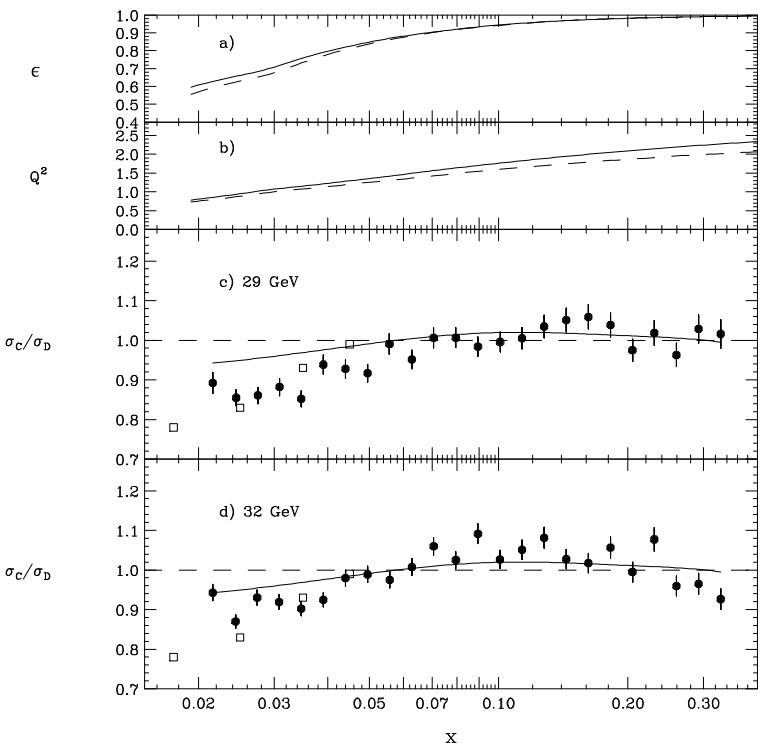
Strong shadowing at low Q^2 seen before !

SLAC data on σ_A/σ_D

- Reanalysis of E61 data (hep-ex/0003007) :



- Reanalysis of E155X data (hep-ex/0003007) :

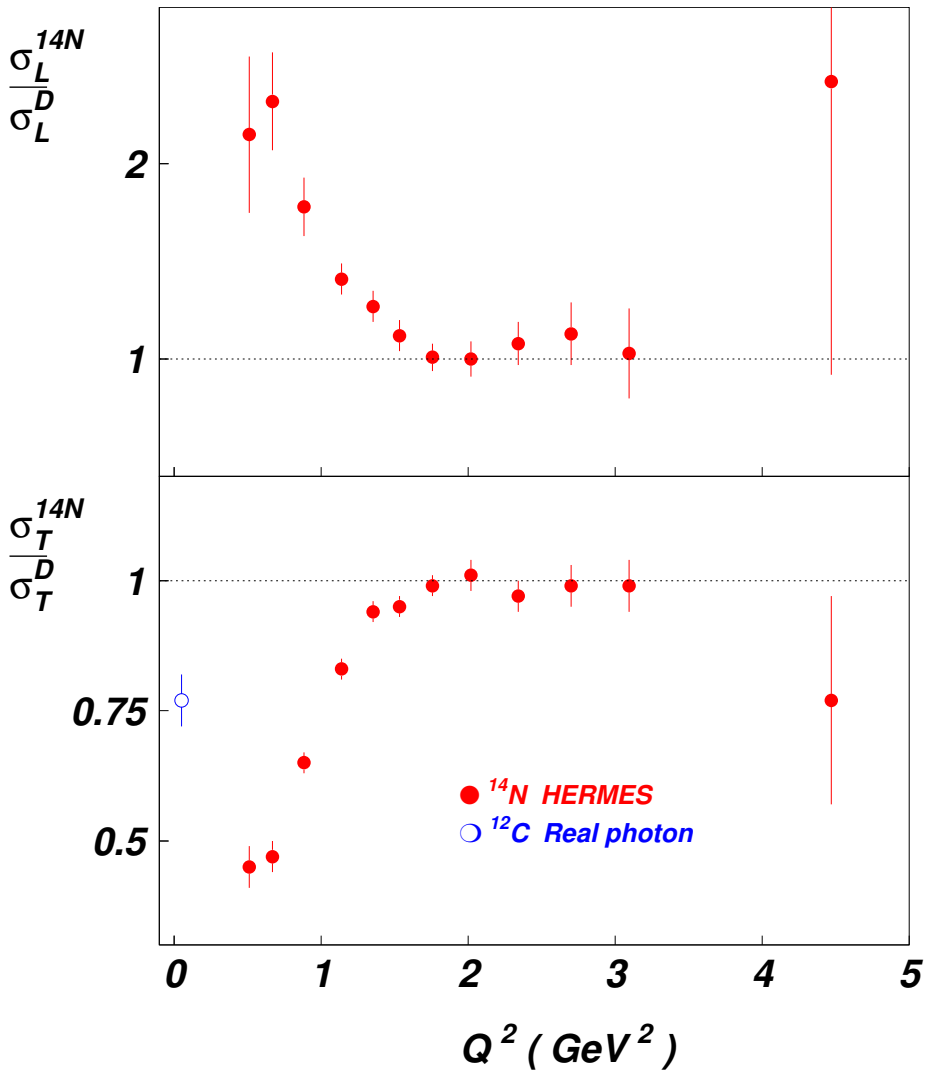


A-dependence of σ_L and σ_T

- Alternative expression for cross-section ratio:

$$\frac{\sigma_A}{\sigma_D} = \frac{\sigma_T^A + \epsilon\sigma_L^A}{\sigma_T^D + \epsilon\sigma_L^D} = \frac{\sigma_T^A/\sigma_T^D + \epsilon\sigma_L^A/\sigma_L^D R_D}{1 + \epsilon R_D}$$

- Fit parameters: σ_T^A/σ_T^D and σ_L^A/σ_L^D :



Coupling to $q\bar{q}$-pairs with S=0 ?

Interpretation of the data

- Twist-4 contribution to $F_L(x, Q^2)$:
  - RK Ellis et al., Nucl. Phys. B207 (1982) 1:

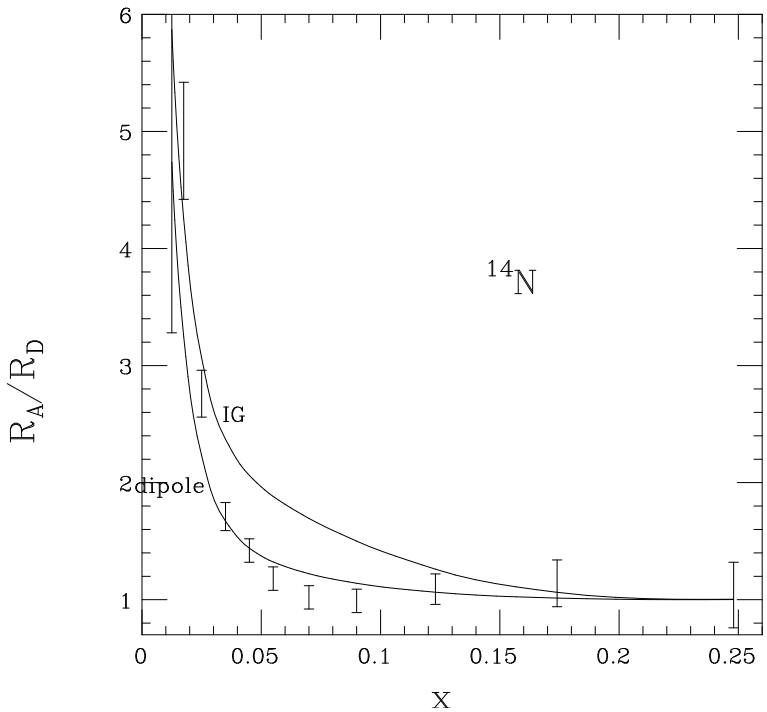
$$F_L^{\tau=4}(x, Q^2) = 4\frac{< k_T^2 >}{Q^2}$$

  - Implication: quark-gluon correlations in nuclei

    J. Milana, Phys. Rev. C49 (1994) 2820
    M. Luo, J. Qiu and G. Sterman, PRD 49 (1994) 4493
    S. Barshay and G. Kreyerhoff, hep-ph/0002233

- Coherent nuclear meson production (σ, ω):

  G.A. Miller, S.J. Brodsky, M. Karliner, hep-ph/0002156



Conclusions

- Ratio of DIS cross sections on ^{14}N and ^{2}D:
  - HERMES and NMC disagree at low x and Q^2
  - Analyse ϵ-dependence:

$R = \sigma_L/\sigma_T$ is A dependent

    * $1/Q^2$-scaling: twist-4 effect in nuclei
    * Interpretation: quark delocalization ?

- Future experiments:
  - Additional HERMES data: ^{4}He, ^{20}Ne, ^{84}Kr, ...
  - HERMES: search for enhanced π-production
  - Rosenbluth separation at JLab (E99-118)