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

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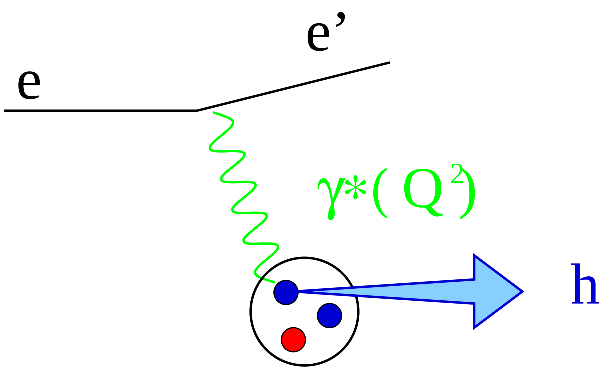
- Introduction
- The extraction of R_A/R_D with $R = \sigma_L/\sigma_T$
- Comparison to existing data
- Interpretation and outlook

Hadron Structure 2000

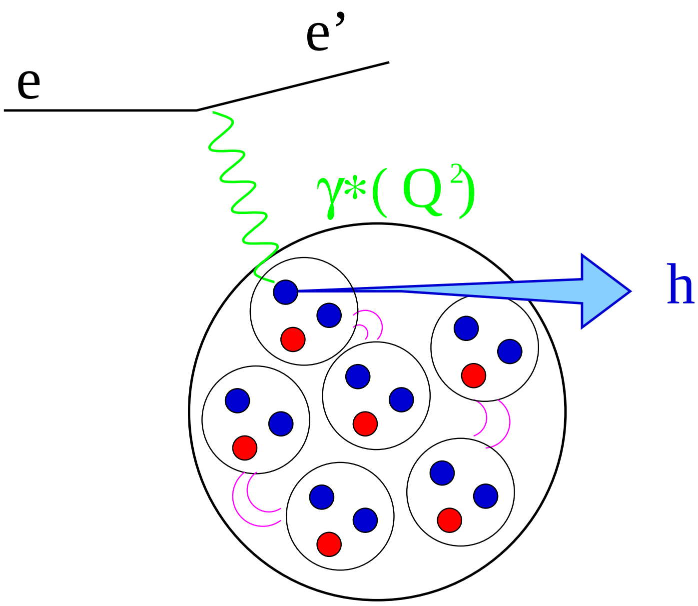
Stara Lesna, Slovakia, October 2-6 , 2000

Nuclear Effects

DIS on a Nucleon



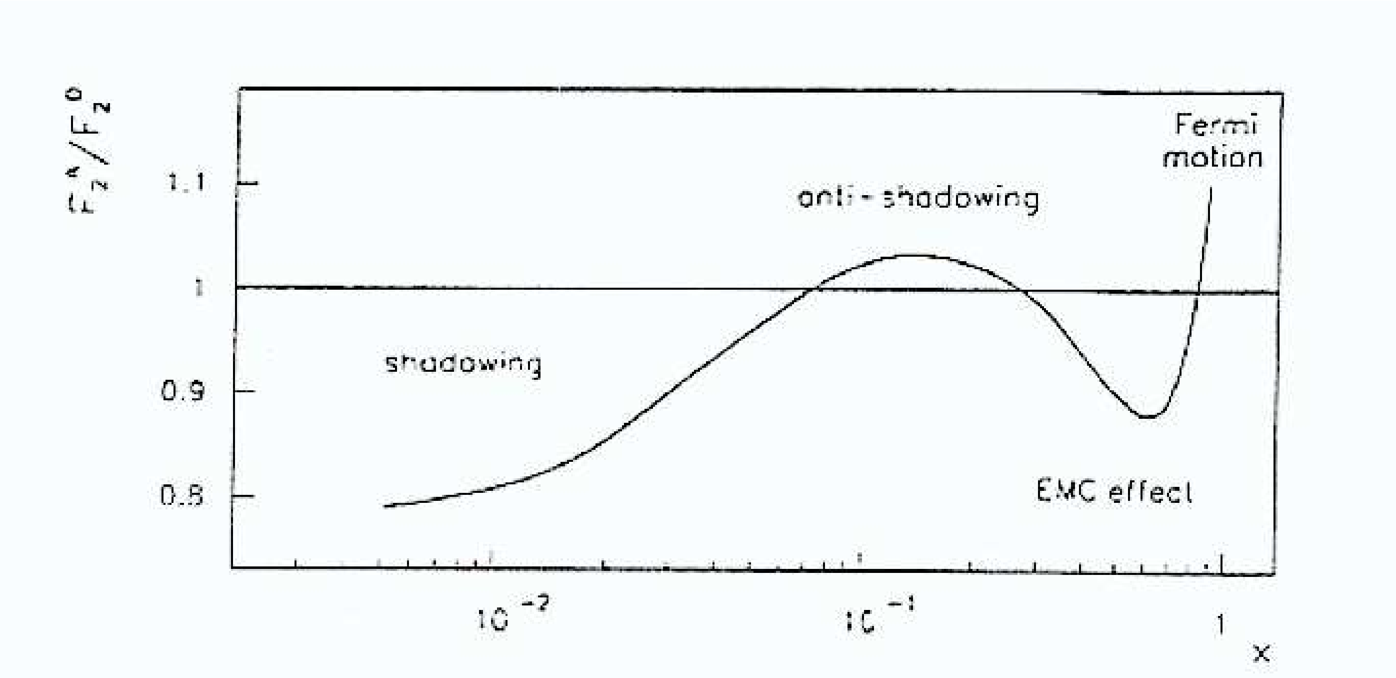
DIS on a Nucleus



$Q^2 < 0.01\ \mathrm{GeV}^2$	$\rightarrow$	$r > 10$ fm	Nucleus
$Q^2 \simeq 0.1\ \mathrm{GeV}^2$	$\rightarrow$	$r \simeq 1$ fm	Nucleons
$Q^2 > 1\ \mathrm{GeV}^2$	$\rightarrow$	$r < 1$ fm	Quarks

NUCLEAR EFFECTS observed at HERMES

Nuclear Effect - History



$x > 0.1 \Longrightarrow$ EMC effect

Nuclear bounding and correlation

$x < 0.1 \Longrightarrow$ Shadowing

Modeled by hadronic structure of γ^*

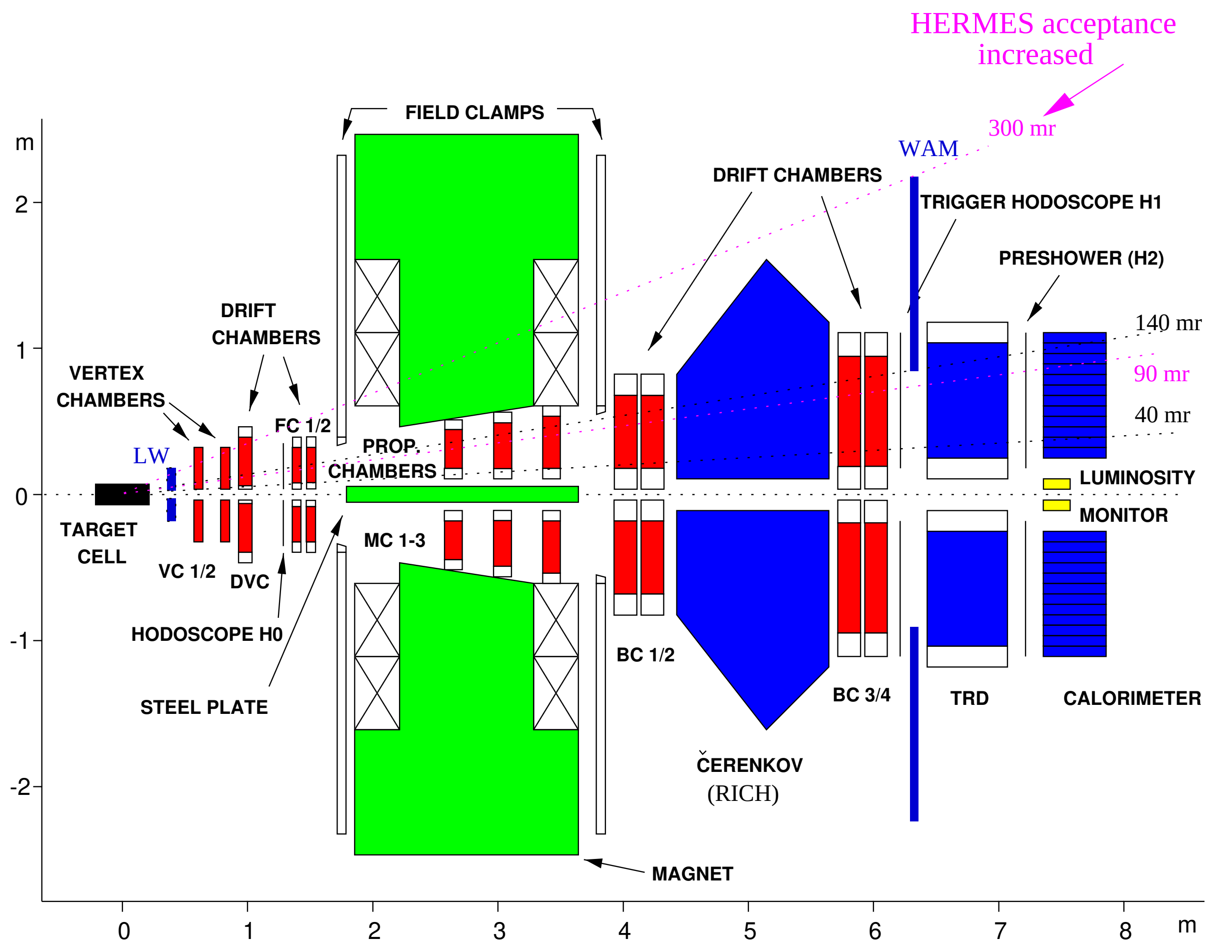
DIS cross section assumed:

$$\frac{d\sigma(x,Q^2,\epsilon)}{dxdQ^2} = \frac{\sigma_{Mott}}{EE'} \cdot \frac{\pi F_2(x,Q^2)}{x\epsilon} \cdot \frac{1+\epsilon R(x,Q^2)}{1+R(x,Q^2)}$$

$F_2(x,Q^2) = x\sum_i e_i^2 q_i(x)$

The HERMES experiment

- Sideview:

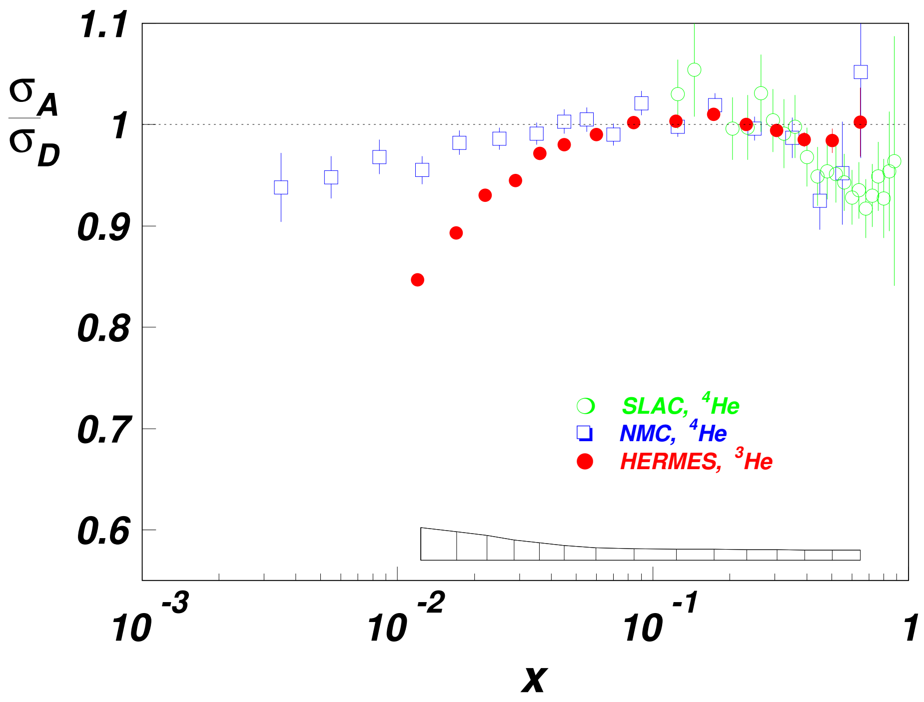


- Data collection:
  - 27.5 GeV positron beam: $8 < I_b < 44$ mA
  - Unpolarized gas targets: ^{1,2}H, ^{3}He, ^{14}N
  - Luminosities: 0.02 - 2 $\times$ 10^{33} N/cm^2/s
  - Deadtime: $<$ 10 %

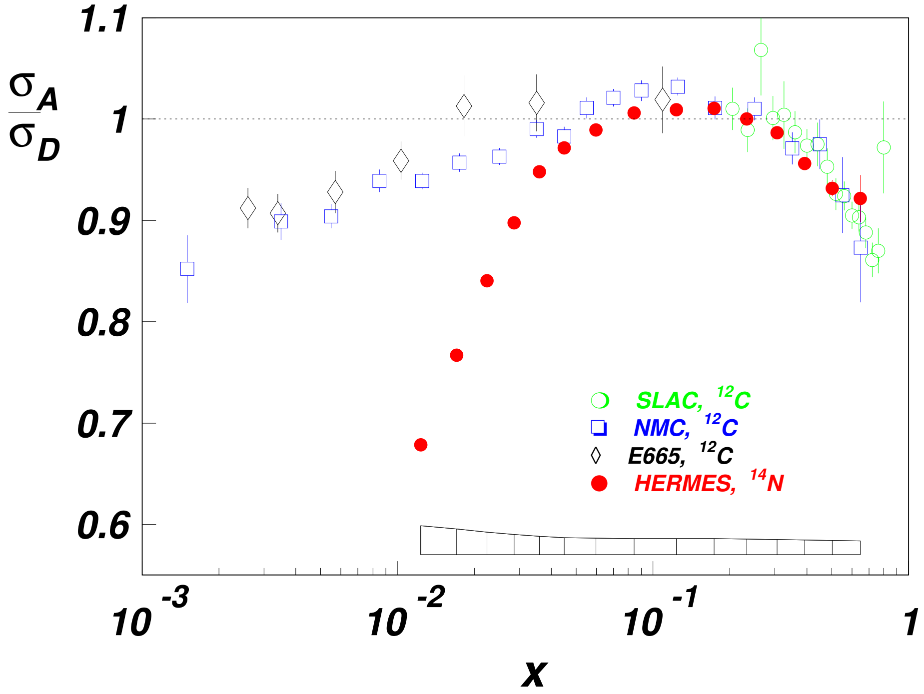
$\Longrightarrow$ more on HERMES in J. Wendland talk !

Deep-Inelastic Scattering

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



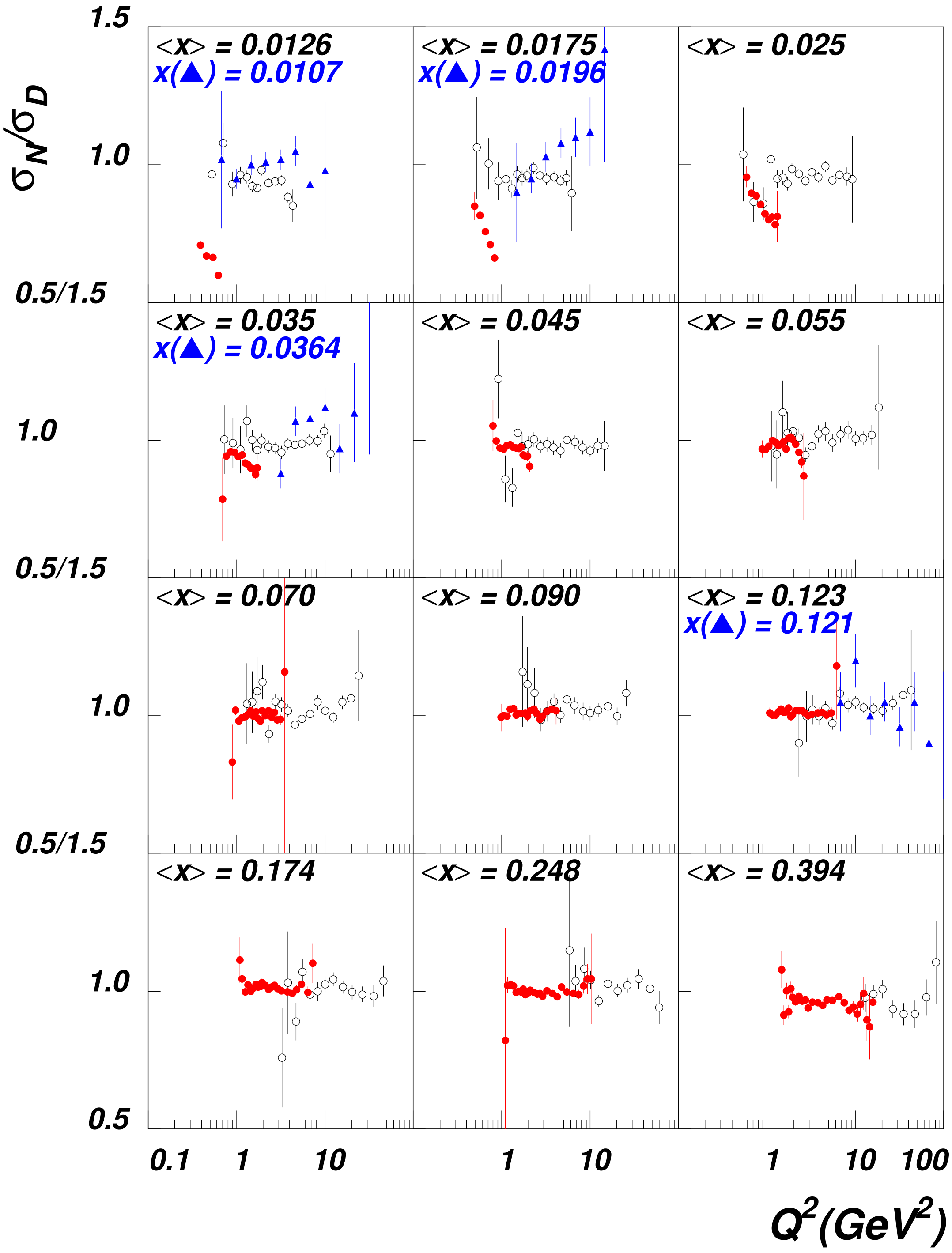
- The ratio of DIS cross sections on ^{14}N and ^{2}D:



HERMES at low x differs from NMC and E665.

Q^2 dependence – ^{14}N

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



Differences at low x increase with Q^2

DIS Formalism

- The inclusive DIS cross section:

$$\frac{d\sigma(x,Q^2,\epsilon)}{dx dQ^2} = \frac{\sigma_{Mott}}{EE'} \cdot \frac{\pi F_2(x,Q^2)}{x\epsilon} \cdot \frac{1+\epsilon R(x,Q^2)}{1+R(x,Q^2)}$$

ϵ = virtual photon polarization

$$R = \frac{\sigma_L}{\sigma_T} \qquad \sigma_L : h_{\gamma^*} = 0$$

$$\sigma_T : h_{\gamma^*} = \pm 1$$

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

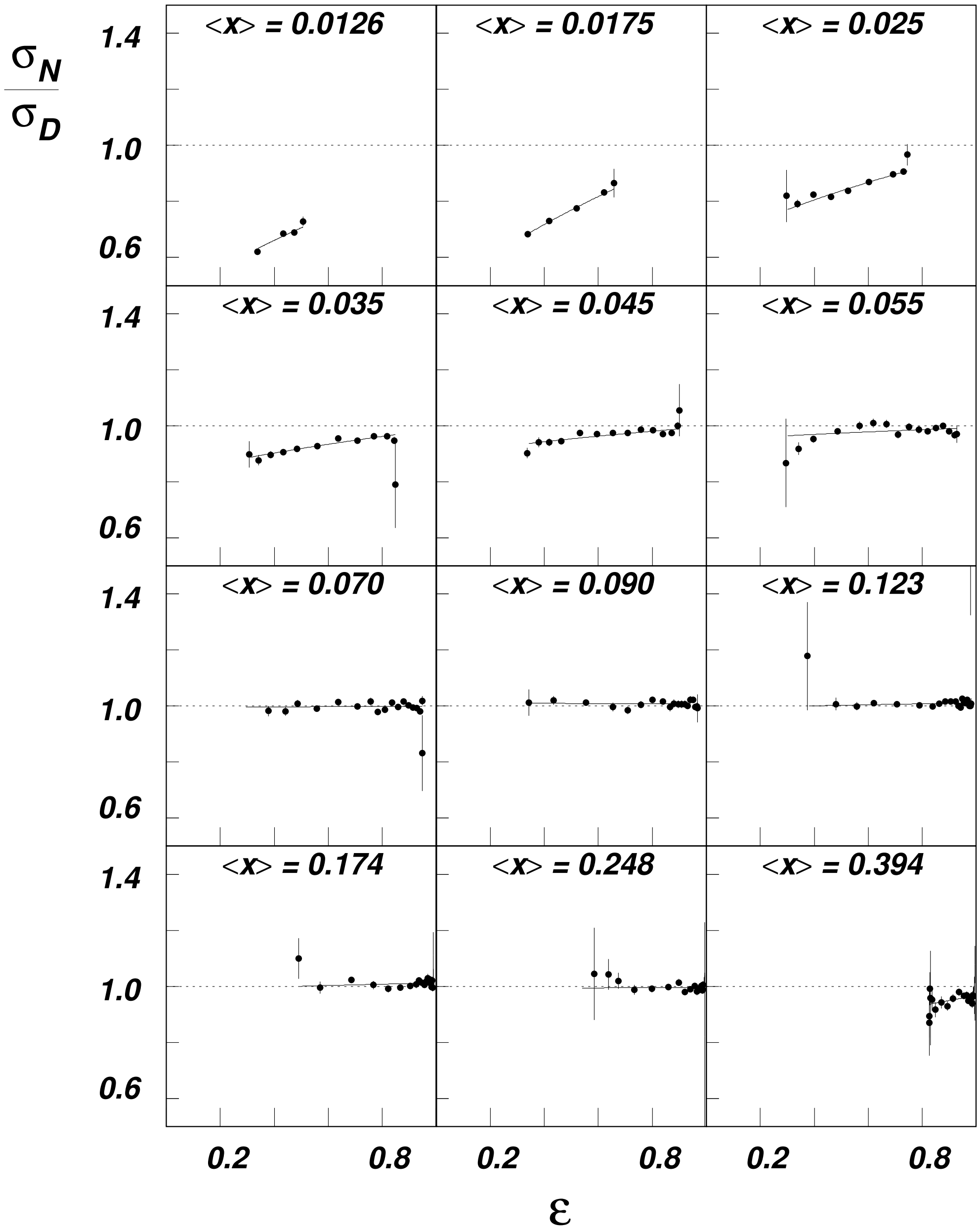
$$\frac{\sigma_A}{\sigma_D} = \frac{F_2^A}{F_2^D} \frac{(1+\epsilon R_A)(1+R_D)}{(1+R_A)(1+\epsilon R_D)}$$

- Limiting conditions:

$\epsilon = 1$ OR $R_A = R_D \implies \frac{\sigma_A}{\sigma_D} = \frac{F_2^A}{F_2^D}$

Fit of ϵ dependence – ^{14}N

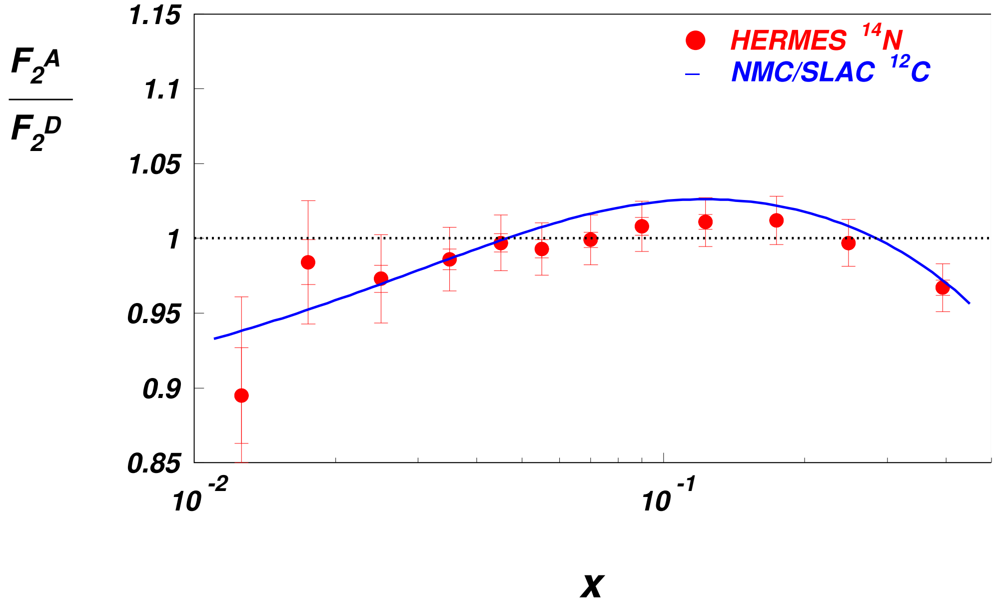
- Fit ϵ-dependence of $\sigma_{^{14}N}/\sigma_{^2H}$:



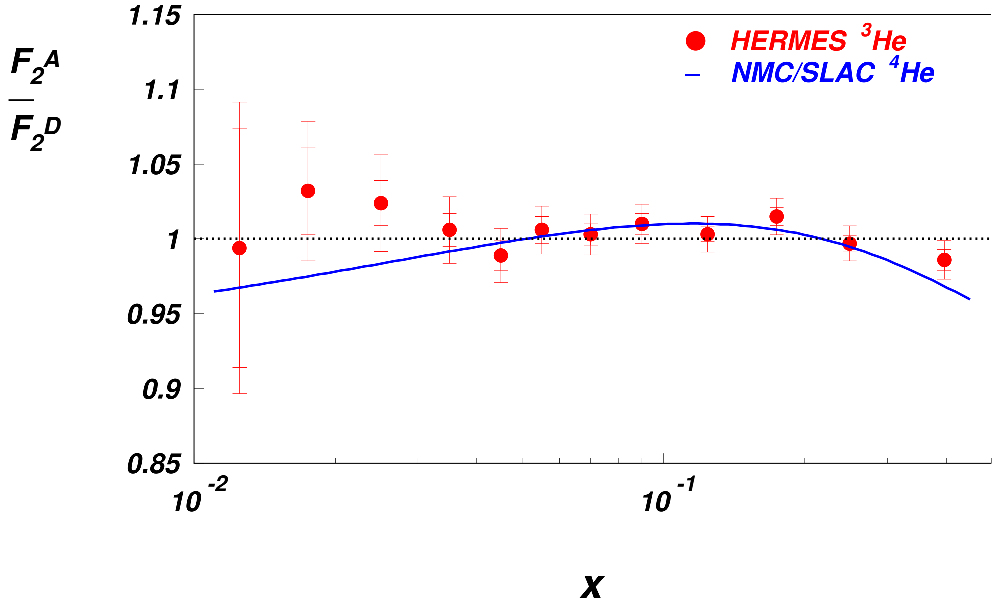
- Sensitivity of the fit:
  - intercept at $\epsilon = 1$: F_2^A/F_2^D .
  - slope with ϵ: R_A/R_D .

A-dependence of $F_2(x)$

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



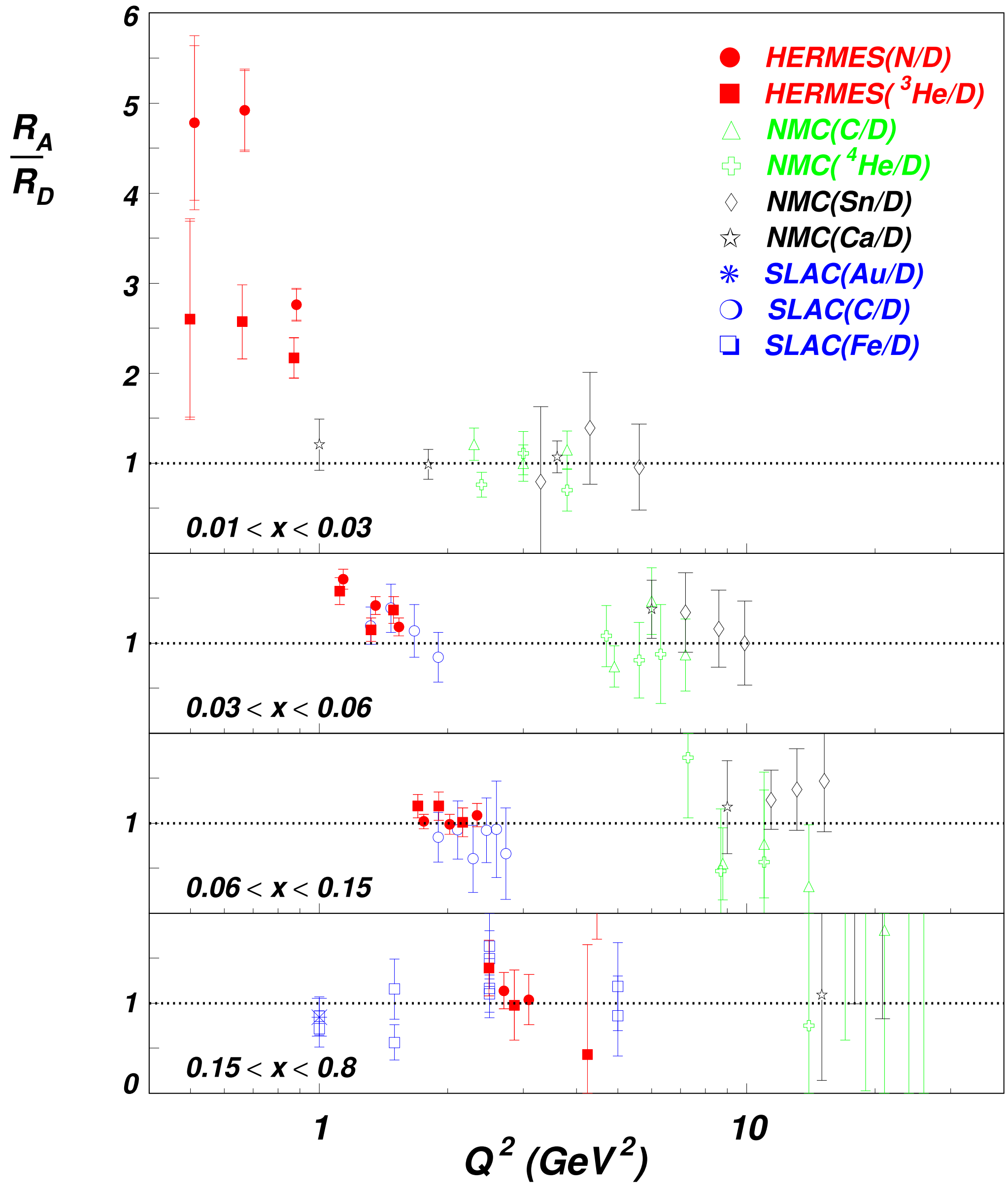
- Fitted values of F_2^A/F_2^D for ^{3}He:



- Conclusion:

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

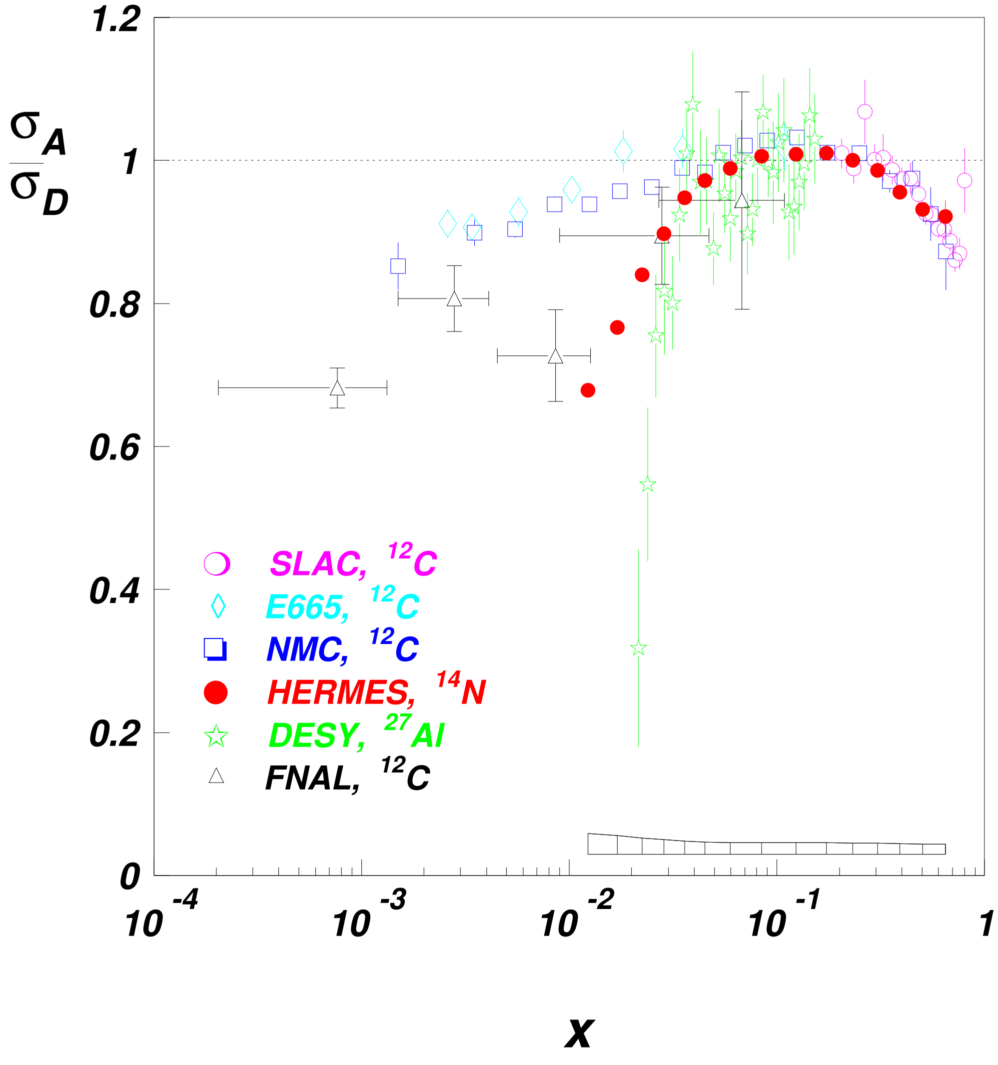
World data on $R_A = \sigma_L / \sigma_T$



$R_A > R_D$ at $x < 0.06$ and $Q^2 < 1.5$ GeV^2

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

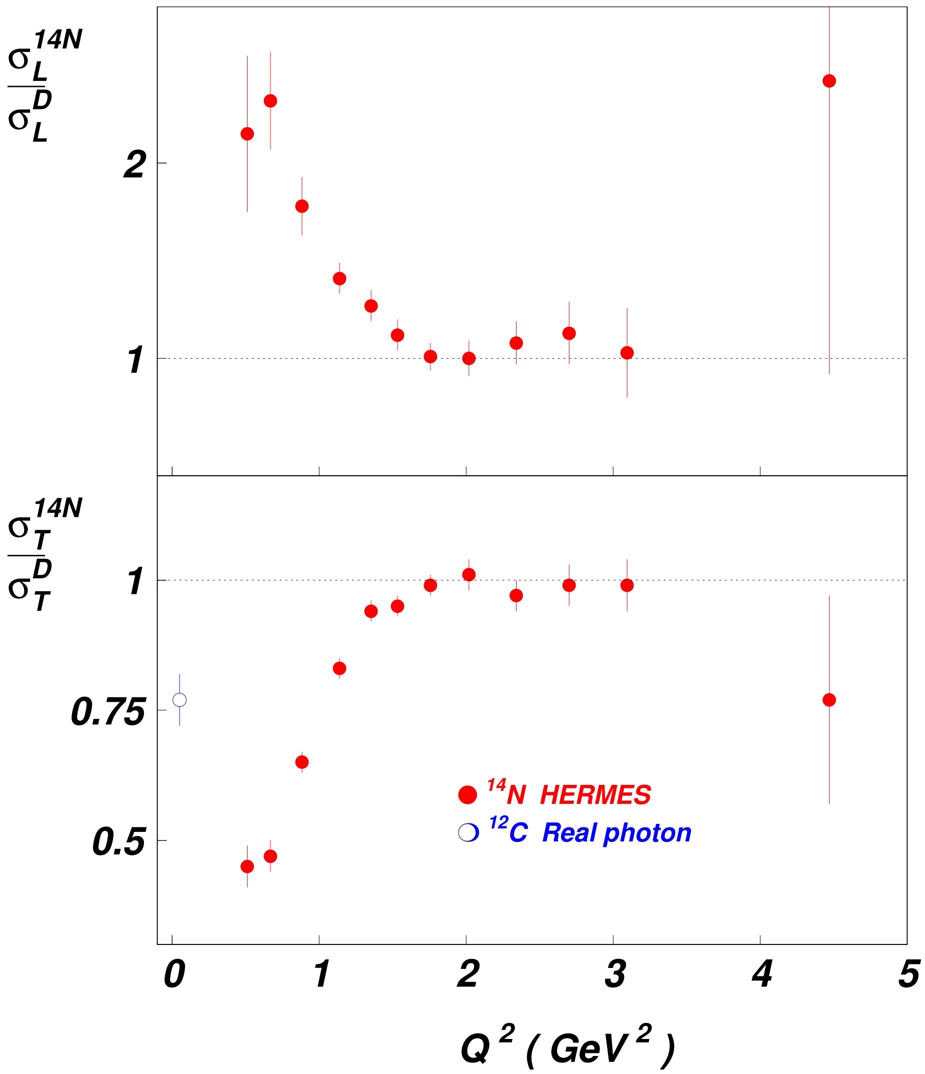
Strong shadowing at low Q^2 seen before !

A-dependence of σ_L and σ_T

- Alternative expression for cross-section ratio:

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

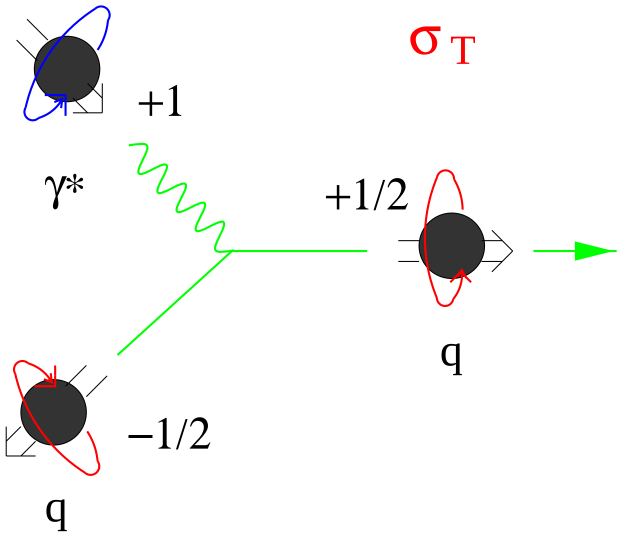
- Fit parameters: σ_T^A/σ_T^D and σ_L^A/σ_L^D :



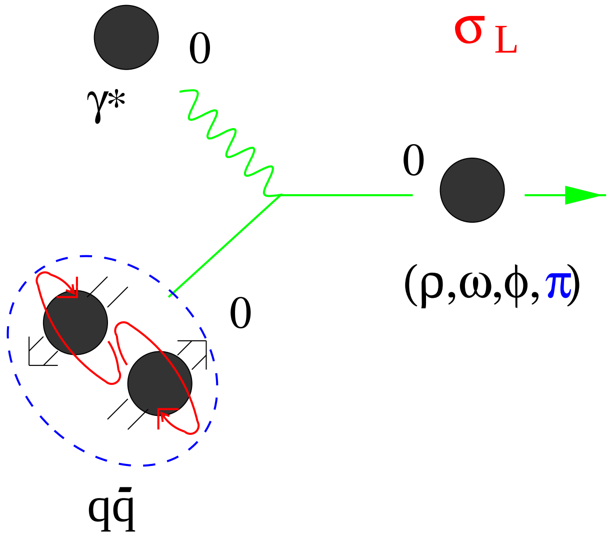
Coupling to $q\bar{q}$-pairs with S=0 ?

Quark Delocalization

- High Q^2 $\Longrightarrow$ mainly magnetic interaction



- Low x and Q^2 $\Longrightarrow$ enhancement of charge-like interaction for A > D



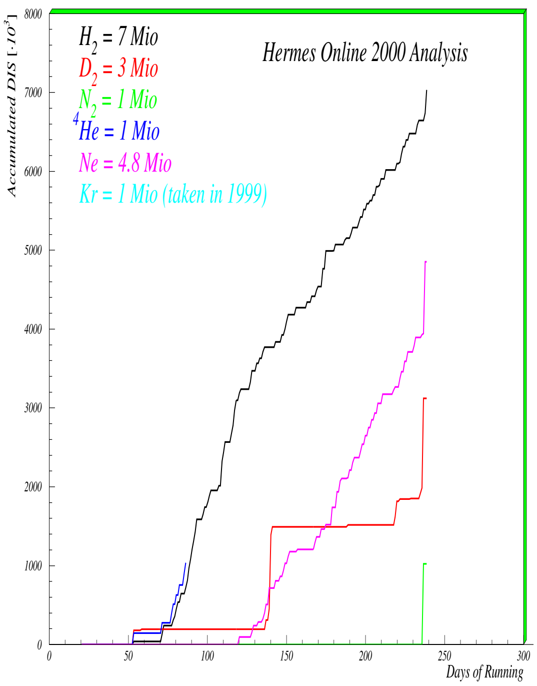
process $1/Q^2$ suppressed

Conclusions & Outlook

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

$$\boxed{R = \sigma_L/\sigma_T \text{ is A dependent}}$$

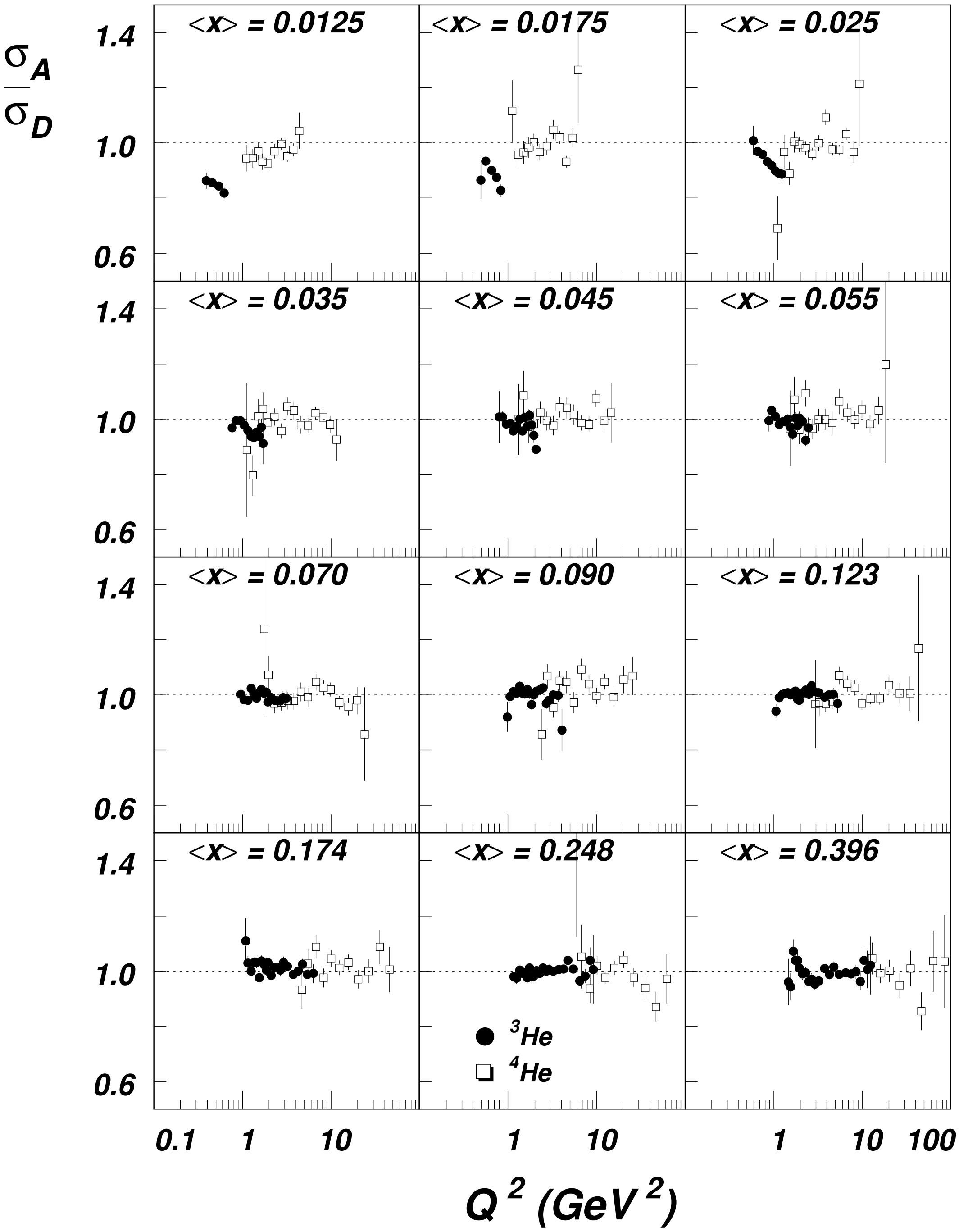
- Interpretation: quark delocalization ?



- Additional HERMES data 27.5 GeV: ^{84}Kr, ^{4}He, ^{20}Ne
- New data 12 GeV, same targets: disemtangle x-Q^2 dependence
- Search for enhanced π production

Q^2 dependence - ^{3}He

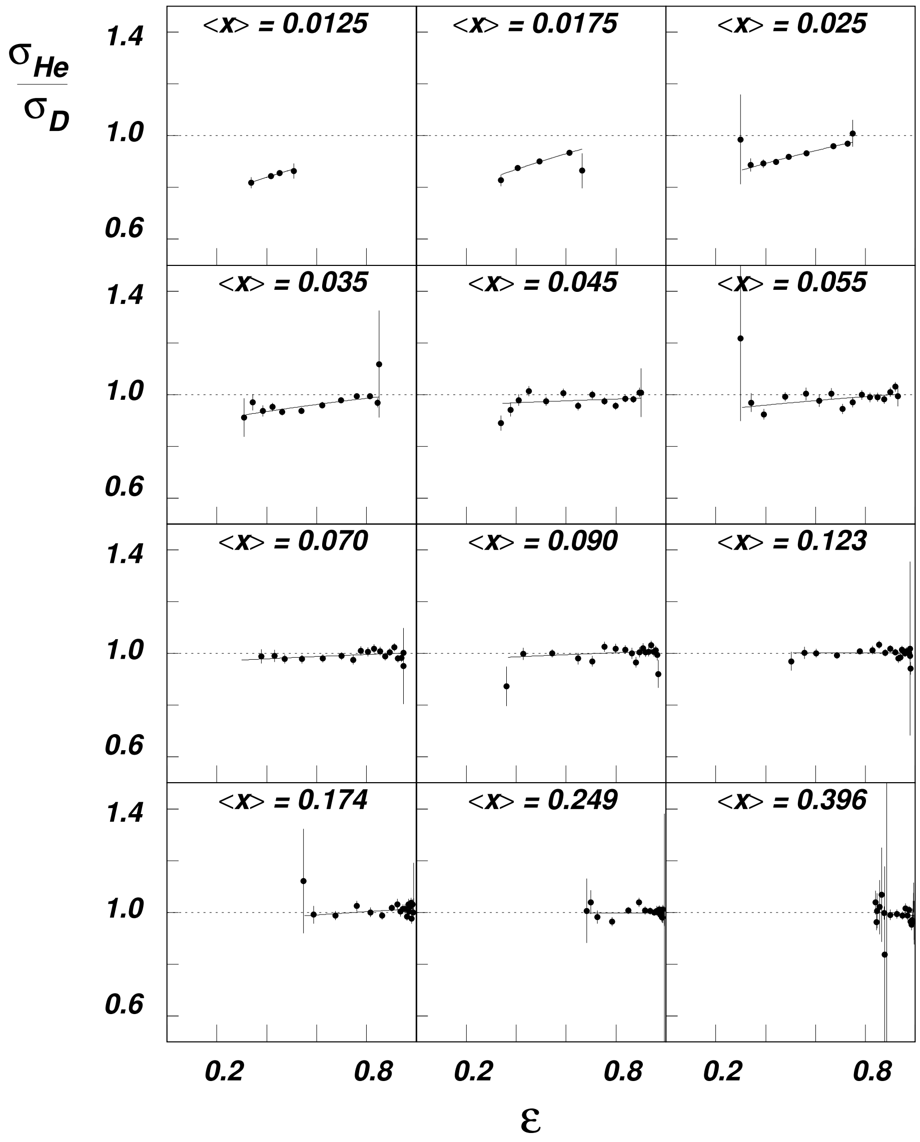
- Q^2-dependence of $\sigma_{^3He}/\sigma_{^2H}$:



Difference at low x increases with Q^2

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

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