Vector Meson production and Deep-Inelastic Scattering on (polarized) ^{1,2}H, ^{3}He and ^{14}N targets

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Outline

- Vector meson production at W = 4 - 7 GeV:
  - Cross Section
  - Target spin asymmetry
  - A-dependence
- Deep-inelastic scattering:
  - A-dependence of $R = \sigma_L/\sigma_T$
  - Hadronization in nuclei

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Introduction

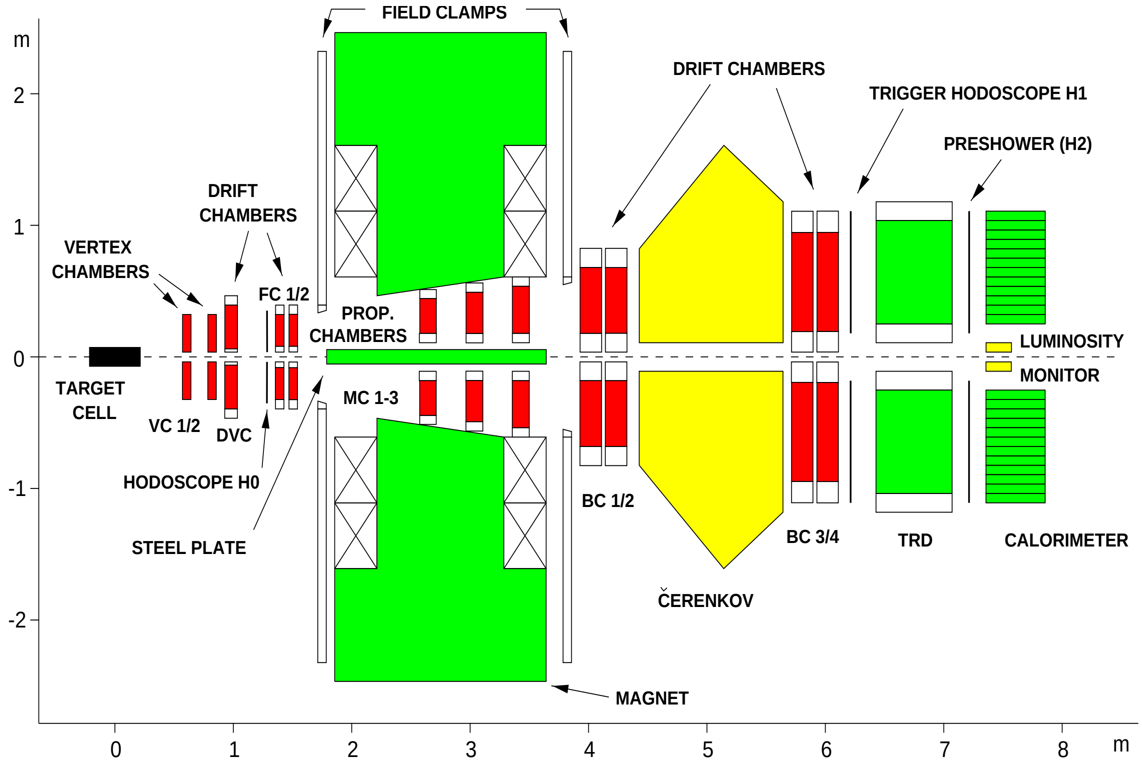
- Diffractive ρ^0 production:
  - Vector-Meson Dominance:
  - Off-forward parton distributions:

quark-exchange gluon-exchange

- Dependence on the target mass A:
  - ρ^0 production: color coherence effects
  - Deep inelastic scattering:
    - existing data: $F_2^A(x) \neq F_2^D(x)$
    - no A-dependence of $R = \sigma_L/\sigma_T$
    - HERMES result: $R_A(x) \neq R_D(x)$ at low (x, Q^2)
  - Hadronization in nuclei - determine $\tau_{formation}$

The HERMES experiment

- Sideview:

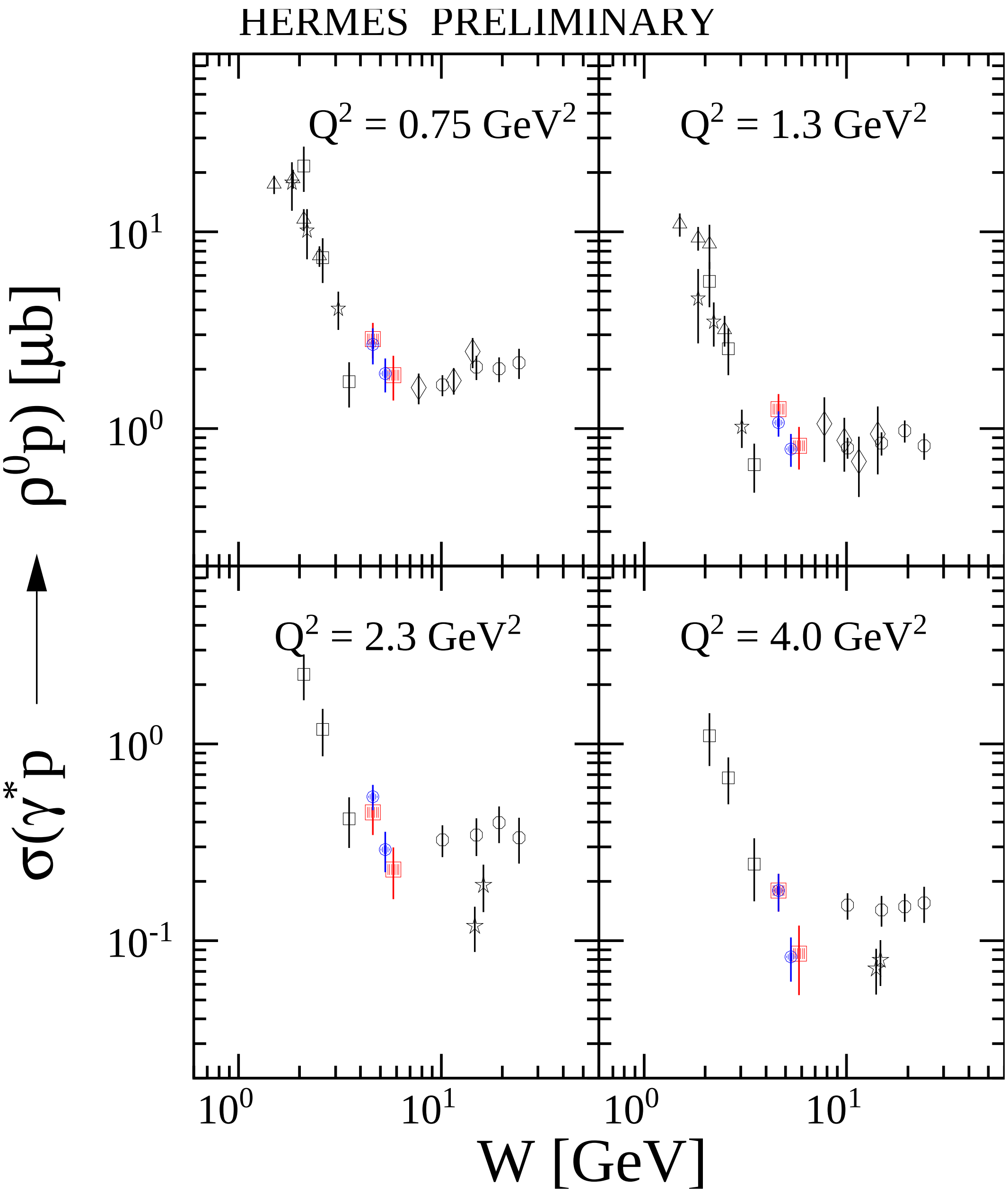


- Data collection:
  - 1995: ^{3}He and unpolarized ^{1,2}H
  - 1996: ^{1}H and unpolarized ^{1,2}H and ^{3}He
  - 1997: ^{1}H and unpolarized ^{1,2}H and ^{14}N
  - 1998: ^{2}H and unpolarized ^{1,2}H and ^{84}Kr

- Polarization:
  - Beam: 55 %
  - Target: 50 % for ^{3}He and 90 % for ^{1}H.

Diffractive ρ^0 production

- Cross section for $\gamma^* p \to \rho^0 p$:



- Conclusion:

Production mechanism changes @ 4 - 5 GeV

Off-forward parton distribution

- Evaluate longitudinal cross section:

$$\sigma_L = \frac{R}{1+\epsilon R}\sigma_{tot}$$

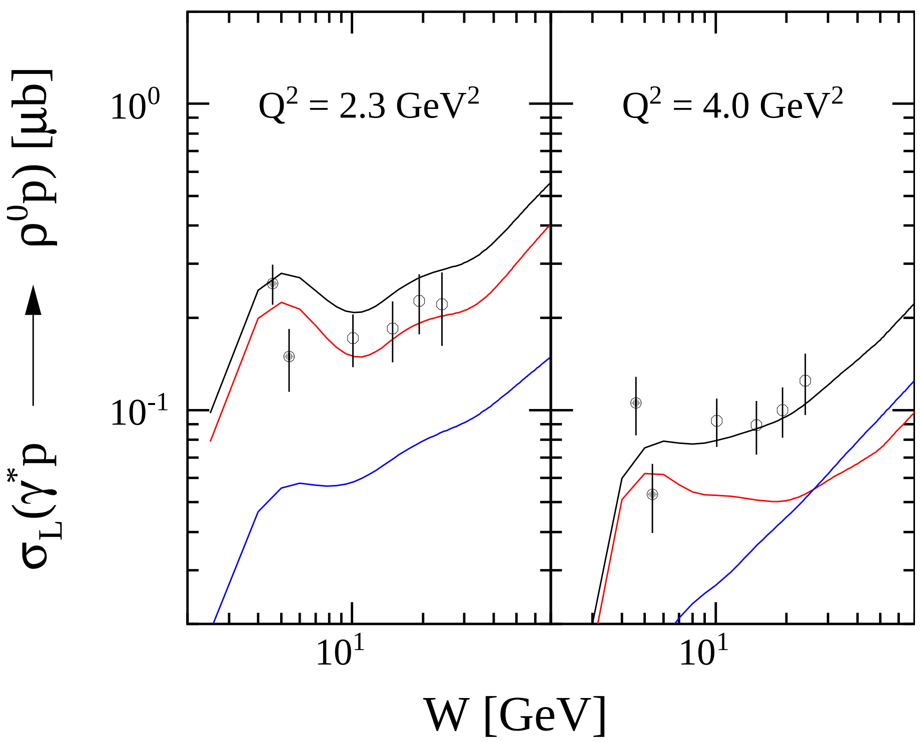
Take $R = \sigma_L/\sigma_T$ from ρ^0 decay angular distribution.

- Compare σ_L to OFPD calculations:

Vanderhaeghen, Guichon, Guidal, PRL 80 (1998) 5064:

—- quark-exchange —- gluon-exchange

HERMES PRELIMINARY



- Conclusion:

Quark exchange dominates @ 4 - 10 GeV

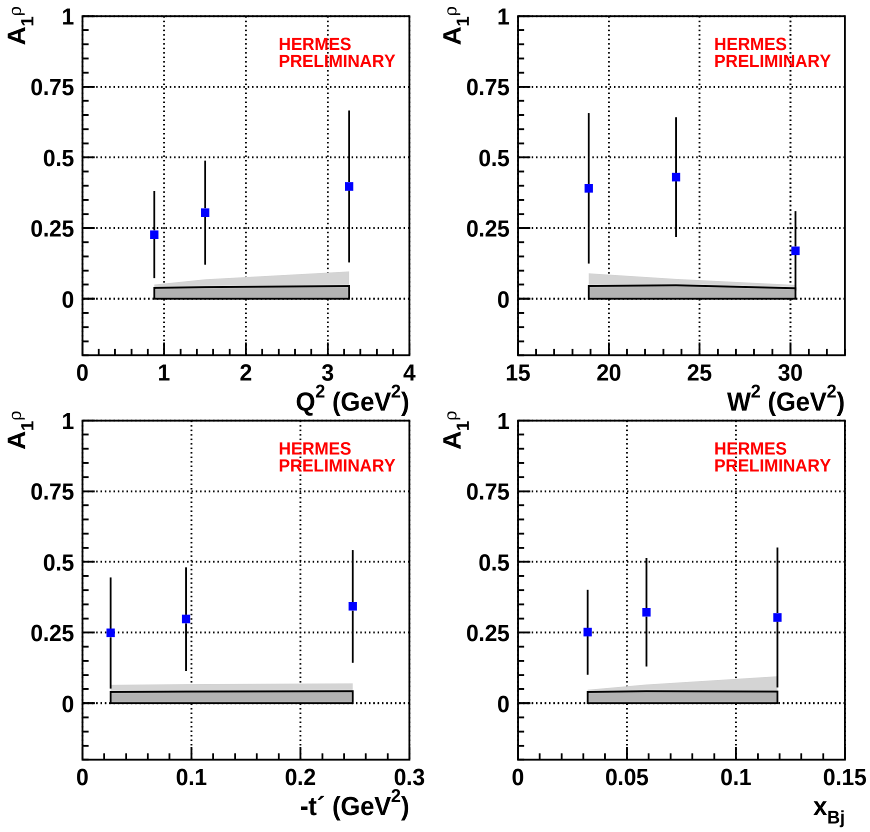
Target spin-asymmetry

- Asymmetry of $\gamma^* p \to \rho^0 p$ w.r.t. target spin:

$$A_1 = \frac{A_\parallel}{D} - \eta A_2 \quad \text{with} \quad A_\parallel = \frac{1}{p_B p_T} \frac{N^- - N^+}{N^- + N^+}$$

At HERMES: $D_\rho \approx 0.40$, $\eta \approx 0.05$ and $A_2 < \sqrt{R}$.

- A_1 vs. four different kinematical variables:



- Non-zero asymmetry in ρ^0 production:

$$\boxed{A_1 = 0.30 \pm 0.11\ \text{(stat)} \pm 0.04\ \text{(syst)} \pm 0.05\ \text{(theo)}}$$

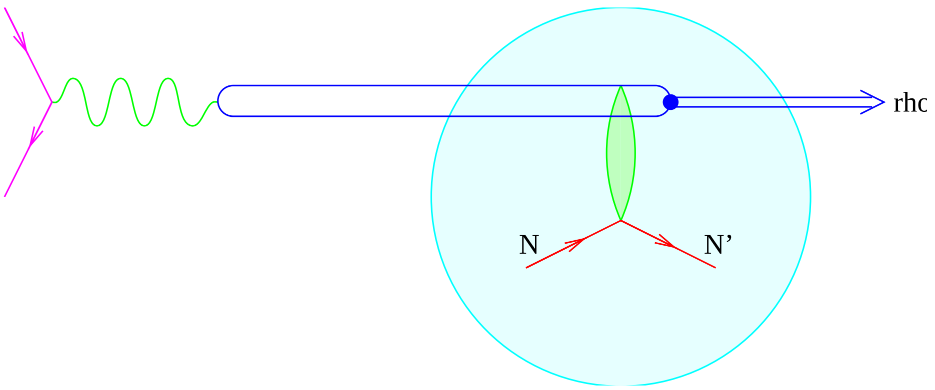
Coherence length effects

- Length of the hadronic fluctuation of the photon:

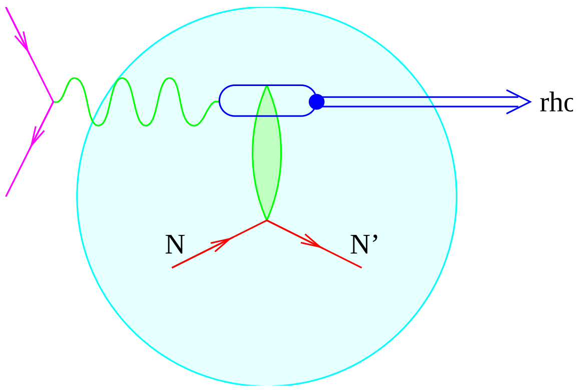
$$\boxed{l_{coh} = \frac{2\nu}{Q^2 + M^2_{q\bar{q}}}}$$

Typical values: 3 fm (HERMES), 10 fm (NMC).

- Small Q^2 → large l_{coh} → small $T_A (= \sigma_A/\sigma_H)$:



- Large Q^2 → small l_{coh} → large T_A:

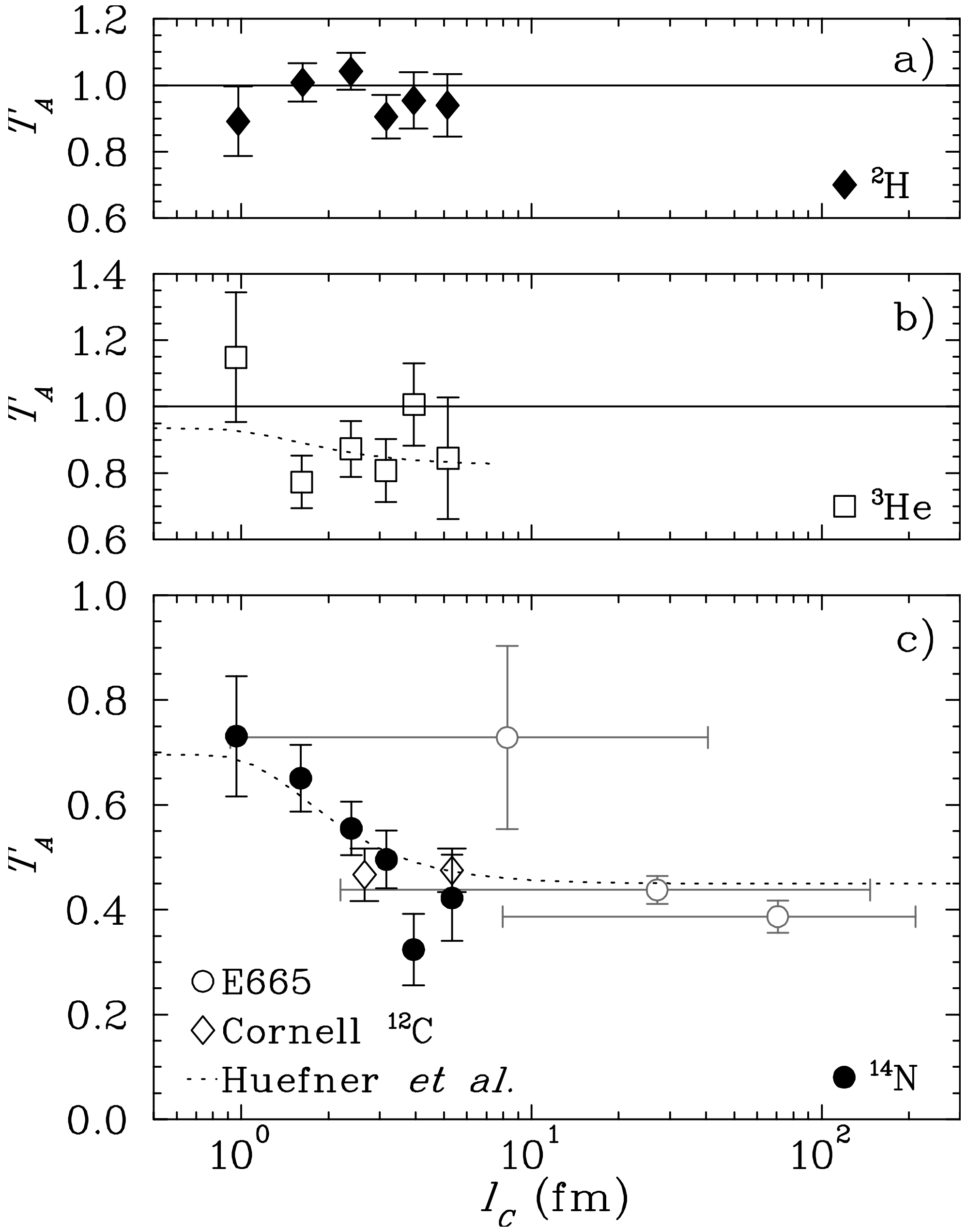


Coherence-length effect in $\gamma^* p \to \rho^0 p$?

A-dependence of ρ^0 production

- Transparency for ρ^0-production on $A = 2, 3$ and 14:

(HERMES Collaboration, PRL 82 (1999) 3025)

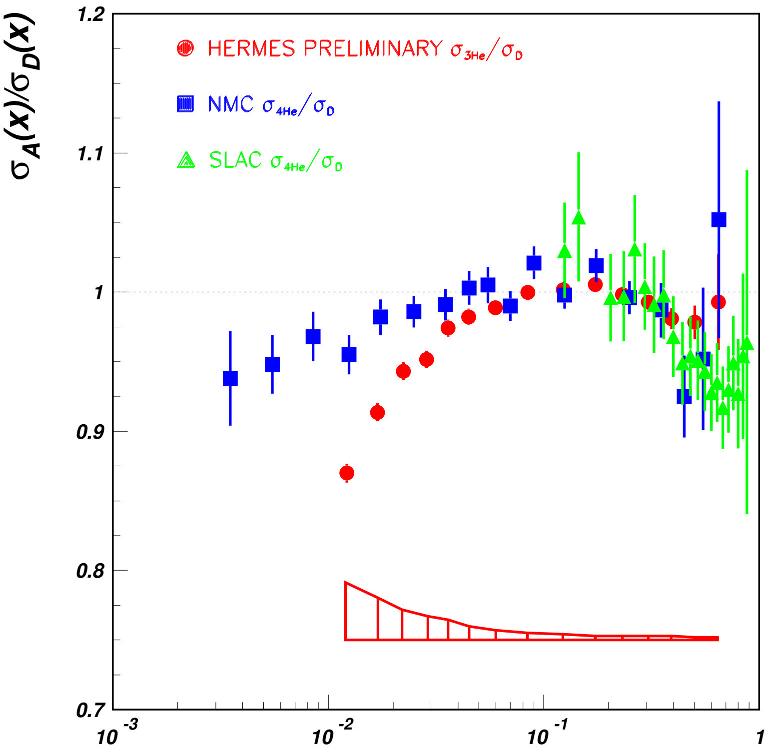


- Calculations: Glauber with l_{coh}-effects included

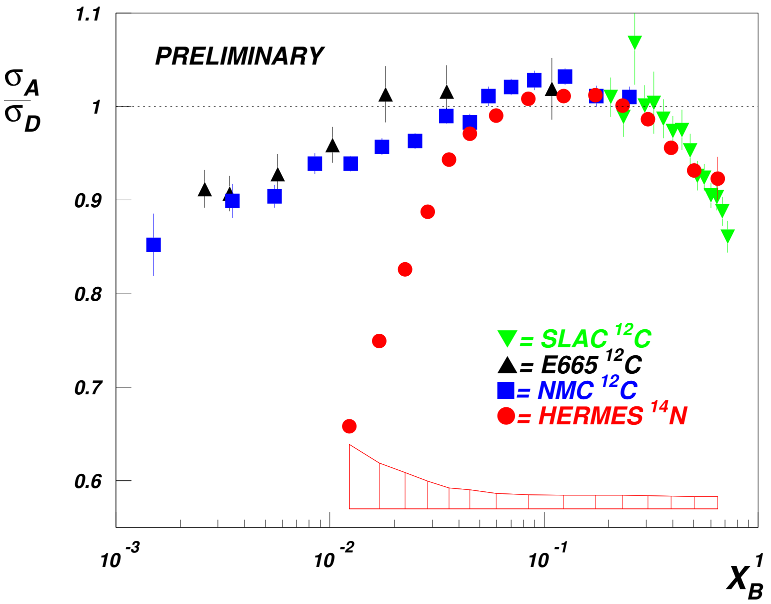
(Hüfner and Kopeliovich, PLB 383 (1996) 362)

Deep-Inelastic Scattering

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



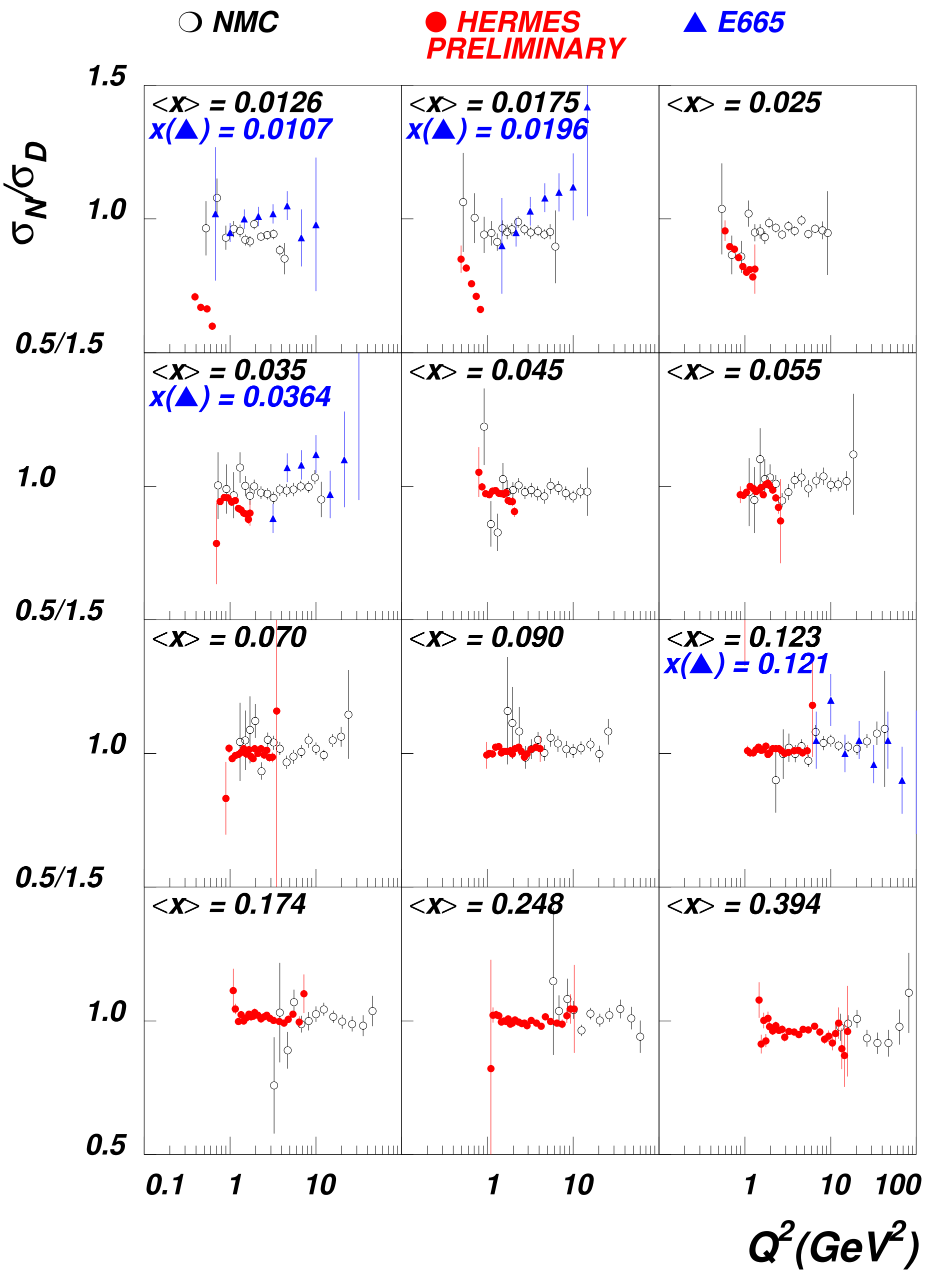
- The ratio of DIS cross sections on ^{14}N and ^{2}D:



Large difference between HERMES and NMC.

Q^2 dependence

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



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:

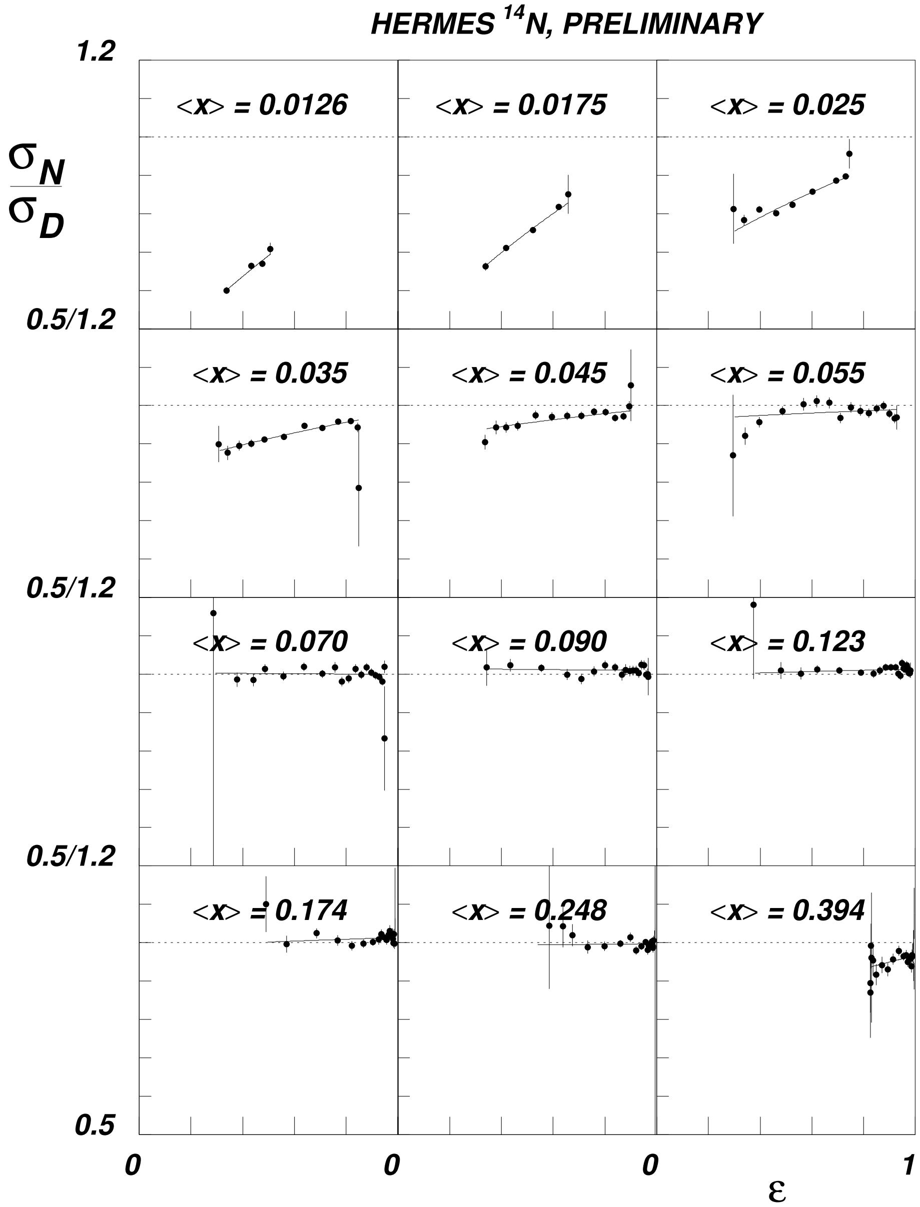
$$\frac{\sigma_A}{\sigma_D} = \frac{F_2^A}{F_2^D}\frac{(1+\epsilon R_A)(1+R_D)}{(1+R_A)(1+\epsilon R_D)}$$

- 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

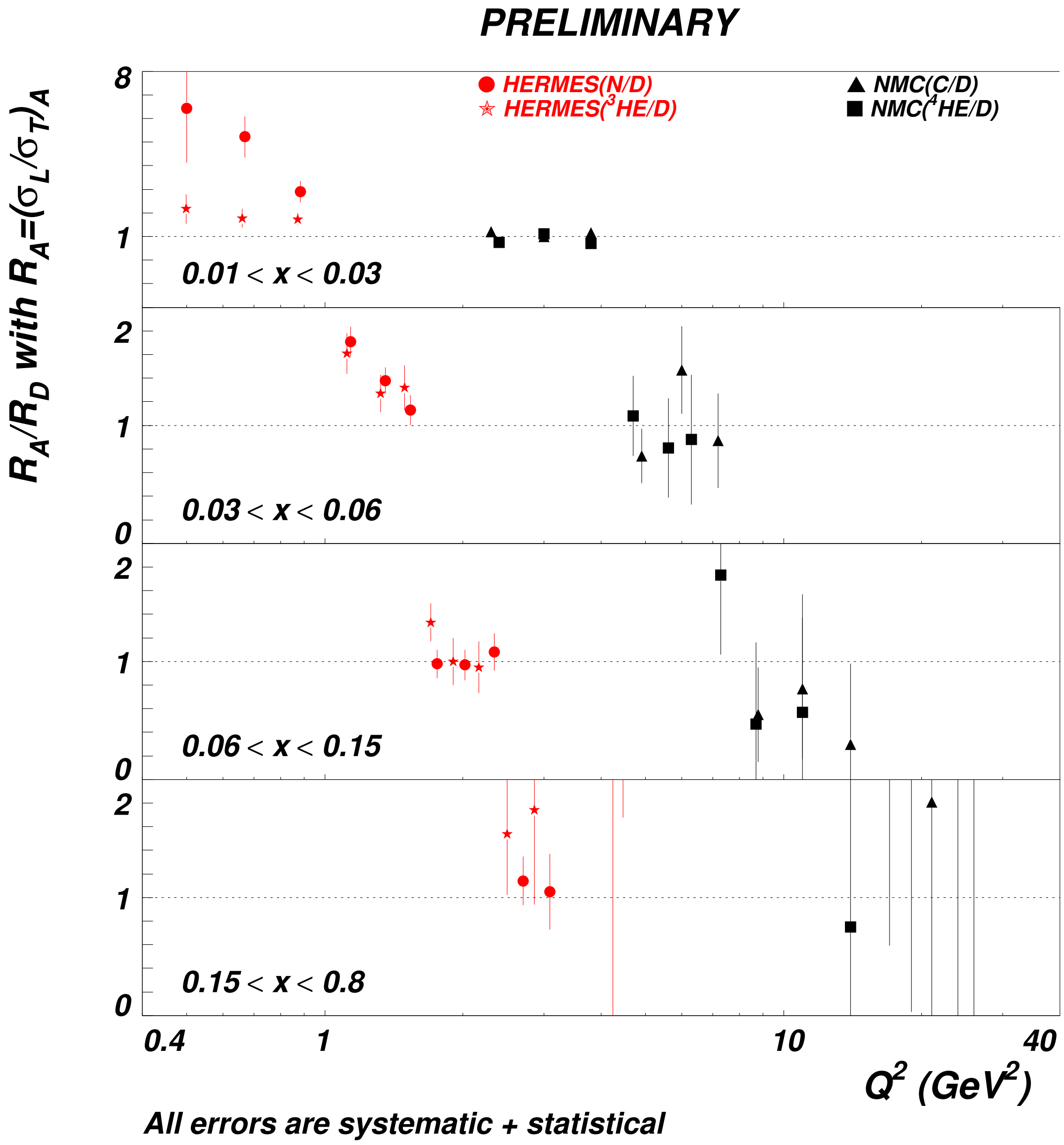
- ϵ-dependence of $\sigma_{^{14}N}/\sigma_{^2H}$:



- Two-parameter fit of the ϵ – depedence:
  - Relative normalization HERMES/NMC: $\pm$ 2 %
  - The ratio R_A/R_D for each x-bin.

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

- Fit result of $R_A(x, Q^2)$ for HERMES and NMC data:

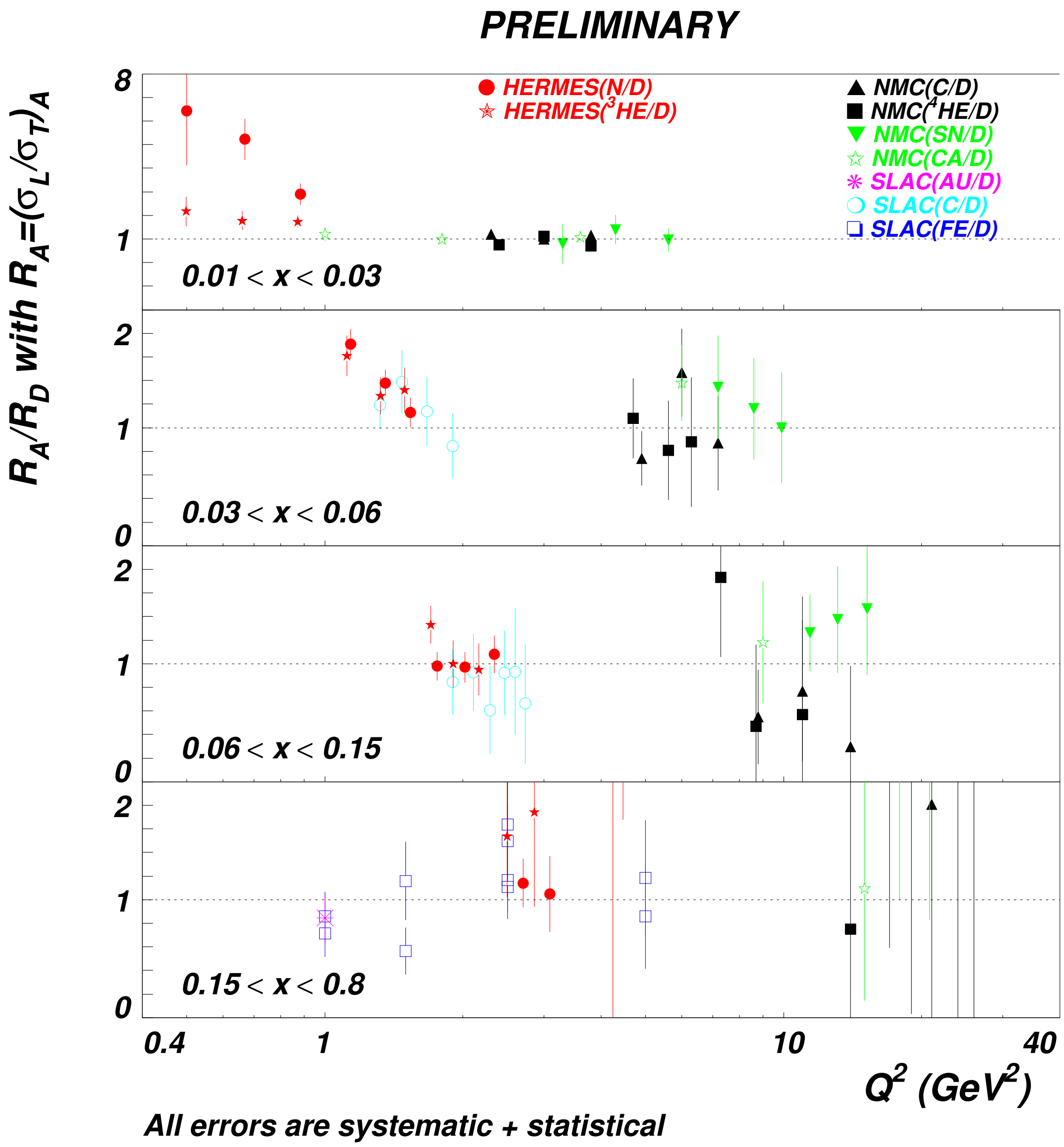


- Conclusion:

$R_A > R_D$ at low x and low Q^2.

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

- Comparison of HERMES data to existing data:

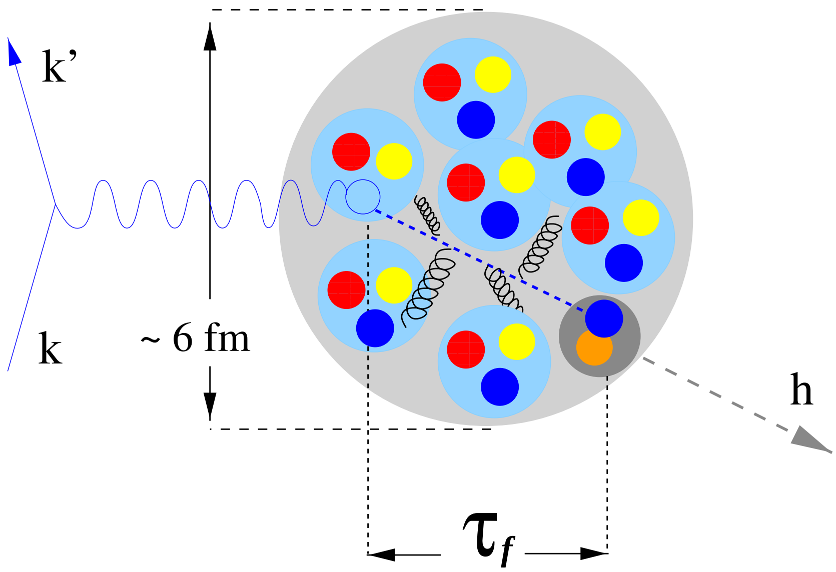


- Conclusion:

No inconsistency with existing data.

Hadronization in nuclei

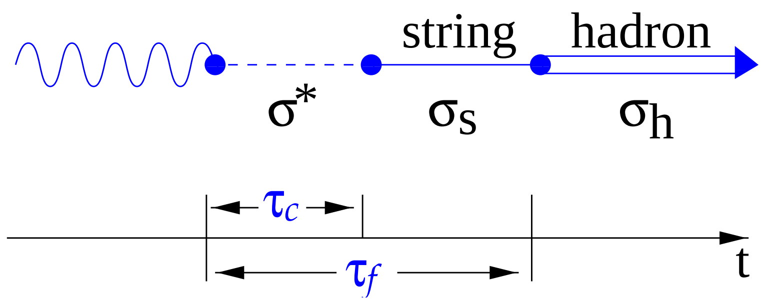
- Use nucleus as a probe of the formation time:



- Measure the attenuation ratio:

$$R_A(z_h,\nu) = \frac{\left(\frac{1}{N_e}\frac{dN^h}{dz_h d\nu}\right)\rfloor_A}{\left(\frac{1}{N_e}\frac{dN^h}{dz_h d\nu}\right)\rfloor_D}$$

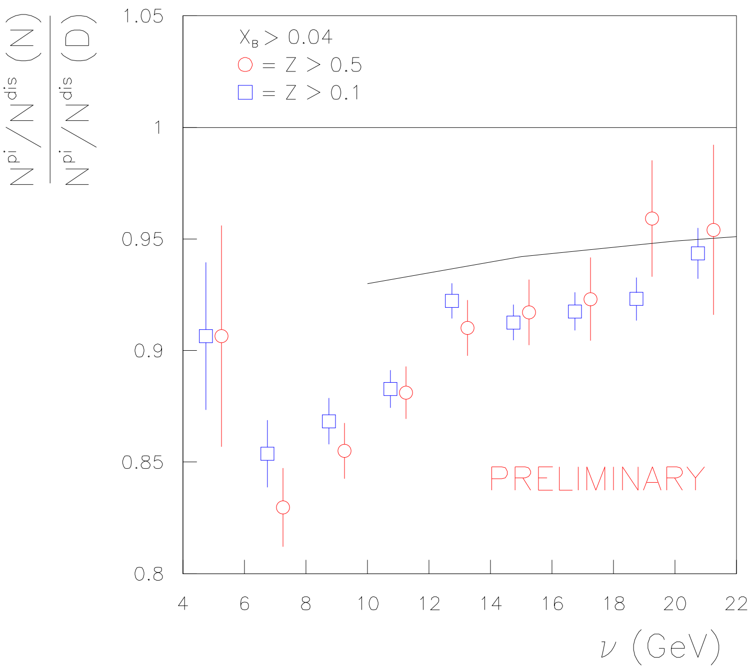
- Space-time structure of the hadronization process:



Derive τ_f and σ_S from a fit to the data.

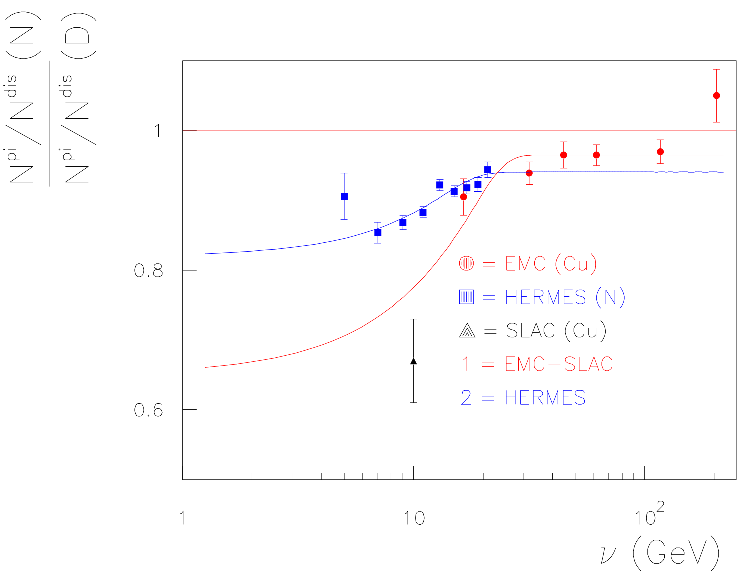
Attenuation measurements

- Preliminary HERMES data for pions from ^{14}N:



—- Gluon Brehmsstrahlung (B. Kopeliovich, J. Nemchik)

- Compare world data to fit of 2-time scale model:



HERMES data in most sensitive domain

Conclusions

- Diffractive ρ^0 production @ W = 4 - 7 GeV:
  - OFPD calculation: dominance q-exchange
  - Non-zero spin asymmetry: similar to A_1^{DIS} ?
  - A-dependence: coherence-length effect

- A-dependence of DIS @ E = 27.5 GeV:
  - HERMES and NMC disagree at low x and Q^2
  - Interpretation:

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

    * Twist-4 effect in nuclei (scales as $1/Q^2$) ?
    * Nuclear gluon fields ?
    * Shadowing differences for σ_L and σ_T ?

  - Pion attenuation in nuclei: τ_{form}