Recent Results from HERMES

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hermes Collaboration

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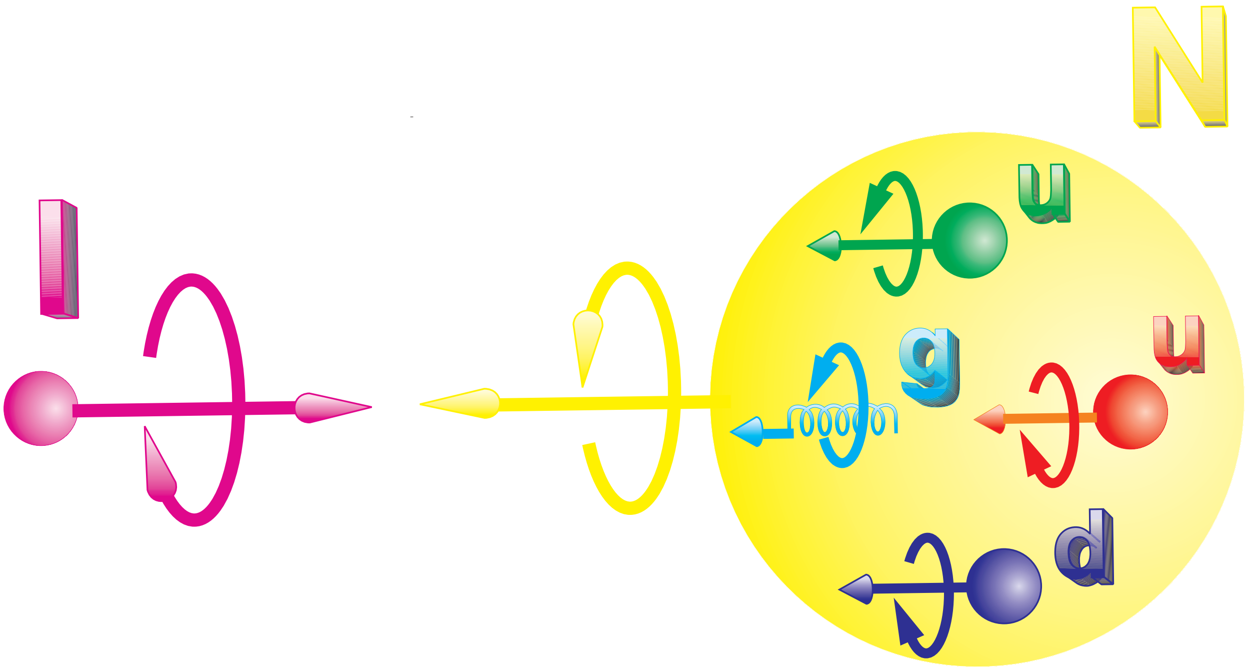
- Introduction
- Spin Structure Studies
- Asymmetry of Pairs of Hadrons at High $\mathbf{p}_T$
- Nuclear Dependence of $R = \sigma_L/\sigma_T$ at low Q^2
- Future and Summary

Components of the Nucleon Spin



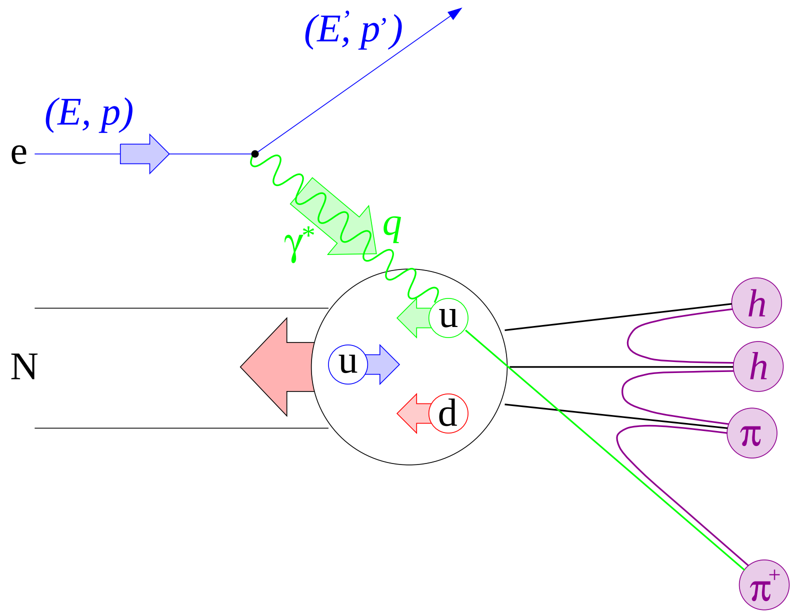
$$\boxed{\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z}$$

From Deep Inelastic lepton scattering:

- quark spins $\Delta\Sigma = (\Delta u + \Delta d + \Delta s) \sim 0.3$
- gluon spins ΔG = ??
- orbital angular momenta L_z = ??

Semi-Inclusive Deep Inelastic Scattering

In semi-inclusive DIS a hadron h is detected in coincidence with the scattered lepton



Flavour Tagging

- Select hadrons from the current fragmentation region by minimum cuts on $z = E_h/\nu$ and $x_F = 2p_{||}/W$
- in LO QCD (assuming spin-independence of fragmentation)

$$A_1^h(x,z) \simeq \frac{A_{||}^h(x,z)}{D(x,Q^2)} \simeq \frac{\sum e_f^2 \Delta q_f(x) \cdot D_{q_f}^h(z)}{\sum e_f^2 q_f(x) \cdot D_{q_f}^h(z)}$$

$D_{q_f}^h$: Fragmentation Function

Comparison of Sea Assumptions

- Sea purities are too small for decomposition with available statistics

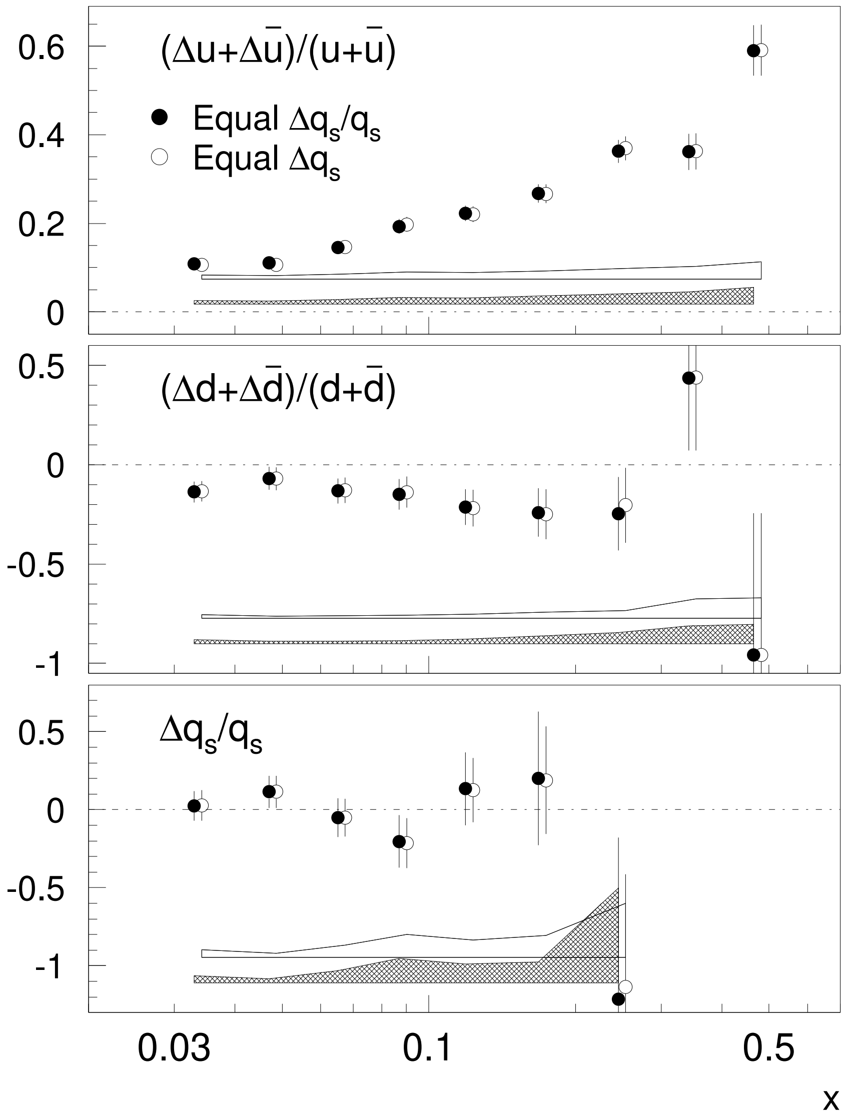
  $\rightarrow$ assume a flavour independent polarization

$$\Delta u_{sea}/u_{sea} = \Delta d_{sea}/d_{sea} = \Delta s/s$$

  $\rightarrow$ assume a flavour symmetric sea

$$\Delta u_{sea} = \Delta d_{sea} = \Delta s$$

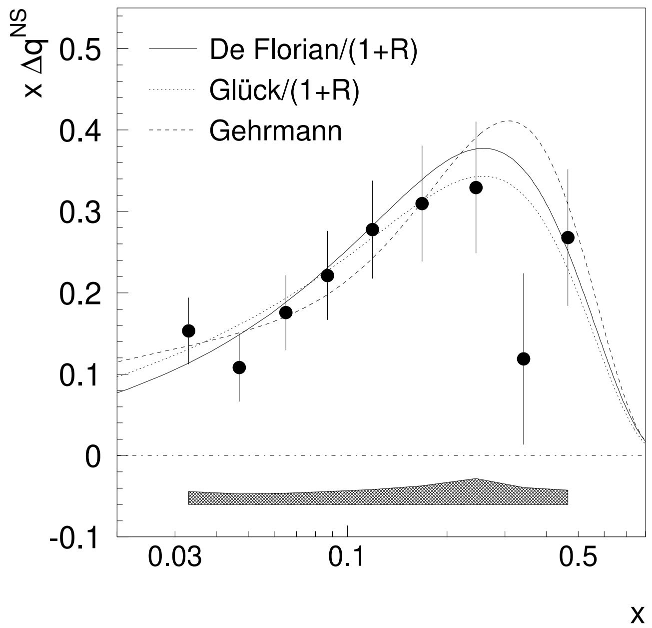
  to reduce number of quark polarizations



$\Rightarrow$ Results insensitive to choice of sea assumption

Interpretation

- Good agreement with SU(3) analyses of other inclusive data
  e.g.: Non singlet combination of quark distributions Δq^{NS}



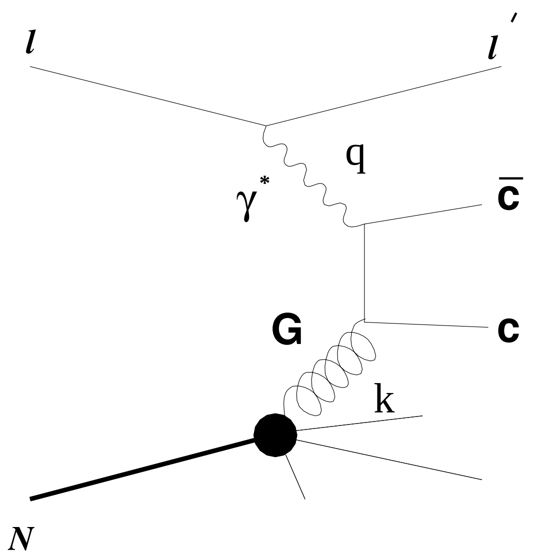
- However: Strange Sea Polarization
  - sea quark contribution is close to zero in semi-inclusive analysis (assuming sea symmetry)
  - strange quark sea is significantly negative in inclusive analysis (assuming SU(3) flavour symmetry)

  $\rightarrow$ **neither result represents direct measurement of Δs**

- RICH offers possibility of direct measurement through Kaon identification

How to measure ΔG?

- x_{bj} scaling violation for polarized structure functions
  $\rightarrow Q^2$ evolution is due to gluons
- direct measurement via isolation of photon gluon fusion (PGF) LO QCD diagram

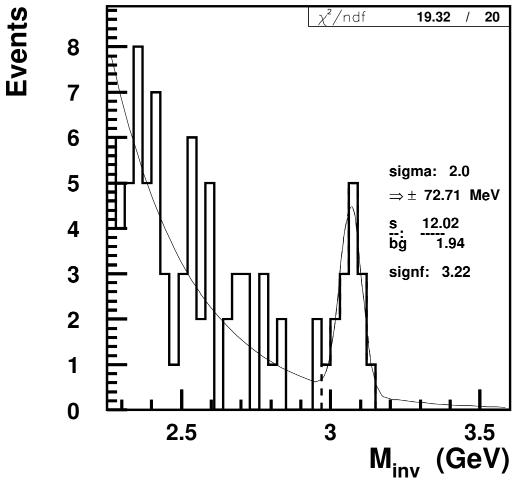


J/ψ
open charm
HERMES
COMPASS
(E-156)

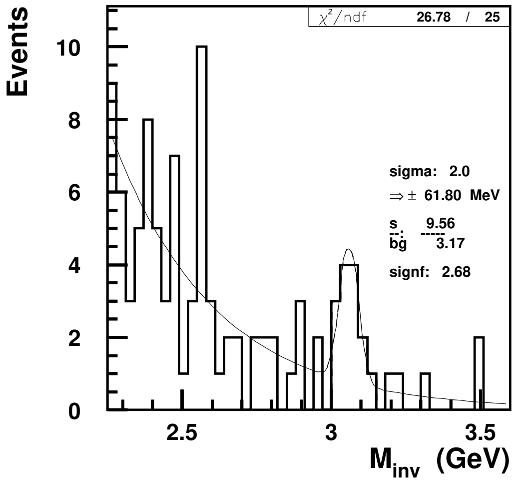
- Dijet production:
  polarized HERA
- high p_T hadrons as substitution for jets at fixed target experiments:
  HERMES, COMPASS
- direct photon gluon production: $g + q \rightarrow \gamma + q$
  RHIC

Charm Production at HERMES

Motivation:
Use charm production (D^0, D^*, and inelastic J/ψ) as clean tag of PGF



$J/\psi \to e+\ e-$, $J/\psi \to \mu+\ \mu-$, N^+



$J/\psi \to e+\ e-$, $J/\psi \to \mu+\ \mu-$, N^-

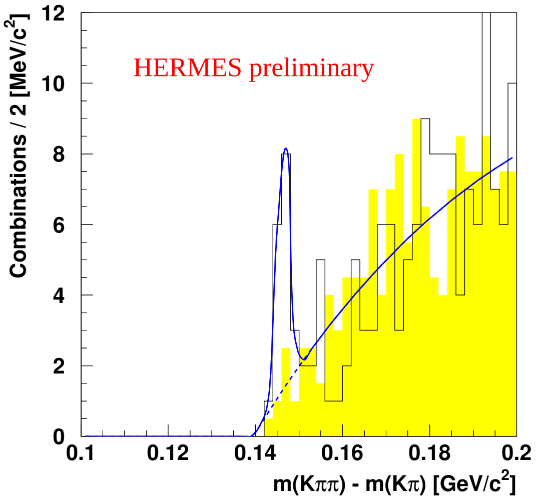
$J/\psi \to e^+e^-$ or $\mu^+\mu^-$: $\sim$ 20 events in 1996/97 data set

$A_1^{J/\psi}$ consistent with zero within statistical error

– no scattered $e^+ \Rightarrow$ no measured DIS kinematics

– possible inelastic contribution (estimated 20-30%)

1998 charm upgrade $\Rightarrow$ factor 4 increase in acceptance



$D^{*+} \to D^0 + \pi^+$: $\sim$ 15 events in 1996/97 data set

Spin Asymmetry in Photoproduction of Hadron Pairs at High-$\mathbf{p}_T$

Motivation:

- PGF is isolated at collider experiments via $e + p \rightarrow e' +$ 2 jets $+$ target fragments.

  H1, Nucl. Phys. B75, 539 (1995), $G(x)$ from dijet production

- HERMES does not have jets, can use high-p_T hadrons instead.

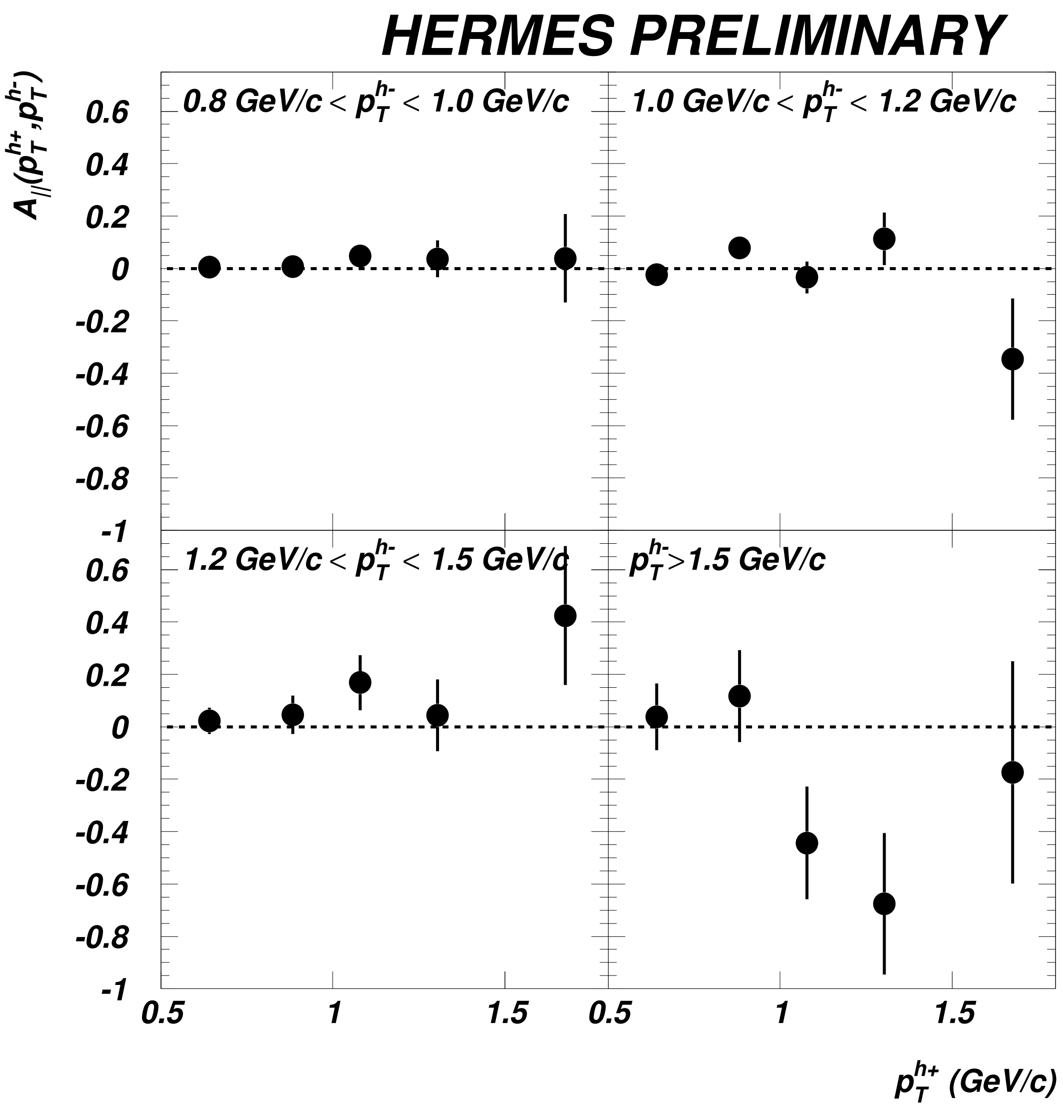
  Study for COMPASS, Bravar at al., Phys. Lett. B241, 349 (1998)

- cross section maximal at Q^2 = 0.
  - spectrometer has no acceptance at Q^2 = 0
    $\rightarrow$ do not require scattered e^+ in spectrometer

- Requirements:
  - at least two hadrons in spectrometer: one h^+ and one h^-
  - both must be high momentum (>4.5 Gev/c) and high p_T (>0.5 Gev/c)
  - $M(2\pi) >$ 1.0 (Gev/c)^2 $\rightarrow$ remove ρ and ϕ resonances

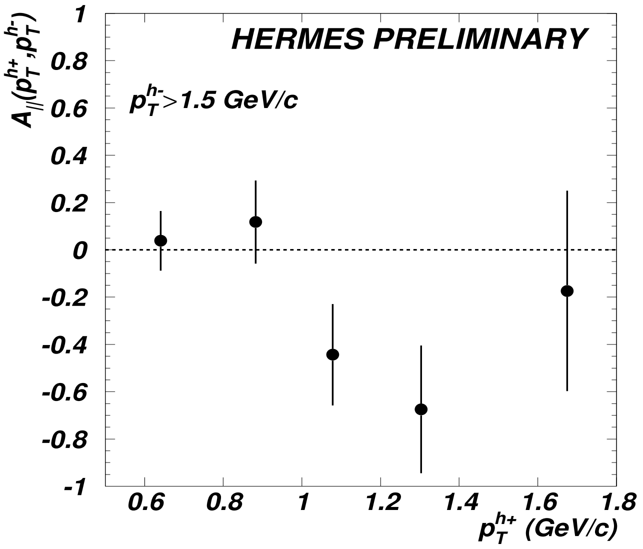
Measured asymmetry $A_{\|}(p_T^{h^+}\, p_T^{h^-})$

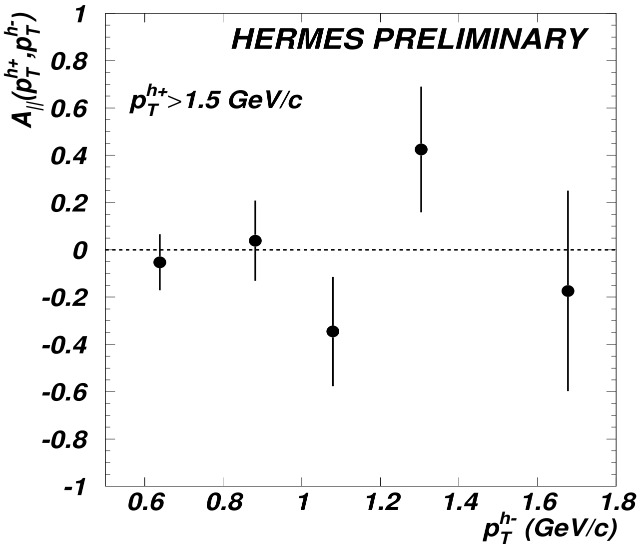
Polarized Hydrogen data (1996+1997)

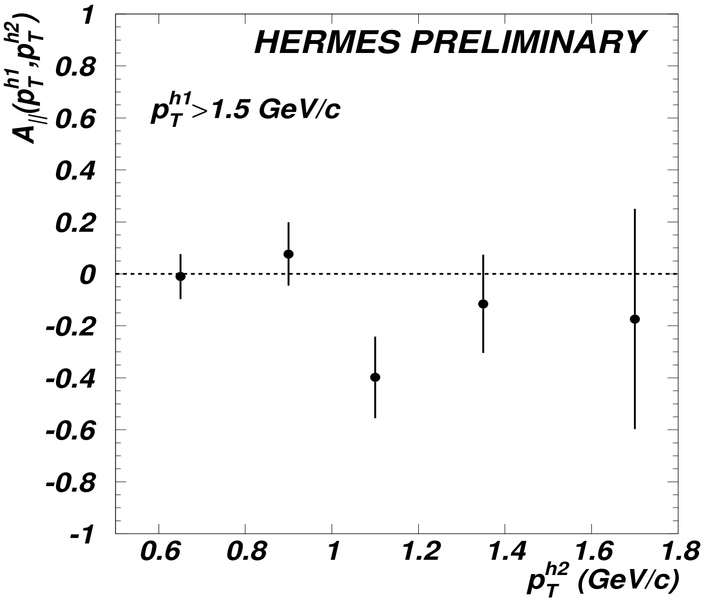


systematic error $\approx$ 8 % of measurement

Region of Interest



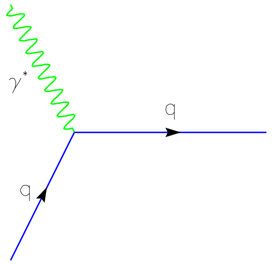




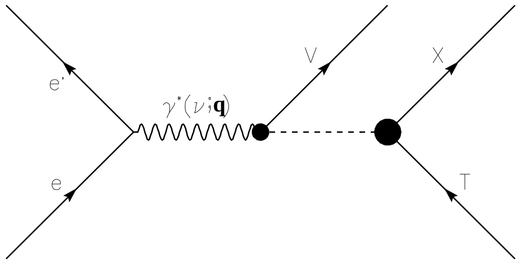
systematic error $\approx$ 8 % of measurement

Interpretation

Assume four different processes may contribute:

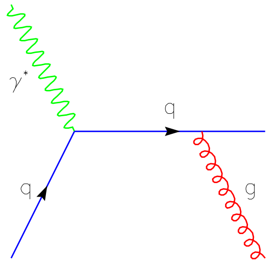


DIS



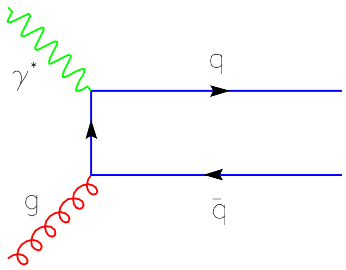
VMD

$A_{\rm VMD} \simeq 0$ (assumed)



QCDC

$A_{\rm QCDC} \sim \frac{\Delta q}{q}$



PGF

$A_{\rm PGF} \sim \frac{\Delta G}{G}$

... and estimate their relative contributions.

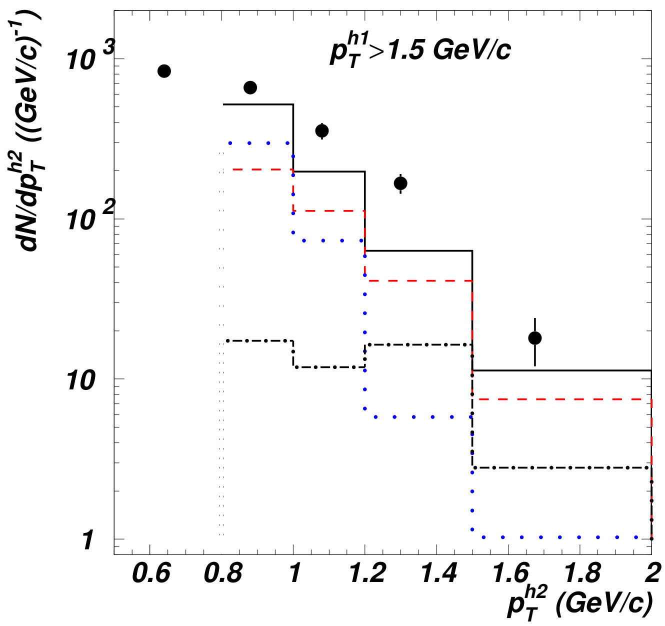
The spin asymmetries each contribute to the measured asymmetry:

$$
\begin{aligned}
A_{\|} &= A_{QCDC} f_{QCDC} + A_{PGF} f_{PGF} + A_{DIS} f_{DIS} A_{VMD} f_{VMD} \\
&\approx A_{QCDC} f_{QCDC} + A_{PGF} f_{PGF}
\end{aligned}
$$

f_i is unpolarized fraction of events for subprocess $i =$ QCDC, PGF, DIS, VMD.

MC-Data Comparisons

Comparisons of measured yields with predictions of model implemented in PYTHIA:

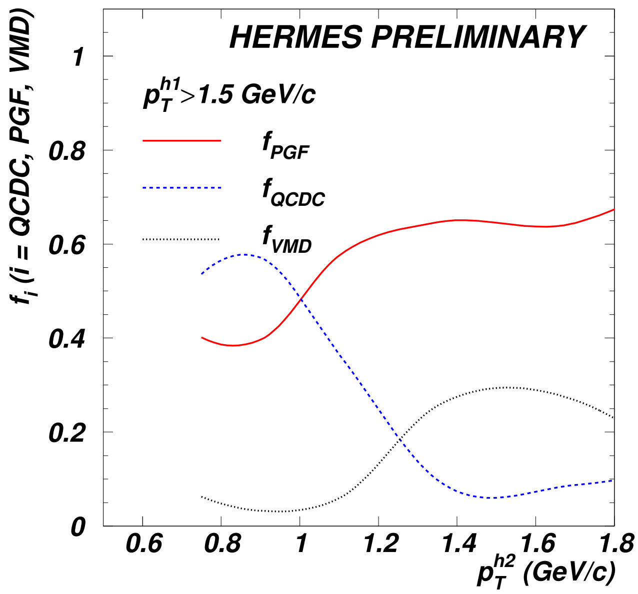


black = total yield | red = PGF | blue = QCDC | dotted black = VMD

unpolarised model

$\rightarrow$ process fractions f_i:

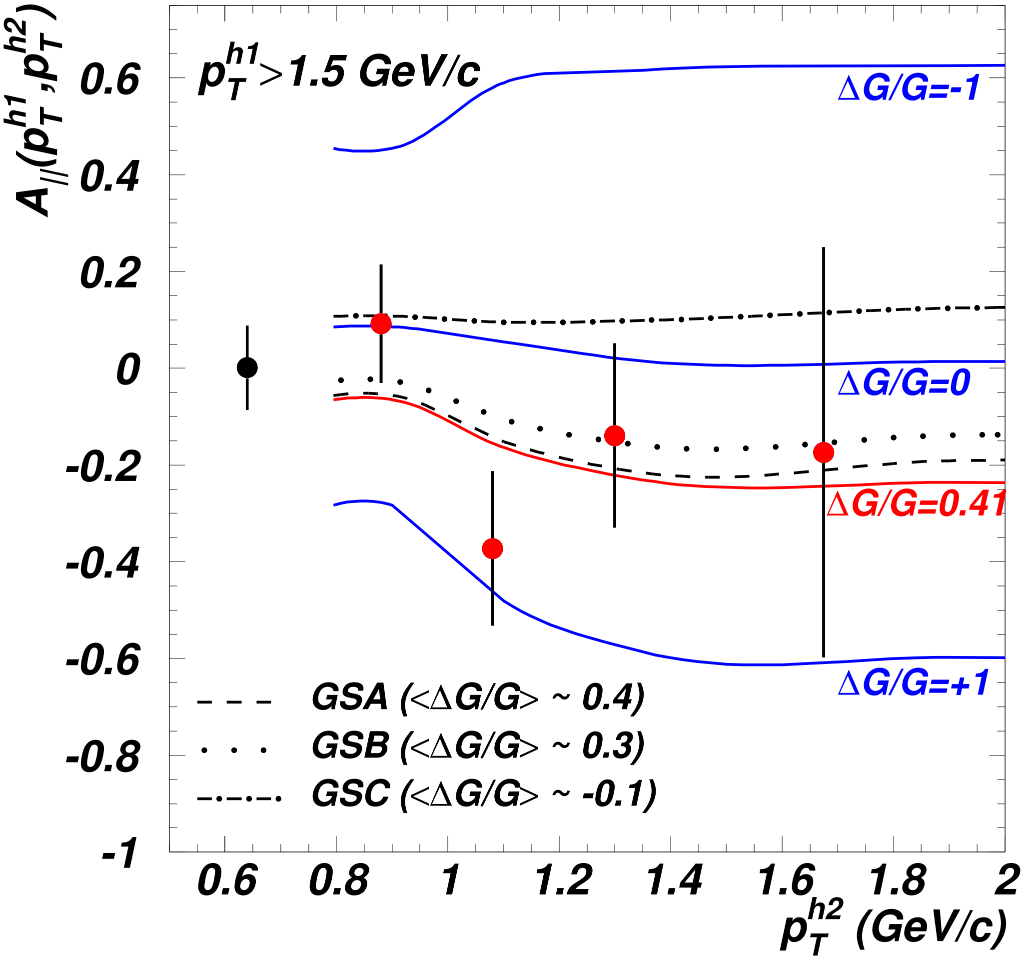
$\Rightarrow$ The **negative** asymmetry is observed where **PGF** is expected to **dominate!**



Result using PYTHIA model

$\Delta G/G = 0.41 \pm 0.18$ (stat) ± 0.03 (exp. syst)

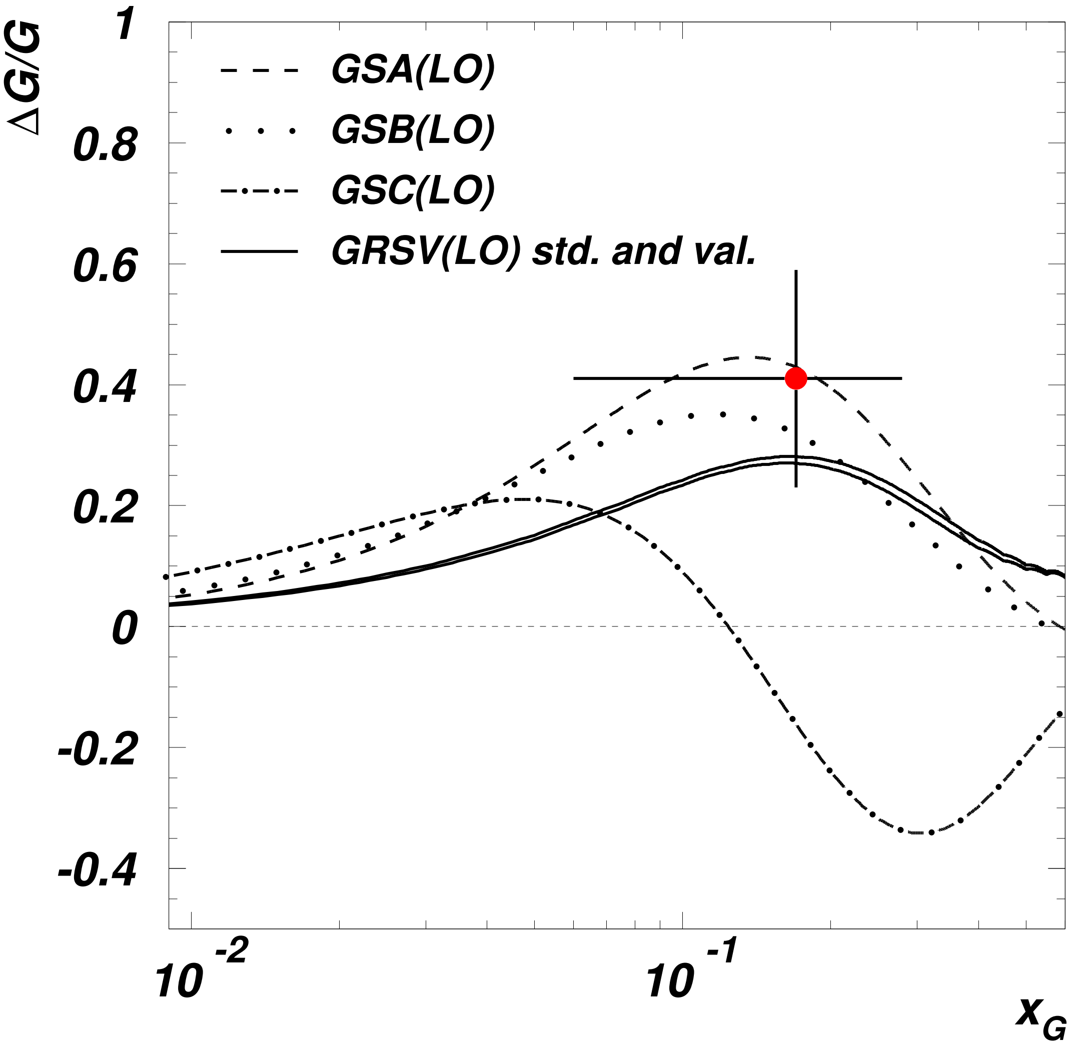
at $\langle x_G \rangle = 0.17$ and $\langle \hat{p}_T^2 \rangle = 2.1$ GeV/c^2



Unknown theoretical uncertainty from contribution and possible spin asymmetry of anomalous photon and NLO QCD corrections.

If only a dilution $\Longrightarrow$ value of $\Delta G/G$ will increase but significance will not change.

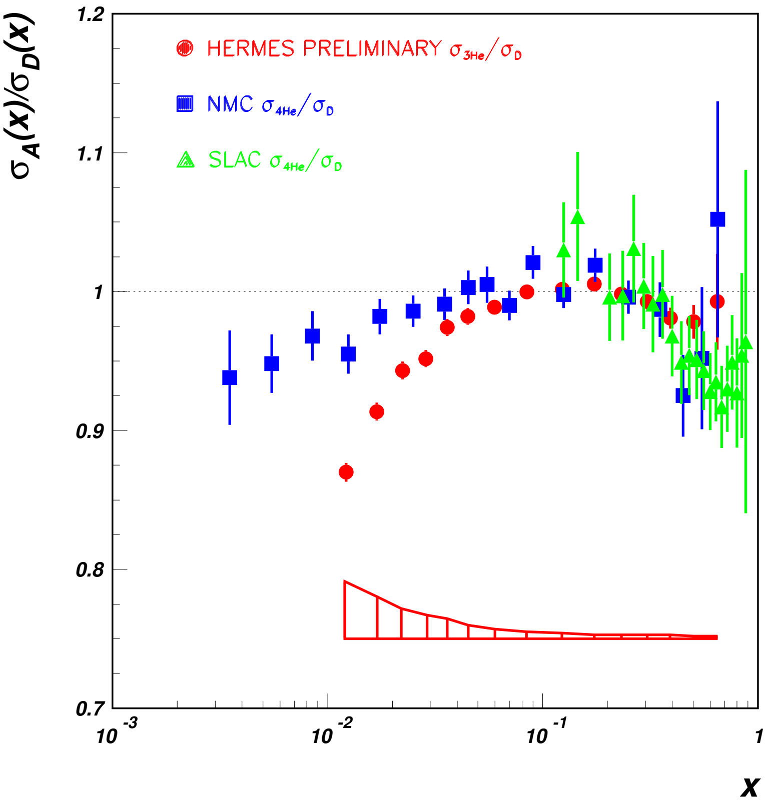
Comparison to Phenomenological Fits



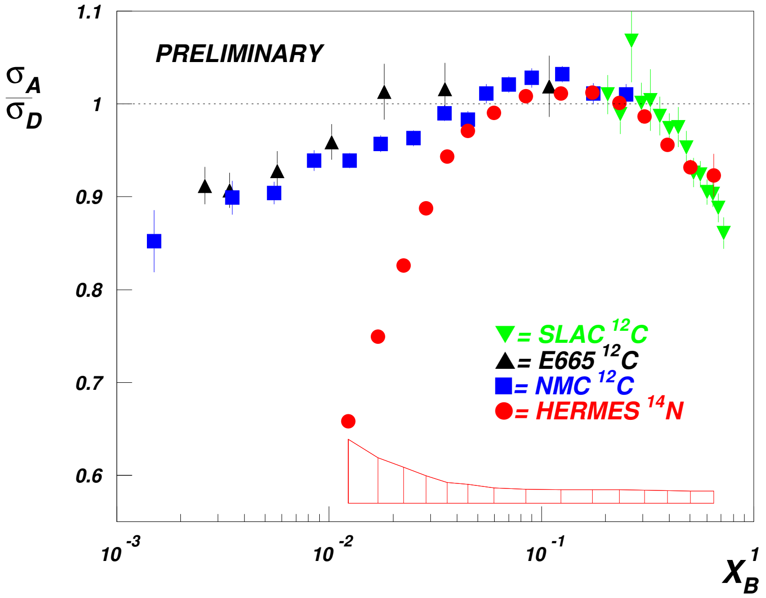
- error does not include potentially large theoretical uncertainty

Deep Inelastic Scattering

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



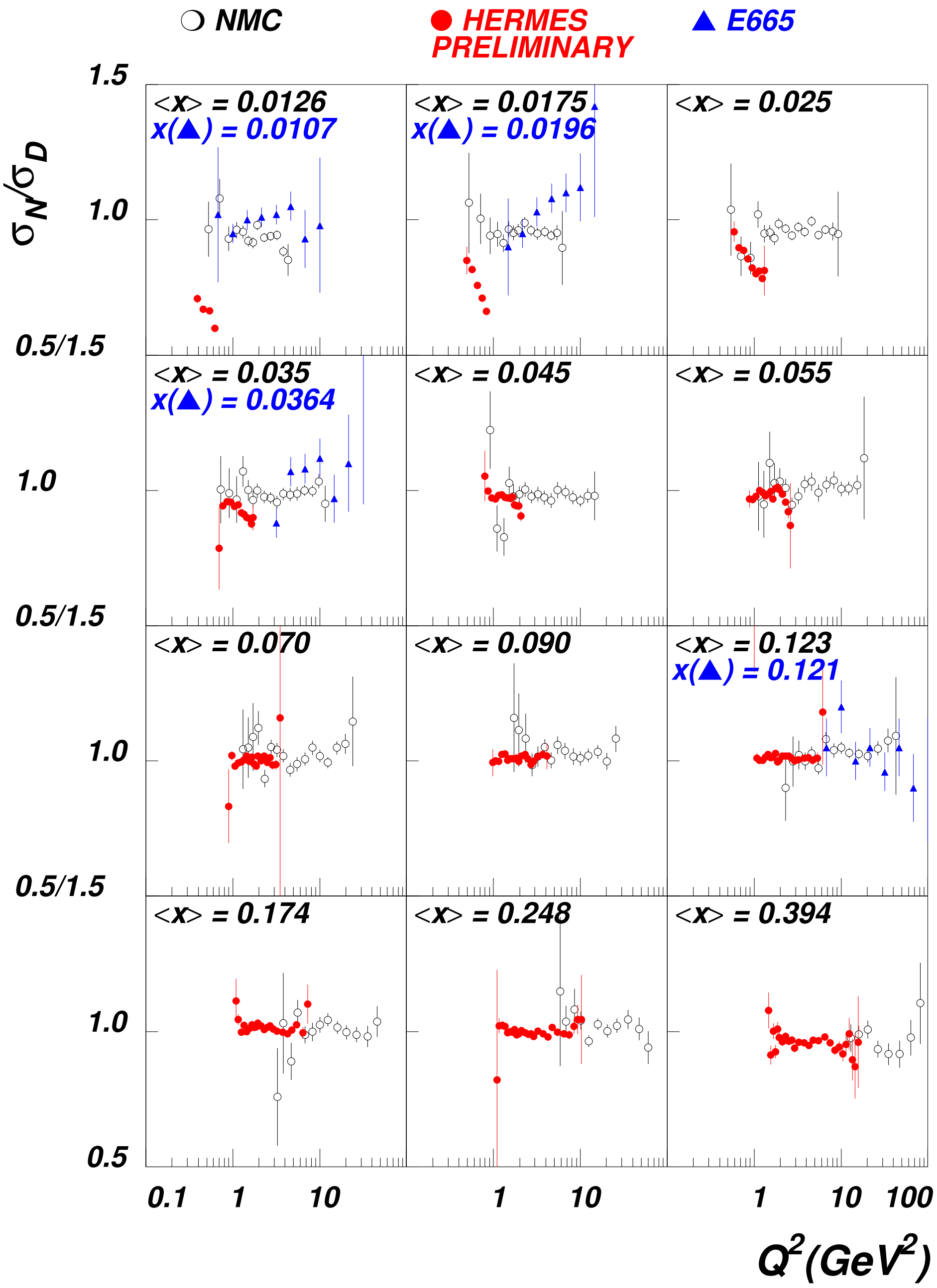
- Ratio of DIS cross sections on ^{14}N and ^{2}D:



Large difference between HERMES and NMC

Q^2 Dependence

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



Difference at low x increases with Q^2

DIS Formalism

- The inclusive DIS cross section:

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

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:

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

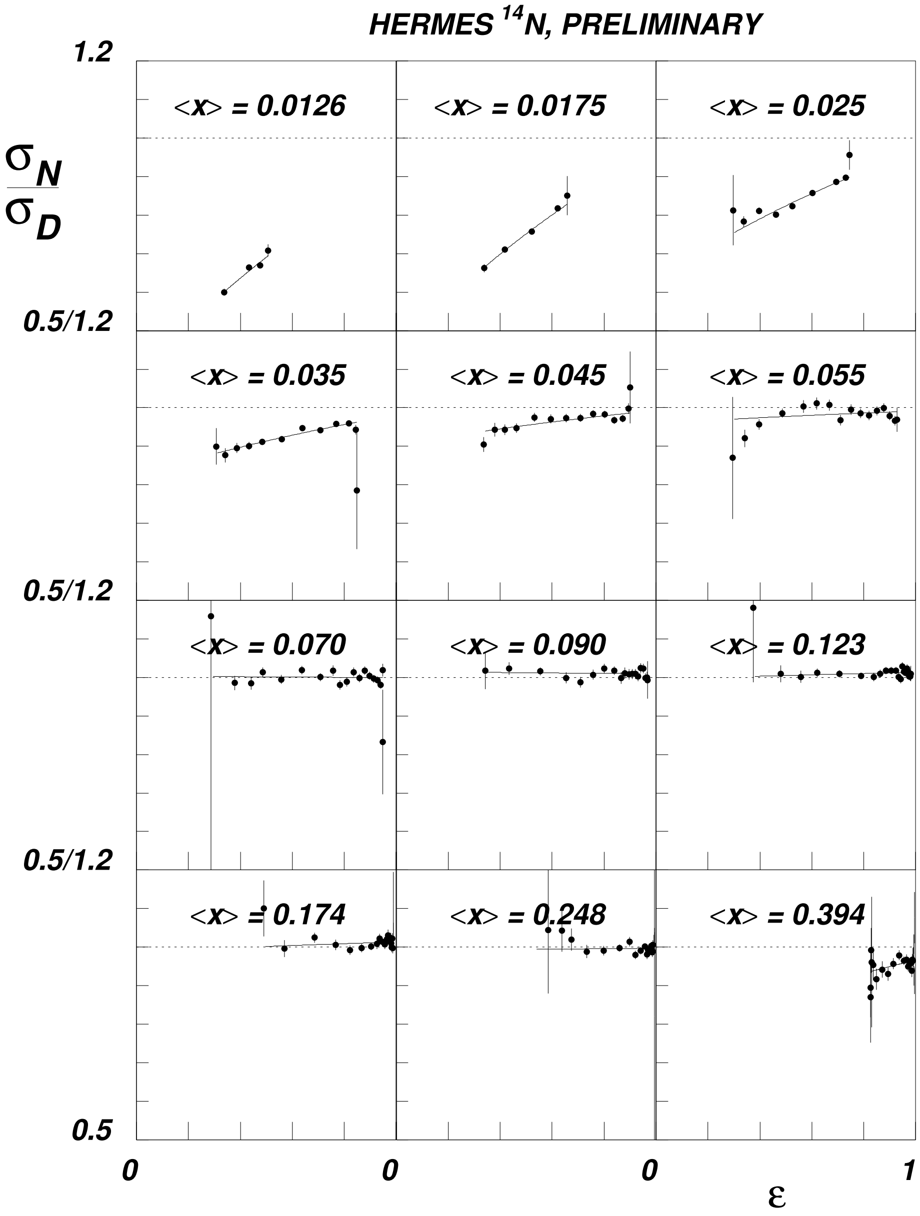
- Limiting conditions:
  - If $\epsilon \to 1$ then $\frac{\sigma_A}{\sigma_D} \to \frac{F_2^A}{F_2^D}$
  - If $R_A = R_D$ then $\frac{\sigma_A}{\sigma_D} = \frac{F_2^A}{F_2^D}$

- Fit R_A/R_D against experimental data:

HERMES: evidence for A-dependence of σ_L/σ_T?

ϵ Dependence

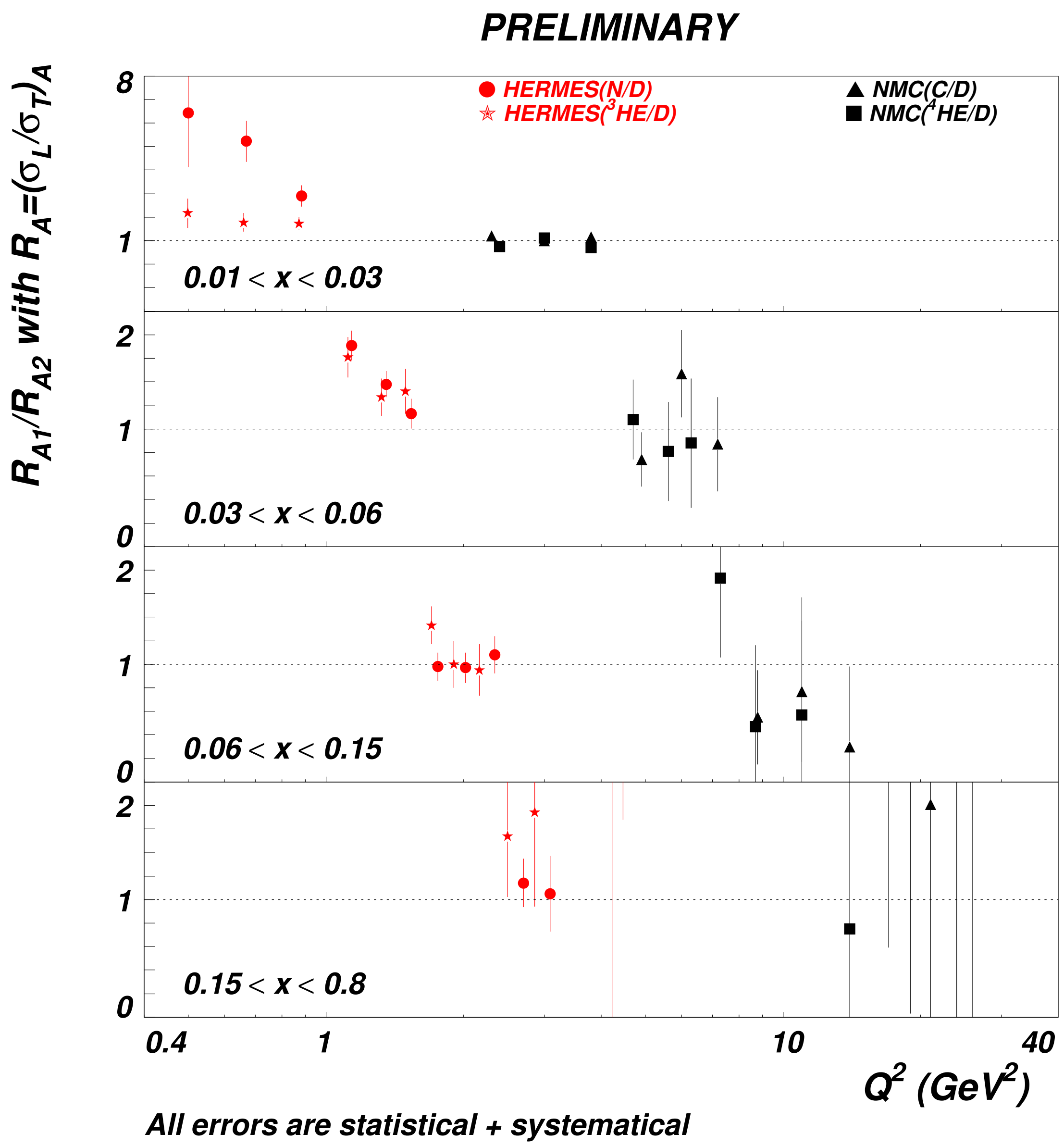
- ϵ-dependence of $\sigma_{^{14}N}/\sigma_{^2D}$:



- Two-parameter fit of the ϵ-dependence:
  - 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:

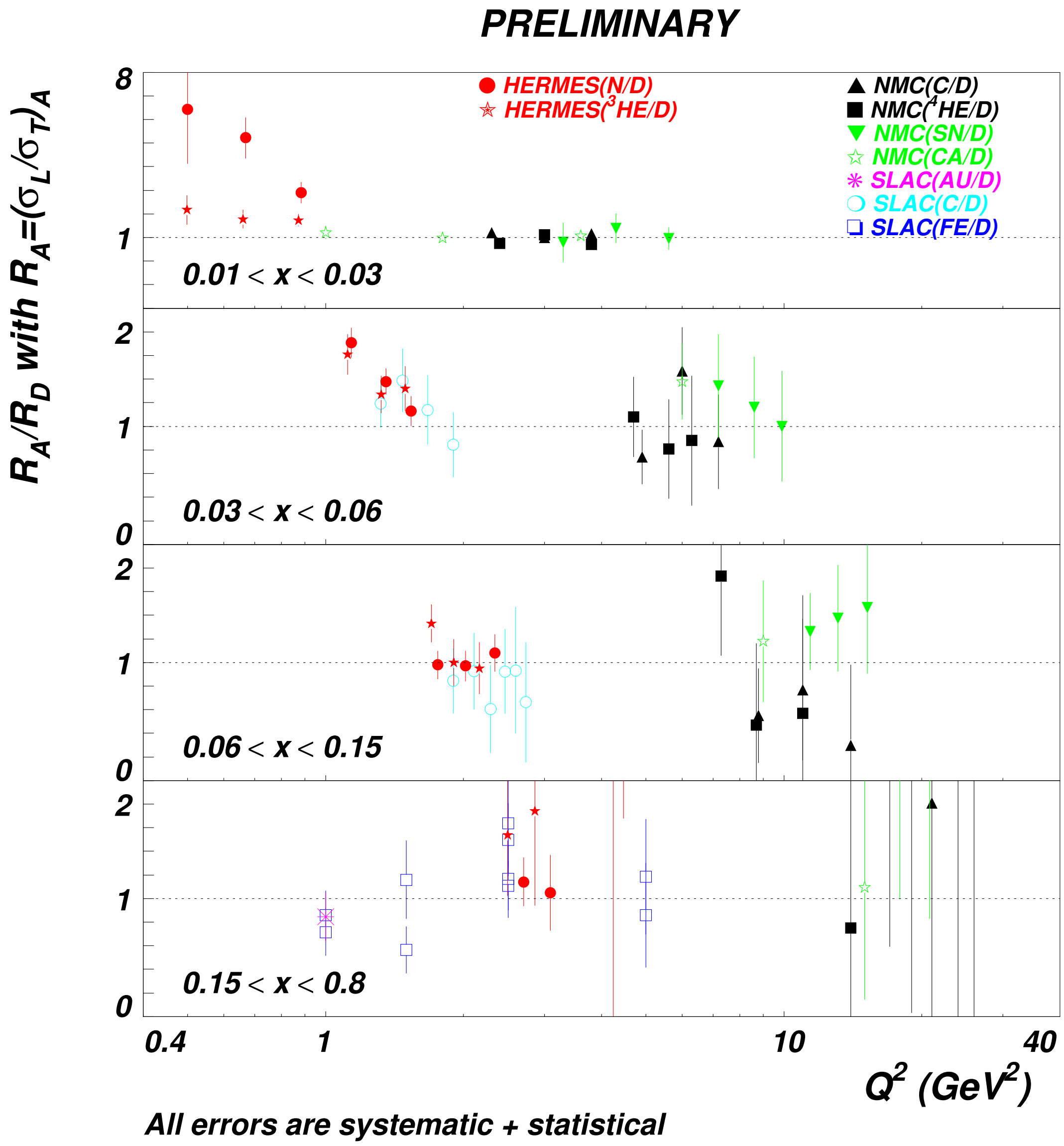


- Conclusion:

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

World Data on $\mathrm{R}_A = \sigma_L/\sigma_T$

- Comparison of HERMES data top existing data:



- Conclusion:

No inconsistency with existing data

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

Future

$\rightarrow$ 2000

- continue running with longitudinally $\overrightarrow{\mathrm{D}}$ target
- 1998/9 upgrades:
  - Kaon identification with RICH $\rightarrow$ probe strange sea
  - Charm Identification $\rightarrow$ probe gluon spin
  - Silicon Upgrade $\rightarrow$ enhanced acceptance for Λ
- end of 99:
  - precise knowledge of Δu_v, Δd_v, and $\Delta(\bar{u}+\bar{d})$
  - first direct measurement of Δs
  - confirmation of $\Delta G/G$ from charm production?

$>$ 2001

- transverse target program under study

Semi-inclusive measurements are the future of spin physics