RECENT SPIN PHYSICS RESULTS from HERMES

Armand Simon

(University of Freiburg)

hermes Collaboration

Outline

- ▷ Polarised DIS
- ▷ The HERMES experiment
- ▷ Double-Spin Asymmetries

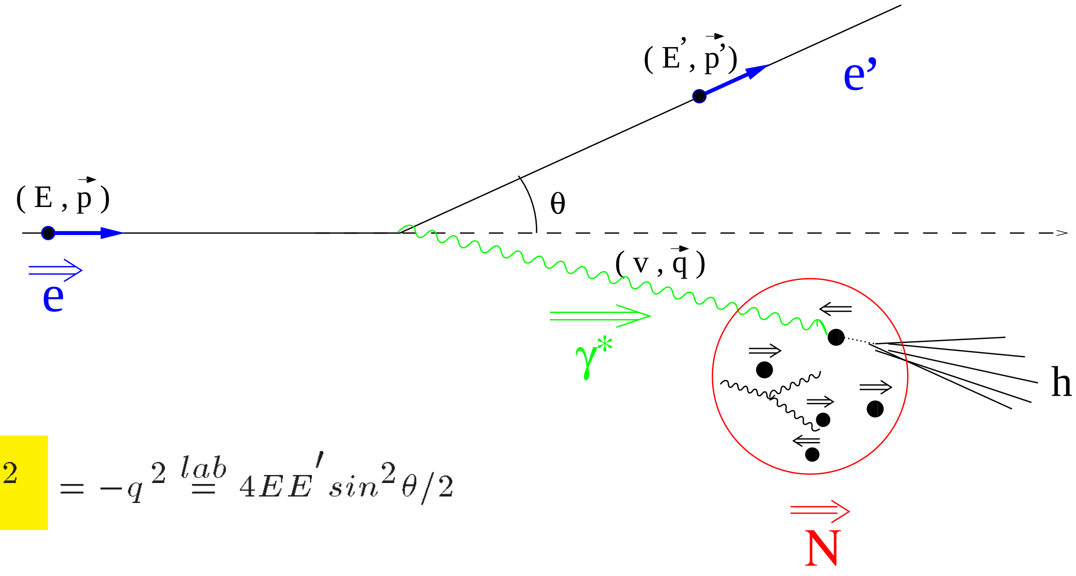
inclusive	$\Longrightarrow$	Polarised SF g_1
semi-incl. $h^{\pm}$	$\Longrightarrow$	Polarised PDF's $\Delta q_f(x)$
hight-p_t $h^{\pm}$	$\Longrightarrow$	Gluon Polarisation $\Delta G/G$
diffractive VM	$\Longrightarrow$	?

- ▷ Single-Spin Asymmetries

$\Longrightarrow$ other Polarised SF's & FF's

- ▷ Summary and outlook

Polarised DIS



$\boxed{Q^2} = -q^2 \overset{lab}{=} 4EE' sin^2\theta/2$

$\boxed{\nu} \overset{lab}{=} (E - E')$ $\boxed{y} \overset{lab}{=} \nu/E$

$\boxed{x} \overset{lab}{=} Q^2/2M\nu$

$\sim$ *quark momentum fraction*

$\boxed{z} \overset{lab}{=} E_h/\nu$

---

inclusive $\rightarrow$ **e'** **semi-inclusive** $\rightarrow$ **e' + h**

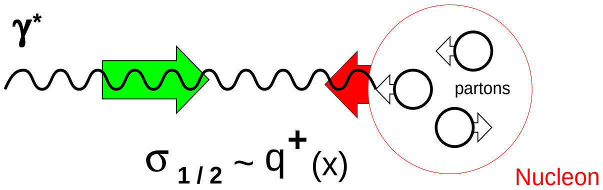
? How is the **Spin of the Nucleon** made up
by the **spin of its constituents** ?

$\rightarrow$ Helicity sum rule:

$$\boxed{< s_z > = 1/2 = 1/2\,(\Delta u + \Delta d + \Delta s) + L_q + \Delta G + L_G}$$

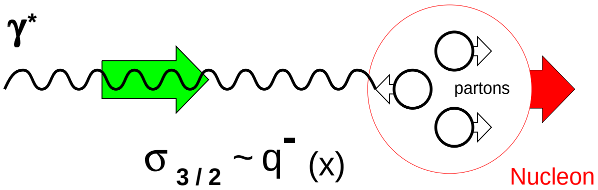
Polarised DIS in the QPM

polarised Photon (Spin 1) can only probe quarks with spin opposite to its own:



$$\vec{S_\gamma} + \vec{S_N} = 1/2$$

+ means: quark spin parallel to Nucleon spin



$$\vec{S_\gamma} + \vec{S_N} = 3/2$$

- means: quark spin opposite to Nucleon spin

$\Rightarrow$ flipping spin of target $\Rightarrow$ Quark Spin Distributions:

$$\boxed{\Delta q_f(x) := q_f^+(x) - q_f^-(x)}$$

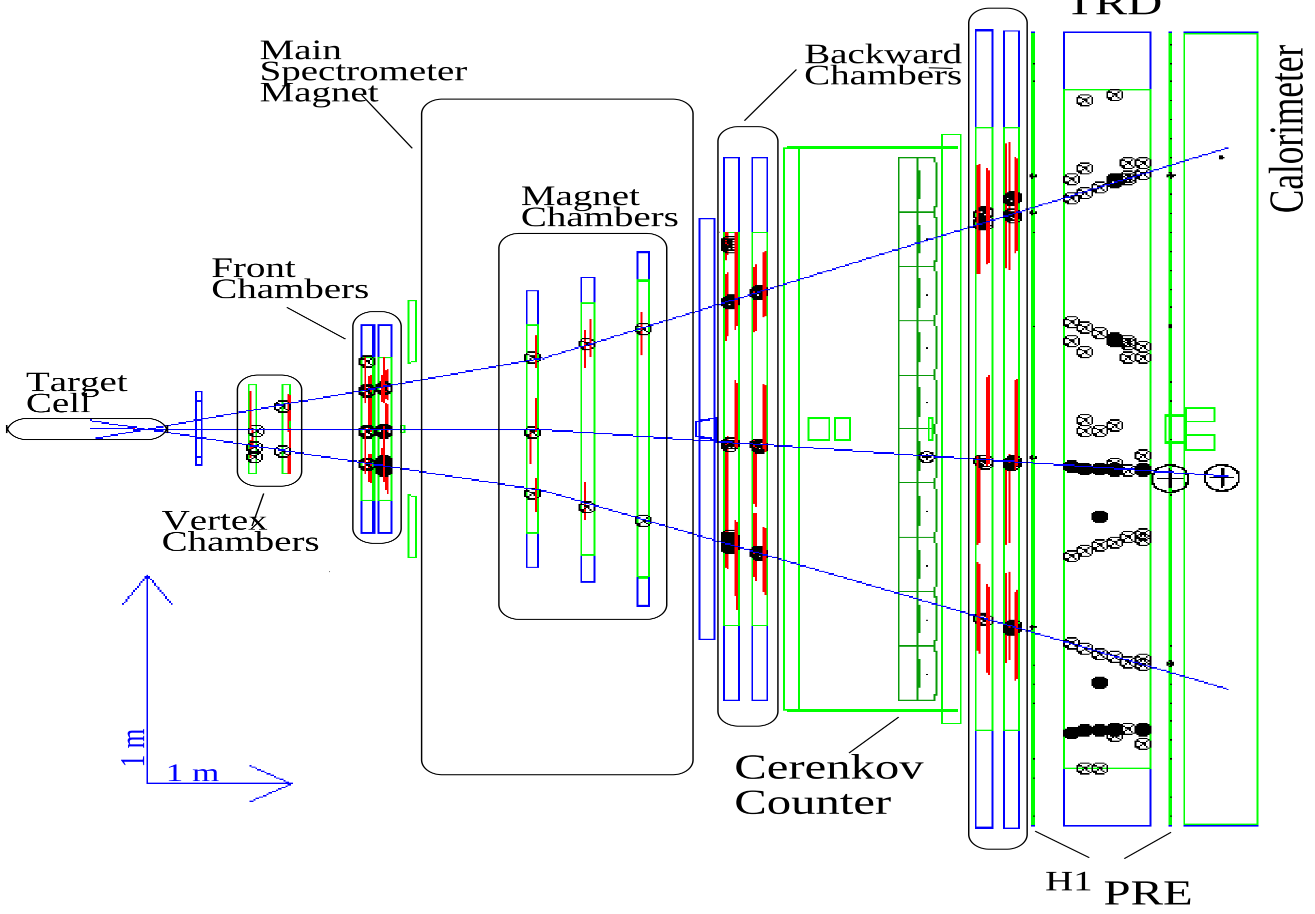
$$(f = u, d, s, \overline{u}, \overline{d}, \overline{s})$$

Virtual Photon Asymmetry ($\overset{\Rightarrow}{\gamma}$, $\overset{\Rightarrow}{\mathrm{N}}$)

$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \simeq \frac{g_1}{F_1} \underset{\substack{\uparrow \\ \text{QCD-QPM (LO)}}}{=} \frac{\sum_f e_f^2 \, \Delta q_f(x, Q^2)}{\sum_f e_f^2 \, q_f(x, Q^2)}$$

The HERMES Experiment

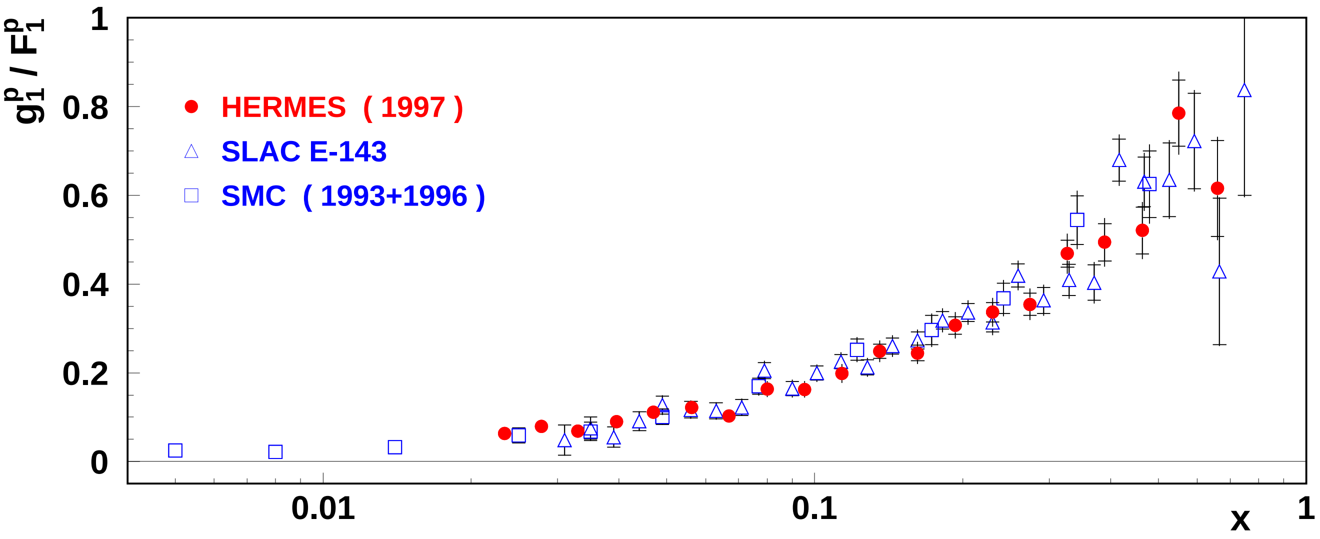
event display:
(topview)

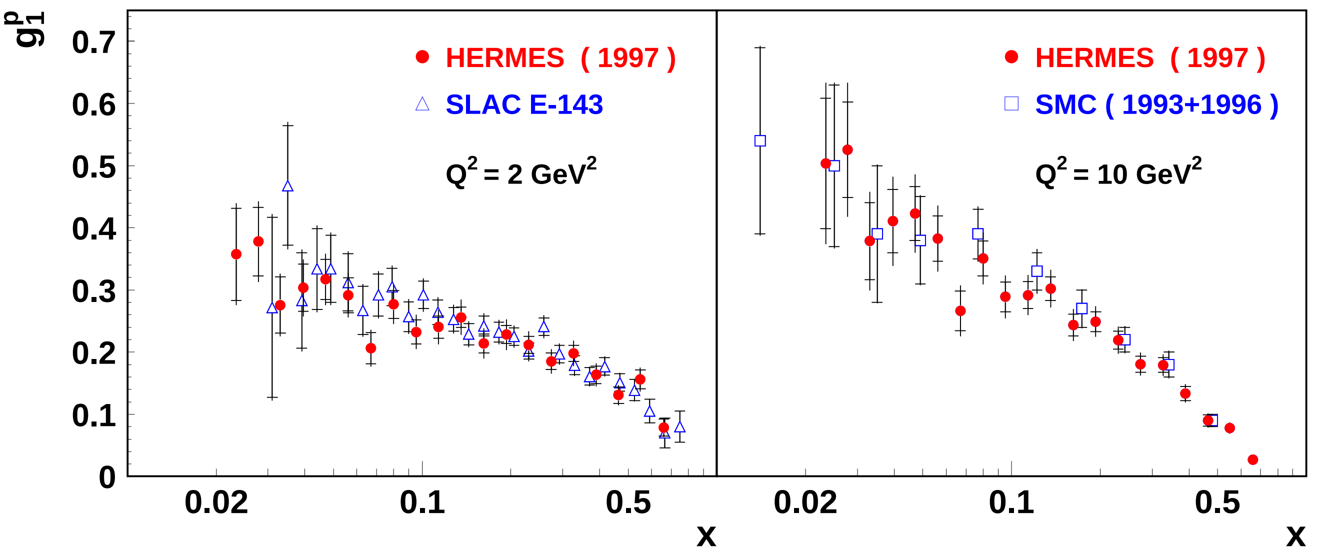


- 27.5 GeV longitudinally polarised e-beam $P_B \sim 0.55$
- Internal target $\Leftarrow$ longitudinally polarised *atoms*: $\vec{\mathrm{H}}, \vec{\mathrm{D}}, ^3\vec{\mathrm{He}}$
- forward spectrometer
- 4 PID detectors $\Rightarrow$ e - h separation

Proton Spin Structure Function $g_1^{\mathrm{p}}(x)$

$$A_1 \simeq g_1/F_1$$

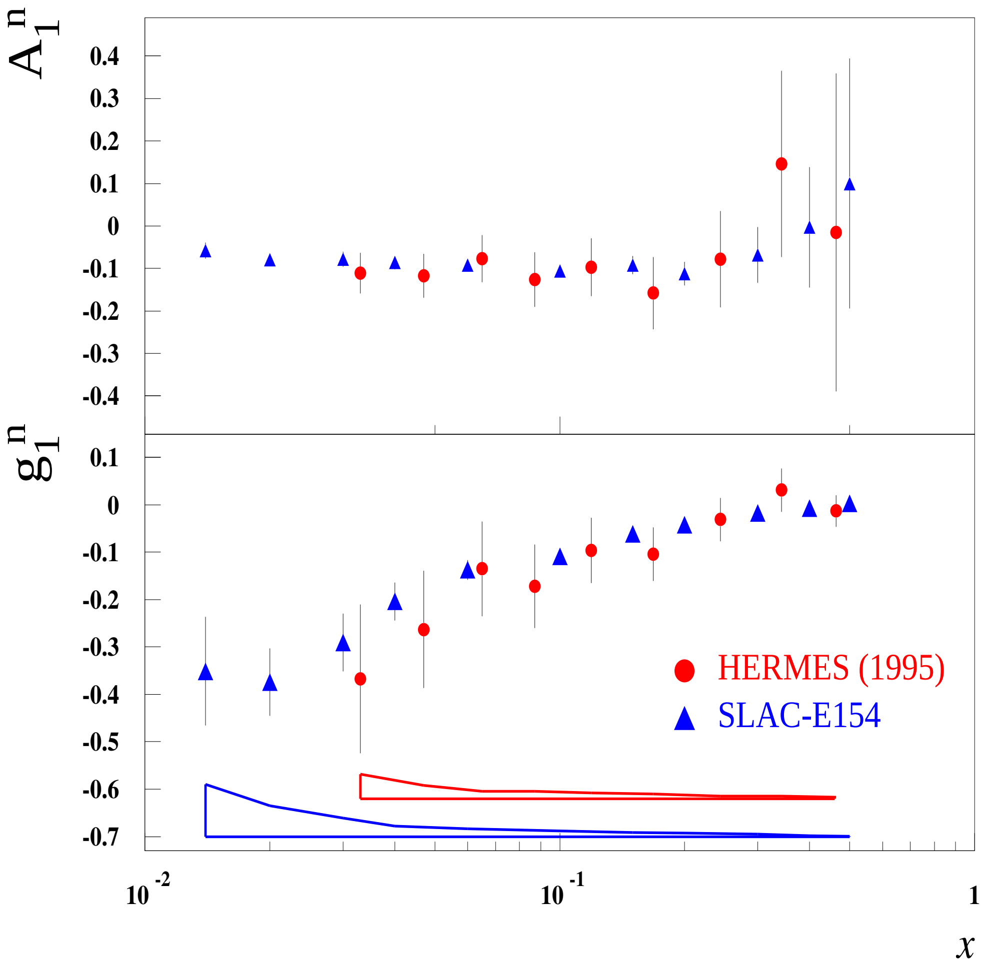




Neutron Spin Structure Function $g_1^{\mathrm{n}}(x)$

- from $^3\overrightarrow{\mathrm{He}}$ (SLAC E142/E154 , DESY HERMES)

$$A_1^{^3\mathrm{He}} \xrightarrow[\text{rad. \& nucl. corr.}]{} A_1^{\mathrm{n}} \longrightarrow g_1^{\mathrm{n}} \simeq A_1^{\mathrm{n}} \cdot F_1^{\mathrm{n}} = A_1^{\mathrm{n}} \cdot \frac{F_2^{\mathrm{n}}}{2x(1+R)}$$



- from "$\overrightarrow{\mathrm{D}}$-$\overrightarrow{\mathrm{H}}$" data (SLAC E143 , CERN SMC)

Semi-inclusive Asymmetries

QCD-QPM (LO) :

$$\boxed{A_1^{\mathrm{h}}(x,Q^2) \simeq \frac{g_1^{\mathrm{h}}(x,Q^2)}{F_1^{\mathrm{h}}(x,Q^2)} = \frac{\int dz \sum_f e_f^2 \, \Delta q_f(x,Q^2) \, D_f^{\mathrm{h}}(z,Q^2)}{\int dz \sum_f e_f^2 \, q_f(x,Q^2) \, D_f^{\mathrm{h}}(z,Q^2)}}$$

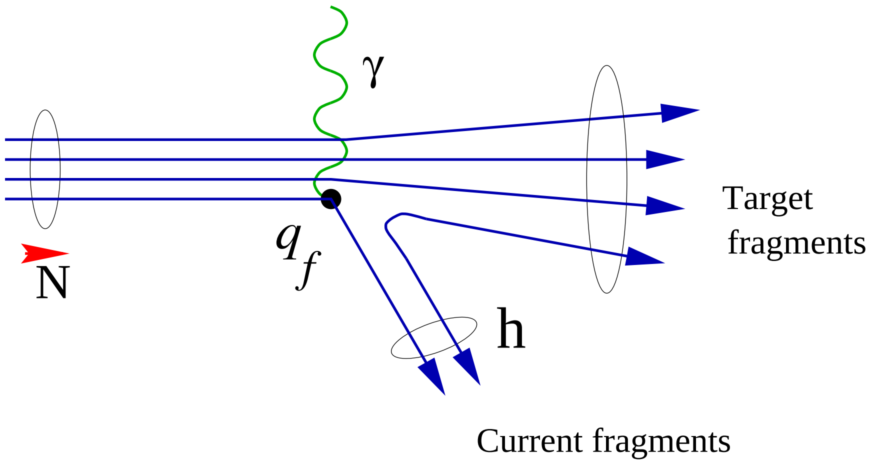
The fragmentation functions $D_f^{\mathrm{h}}(z)$ give the probability that the (struck) quark of flavour f fragments into a hadron of type h.

Assumptions:

- Factorisation (deep-inleastic scattering , hadronisation)
- Fragmentation functions *spin-independent*

$\rightsquigarrow$ $\boxed{\Delta q_f\text{'s}}$ using $q_f(x,Q^2)$ [parametr.] and $D_f^{\mathrm{h}}(z,Q^2)$ [Lund MC]

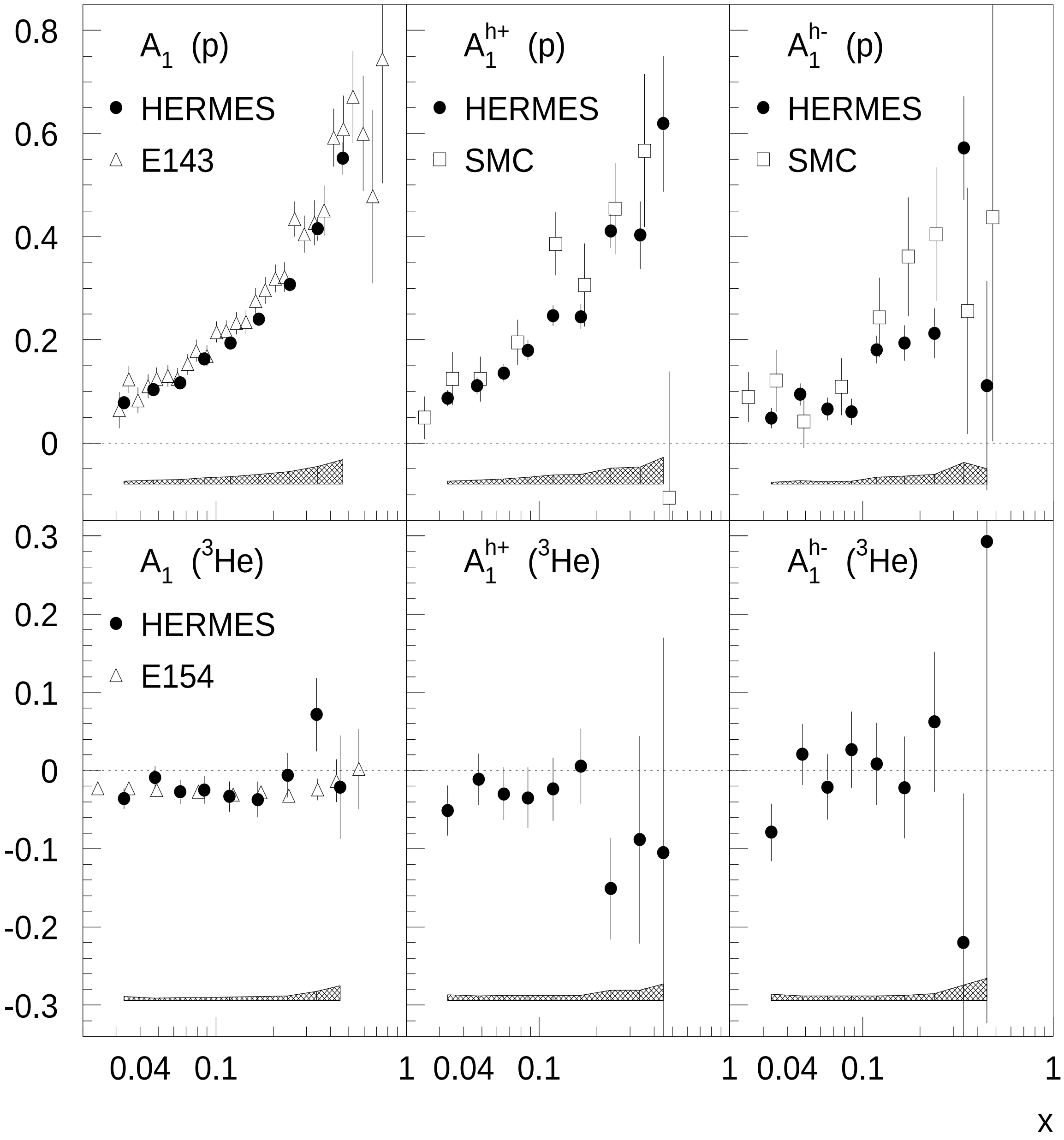
Precondition: Correlation (h , scattered q_f) $\longrightarrow$ 'Flavour - Tagging'



at HERMES : typ. $z > 0.2$, $x_F > 0.1$, $W^2 > 10$ GeV^2

Hadron Asymmetries

HERMES Data on $^3\overrightarrow{\mathrm{He}}$ (1995) and $\overrightarrow{\mathrm{H}}$ (1996+1997)

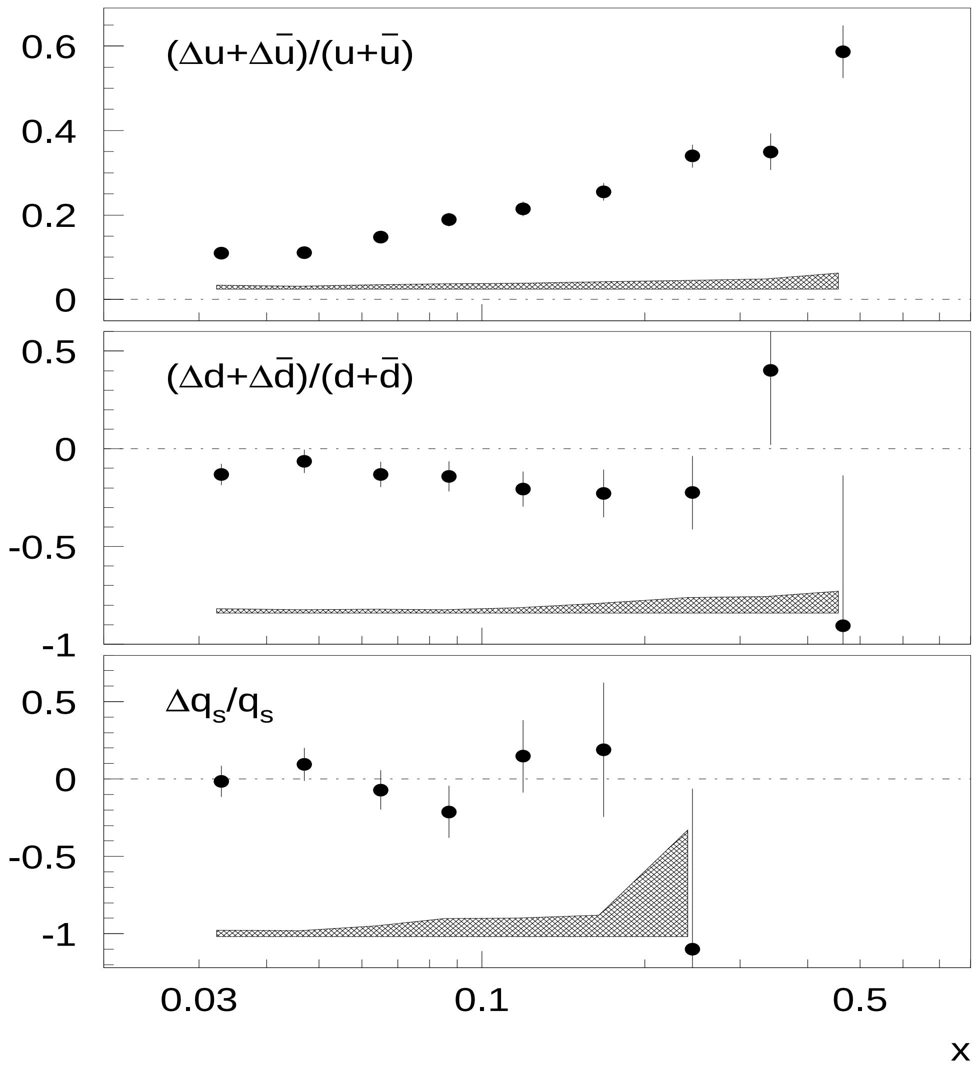


Polarised Quark Distributions

- *inclus.* and h$^{\pm}$ Asymmetries on $^3\overrightarrow{\mathrm{He}}$ (1995) and $\overrightarrow{\mathrm{H}}$ (1996+1997)
- Ass.: *flavour-independent* sea polarisation: $\frac{\Delta\overline{u}}{\overline{u}} = \frac{\Delta\overline{d}}{\overline{d}} = \frac{\Delta s}{s} \equiv \frac{\Delta q_{sea}}{q_{sea}}$

  (N.B. Results insensitive to specific sea assumption, e.g. equal Δq_{sea})

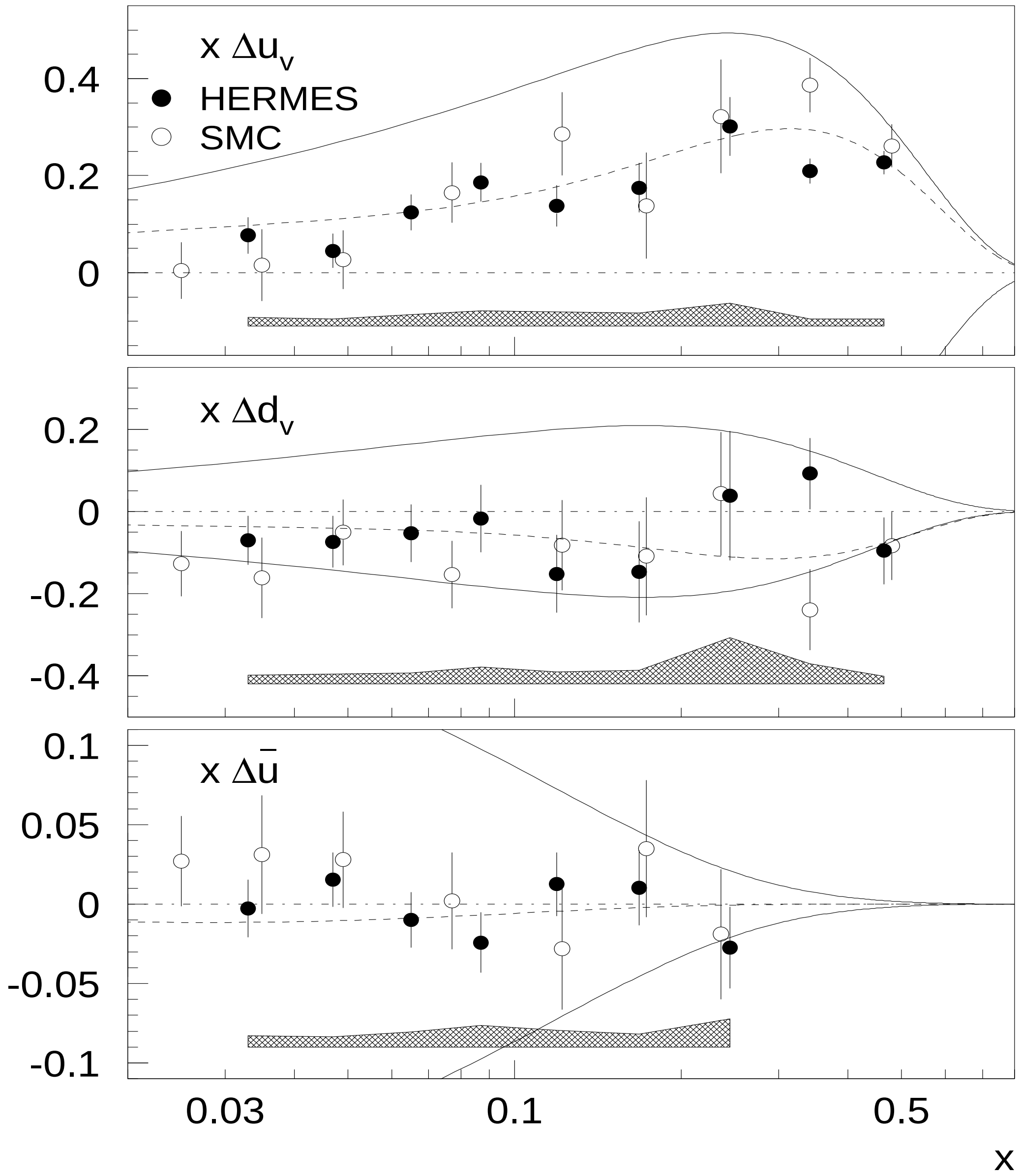
Flavour Decomposition:



Polarised Quark Distributions

Decomposition in valence and sea:

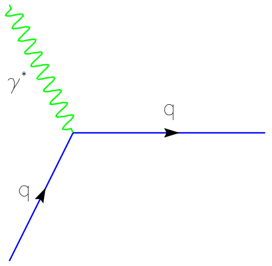
$Q^2 = 2.5\ \mathrm{GeV}^2$



Spin asymmetries of high-p_T h$^{\pm}$ pairs

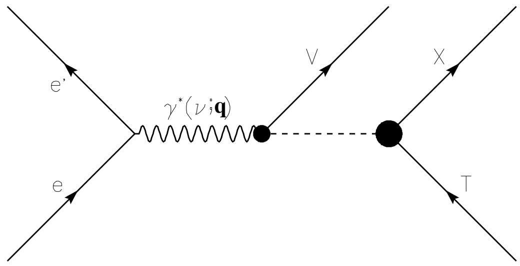
Motivation

From the potential processes contributing (in LO QCD) to high-p_T h$^{\pm}$ pair production:



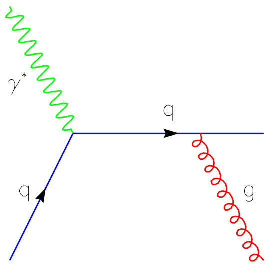
DIS

negligible contribution



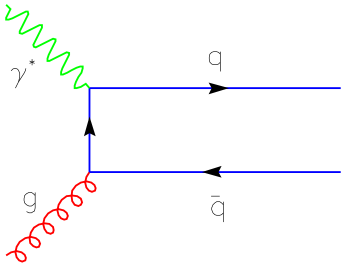
VMD

assume $A_{\mathrm{VMD}} = 0$



QCDC

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



PGF

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

the **spin asymmetry** of the **PGF process** is sensitive to the

gluon polarisation!

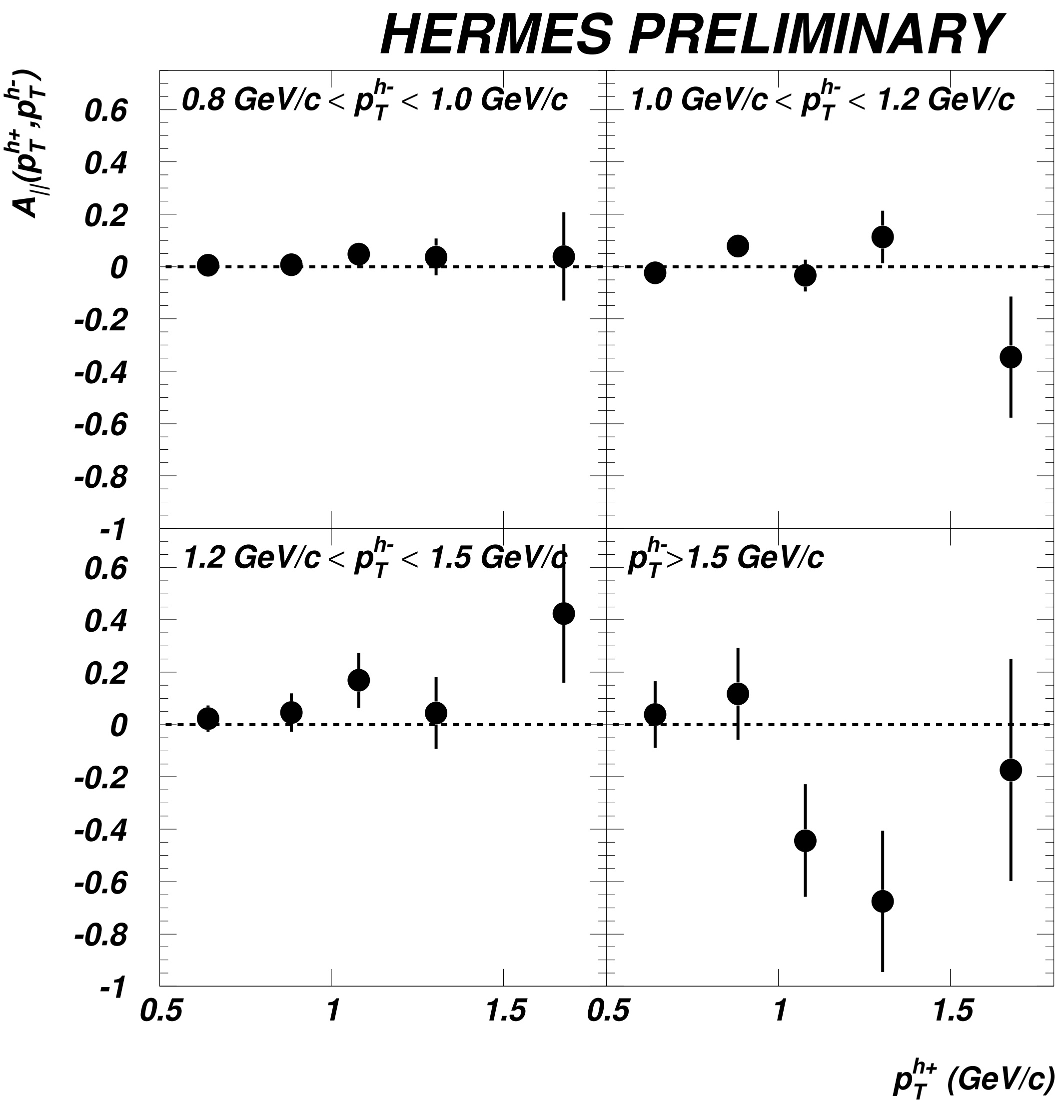
$\rightsquigarrow$ $\boxed{\frac{\Delta G}{G}}$ in kinematic region where PGF dominates
+ knowledge of relative contributions from the other processes

N.B: Possible contribution from **anomalous photon** neglected, expected to be small at these energies.

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

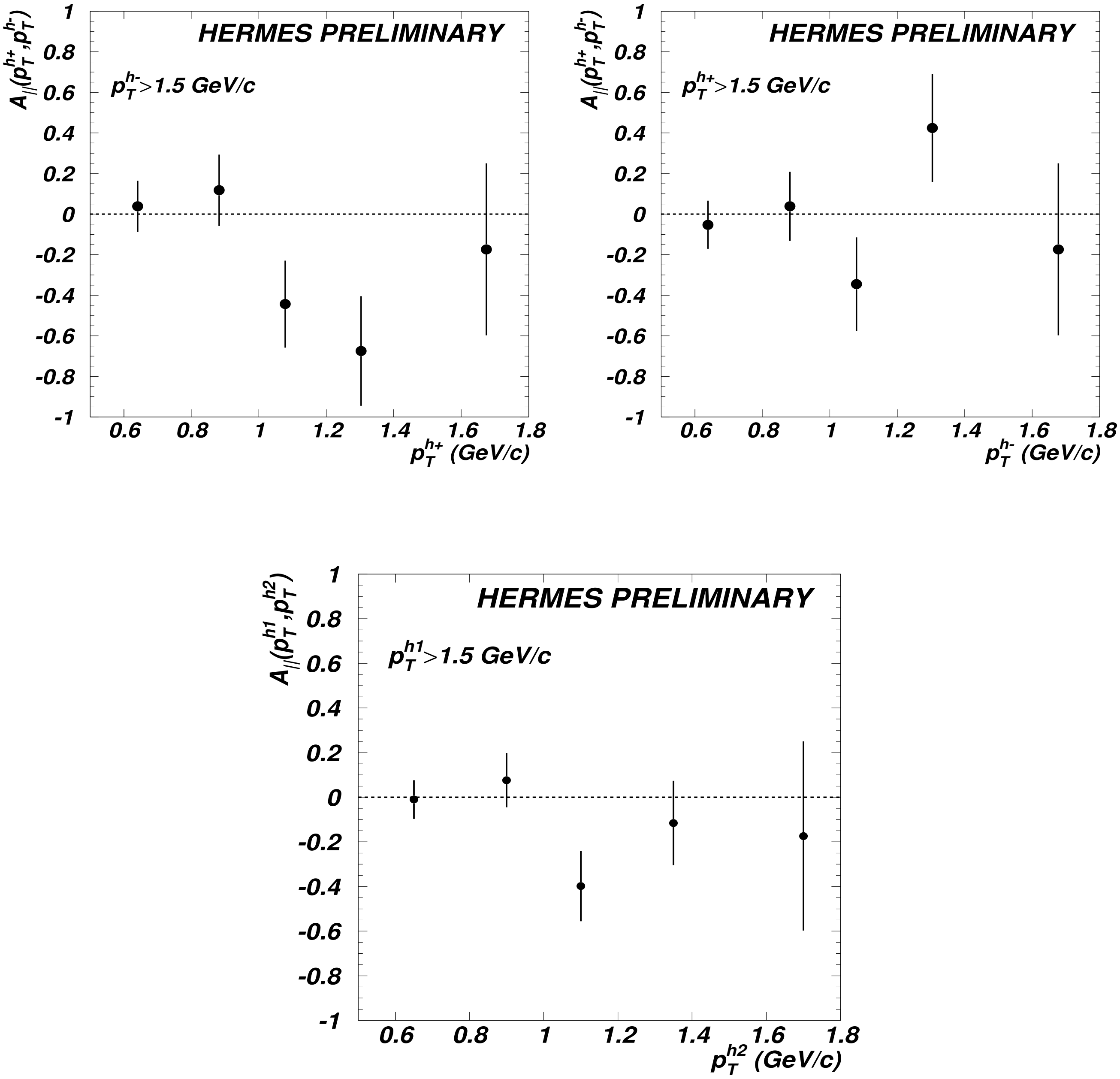
No scattered e^+ required $\Rightarrow$ mostly photoproduction $(Q^2 \simeq 0)$

$\overrightarrow{\mathrm{H}}$ data (1996+1997)



systematic error $\approx$ 8 % of measurement

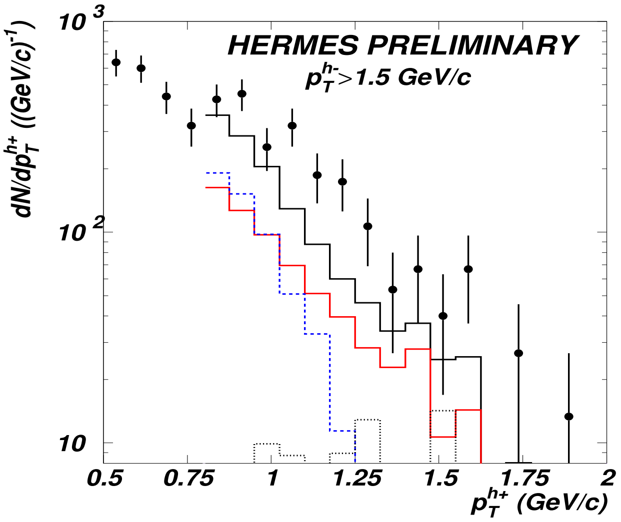
Measured asymmetry $A_{||}(p_T^{h^+}\, p_T^{h^-})$

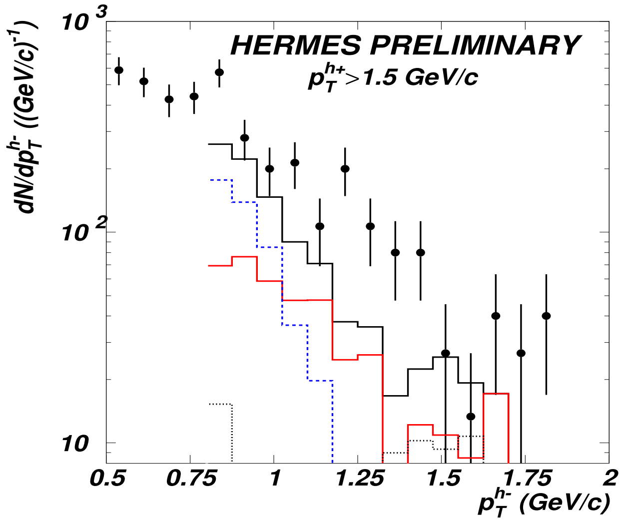


systematic error $\approx$ 8 % of measurement

Interpretation using PYTHIA model

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



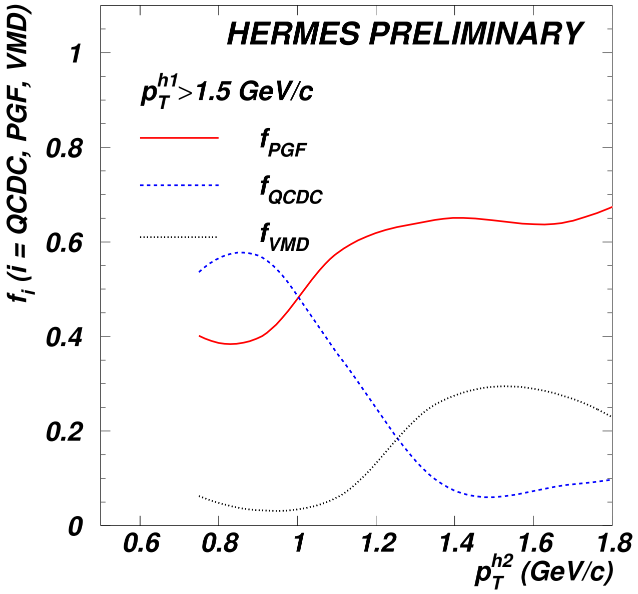


black = total yield | red = PGF | blue = QCDC | dotted black = VMD

unpolarised model

$\rightarrow$ process fractions f_i:

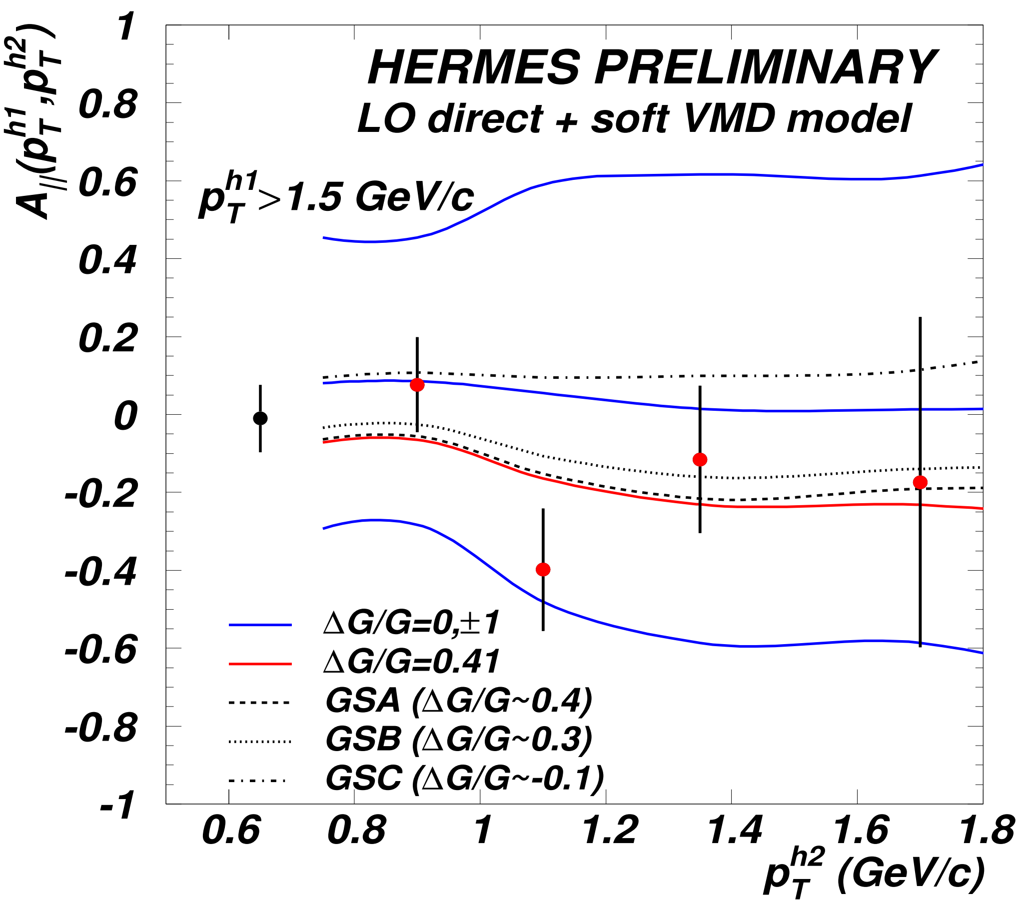
$\Rightarrow$ The **negative** asymmetry is observed where **PGF** is expected to **dominate!**



Result using PYTHIA model

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

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

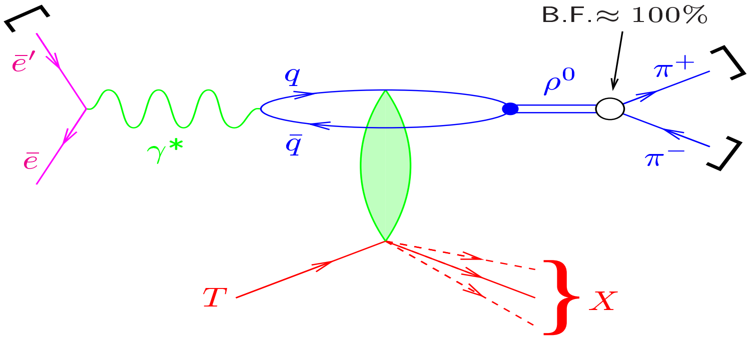


Unknown theoretical uncertainty from contribution and spin asymmetry of anomalous photon and NLO QCD corrections.

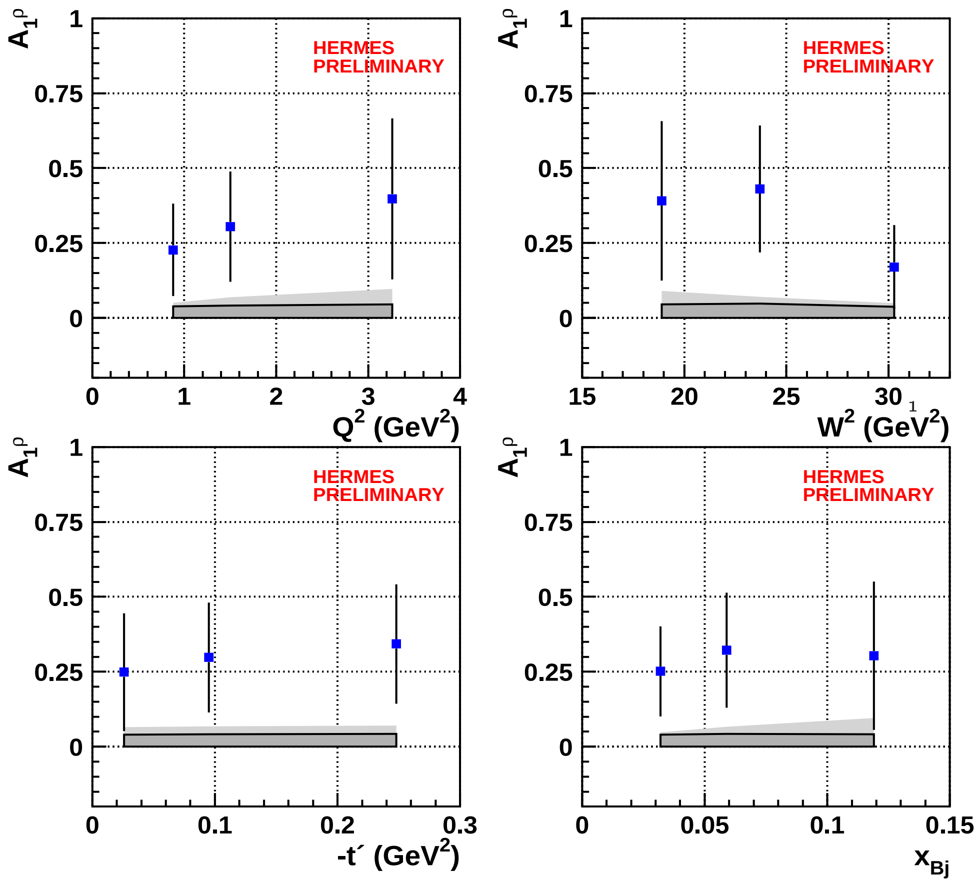
If only a dilution $\Longrightarrow$ value of $\Delta G/G$ will increase but significance of deviation from zero will not change.

Spin asymmetries in diffractive VM production

Naive expectation: no spin dependence



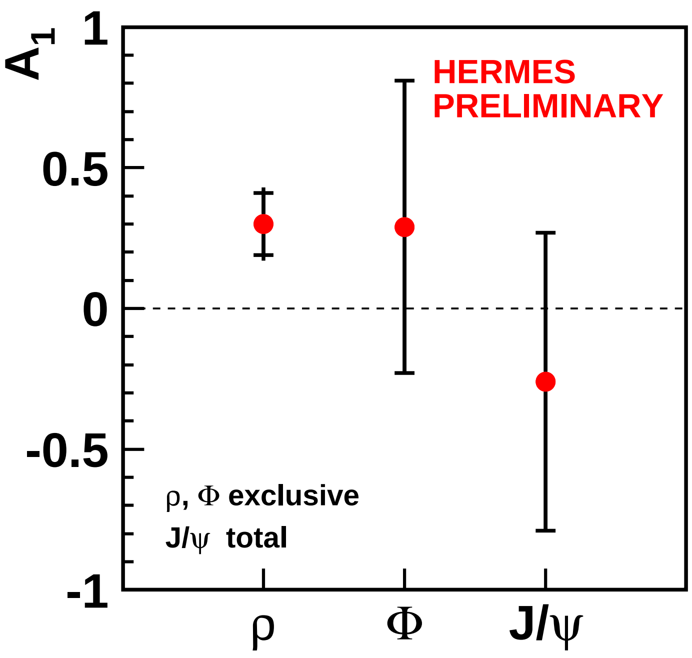
Spin asymmetry for ρ^0:



Spin Asymmetries in diffractive VM production

Spin asymmetries for

$$\rho^0 \rightarrow \pi^+\pi^- \qquad \phi \rightarrow K^+K^-$$
$$J/\psi \rightarrow e^+e^- \qquad J/\psi \rightarrow \mu^+\mu^-$$

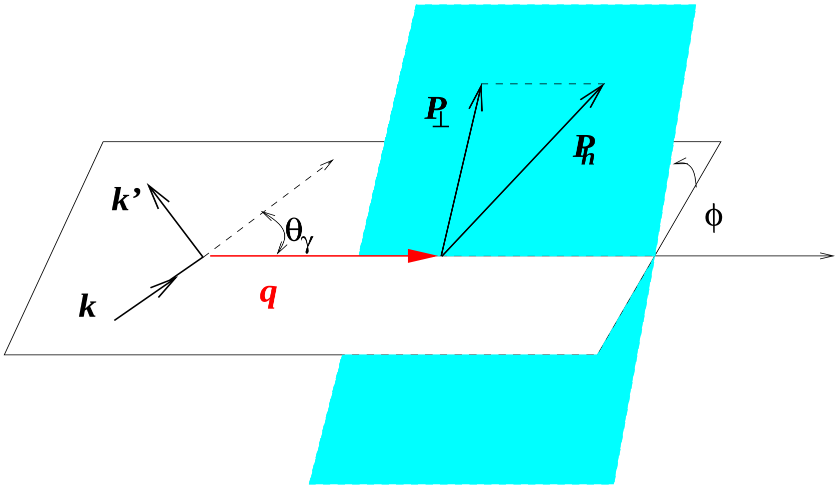


$\Rightarrow$ ρ^0: 2.4 σ non-zero spin asymmetry
($< W > \sim 5$ GeV, Q^2 typ. 0.5 .. 5 GeV^2)

.. not observed by SMC
($< W > \sim 15$ GeV, Q^2 typ. 0.01 .. few 10 GeV^2)

$\Rightarrow$ $\phi, J/\Psi$: no significant spin asymmetry

Single Spin Asymmetries



Goal:

measure azimuthal moments $(\sin\phi, \cos\phi, \ldots)$ of asymmetries with respect to:

spin of
- beam
- target
- final-state hadron

which can be
- un-
- longitudinally
- transversely

polarized

$\Longrightarrow$ Access to new SF's and FF's extending the description by F_1, g_1, h_1 and D_1
(recent theoretical work on classification)

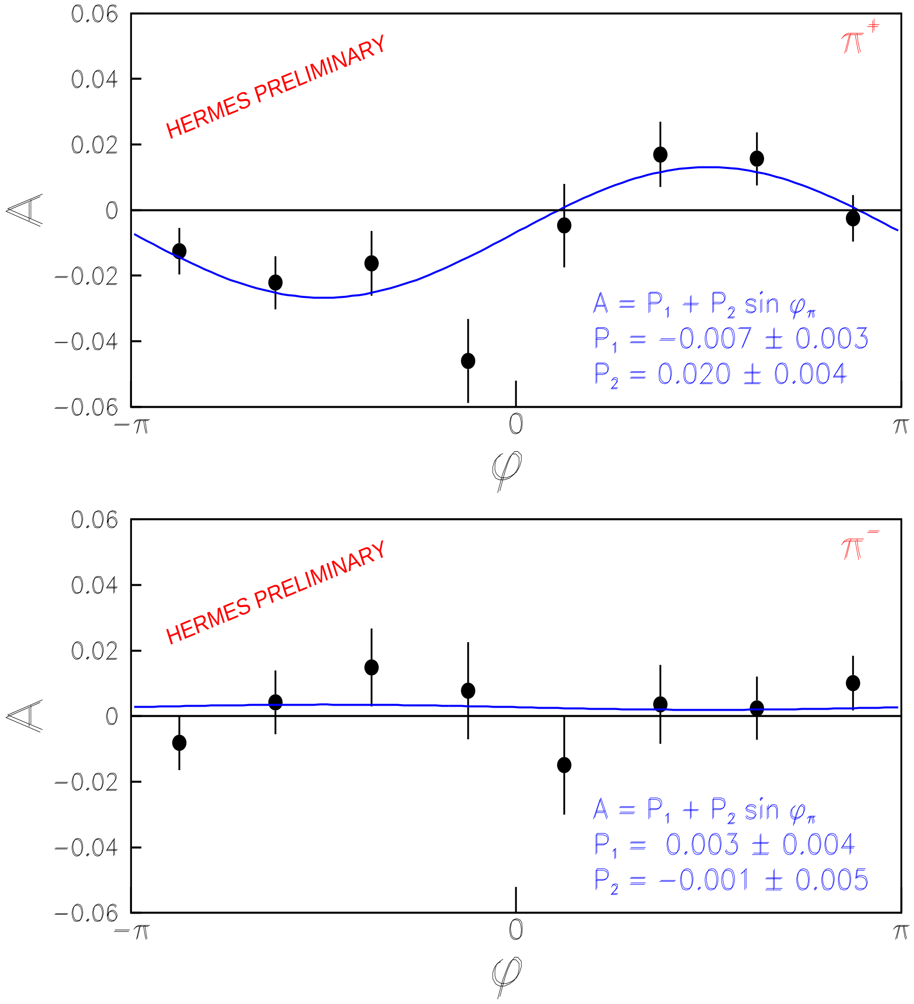
$\Longrightarrow$ View on the structure of the nucleon beyond the naive model of colinear, non-interacting quarks
(k_t , correlations, ..)

Spin-Azimuthal Asymmetries

Longitudinal target spin asymmetry:

$$A(\phi) = \frac{1}{P_T} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

$\vec{\mathrm{H}}$ data (1996+1997)



Non-zero asymmetries $\rightsquigarrow$ T-odd effects in the fragmentation

Outlook

1998/1999/2000

main physics goals

Longitudinally $\overrightarrow{\mathrm{D}}$ target
with additional upgrades:

$\Delta d_V(x)$, $\Delta u_V(x)$

- identification of π , K , p
  over full kinematic range
  (Dual-radiator RICH)

$\Delta s(x)$, $\Delta\overline{u}(x)$,
$\Delta\overline{d}(x)$

- sensitivity to open charm
  $(D^O \to K\pi, D \to K\mu X)$
  and enhanced sensitivity to
  $J/\Psi \to \mu^+\mu^-, (e^+e^-)$
  (RICH + instrumented Fe-wall)

$\frac{\Delta G}{G}(x_G \sim .3)$

- enhanced sensitivity to Λ

polarisation transfer

$>$ **2000**

Transversely polarised target?

"Semi-inclusive measurements are the future of spin physics"