Measurement of Polarised Quark Distributions in the Nucleon at hermes

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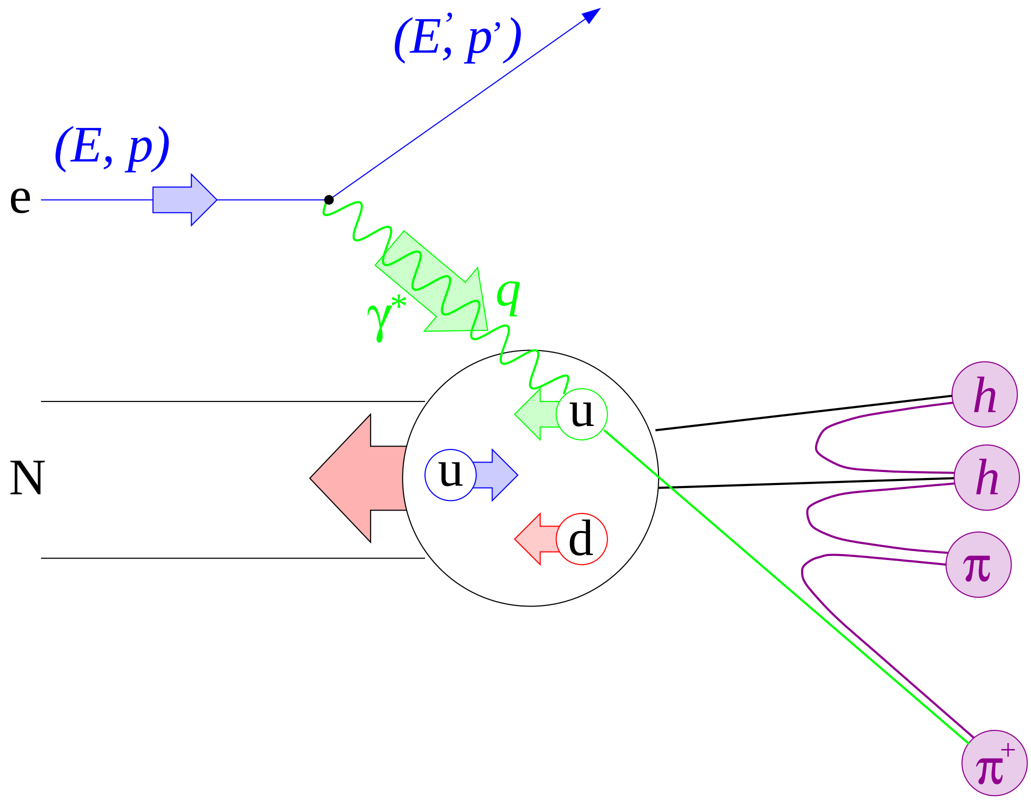
Outline:

- Polarised Semi Inclusive DIS
- The HERMES Experiment
- Semi Inclusive Asymmetries
- $\Delta\,q$ Extraction
- Results
  - Quark Polarisation in Flavour Decomposition
  - Polarised Valence and Sea Quark Distributions

Polarised Semi Inclusive DIS

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

- Inclusive: $e + N \rightarrow e' \quad + X$
- Semi-Inclusive: $e + N \rightarrow e' + h + X$

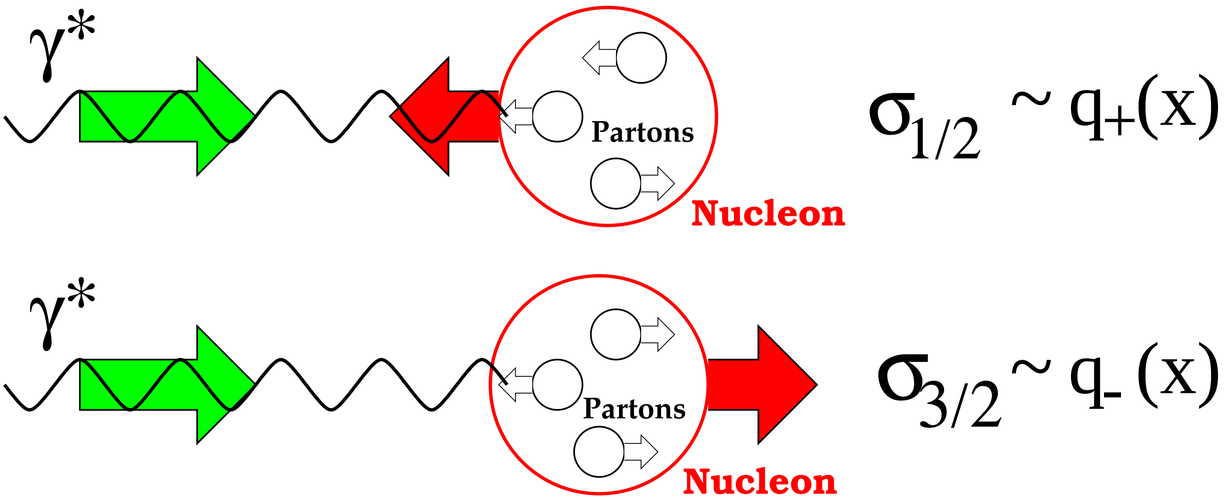


- Select hadrons from the current fragmentation region by cuts on

$$
\begin{aligned}
z &= E_h/\nu \geq 0.2 \\
x_F &= 2p_{||}/W \geq 0.1
\end{aligned}
$$

Virtual Photon Asymmetry A_1

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



Flipping of target
$\Rightarrow$ Quark Spin Distributions $\Delta q_f(x)$:

$$\Delta q_f(x) \; := \; q_f^+(x) - q_f^-(x)$$

with $f \; = u, \; d, \; s, \; \bar{u}, \; \bar{d}, \; \bar{s}$

A_1 relates to the nucleon structure functions:

$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{g_1 - \gamma^2 g_2}{F_1} \approx \frac{g_1}{F_1} = \frac{\sum_f e_f^2 \, \Delta q_f(x)}{\sum_f e_f^2 \, q_f(x)}$$

Experimental Determination of A_1^h

In LO QCD

$$A_1^h(x,Q^2) = \mathcal{C} \cdot \frac{\sum_f e_f^2 \, \Delta q_f(x,Q^2) \, \int_{z_{min}}^1 dz \, D_f^h(z,Q^2)}{\sum_f e_f^2 \, q_f(x,Q^2) \, \int_{z_{min}}^1 dz \, D_f^h(z,Q^2)}$$

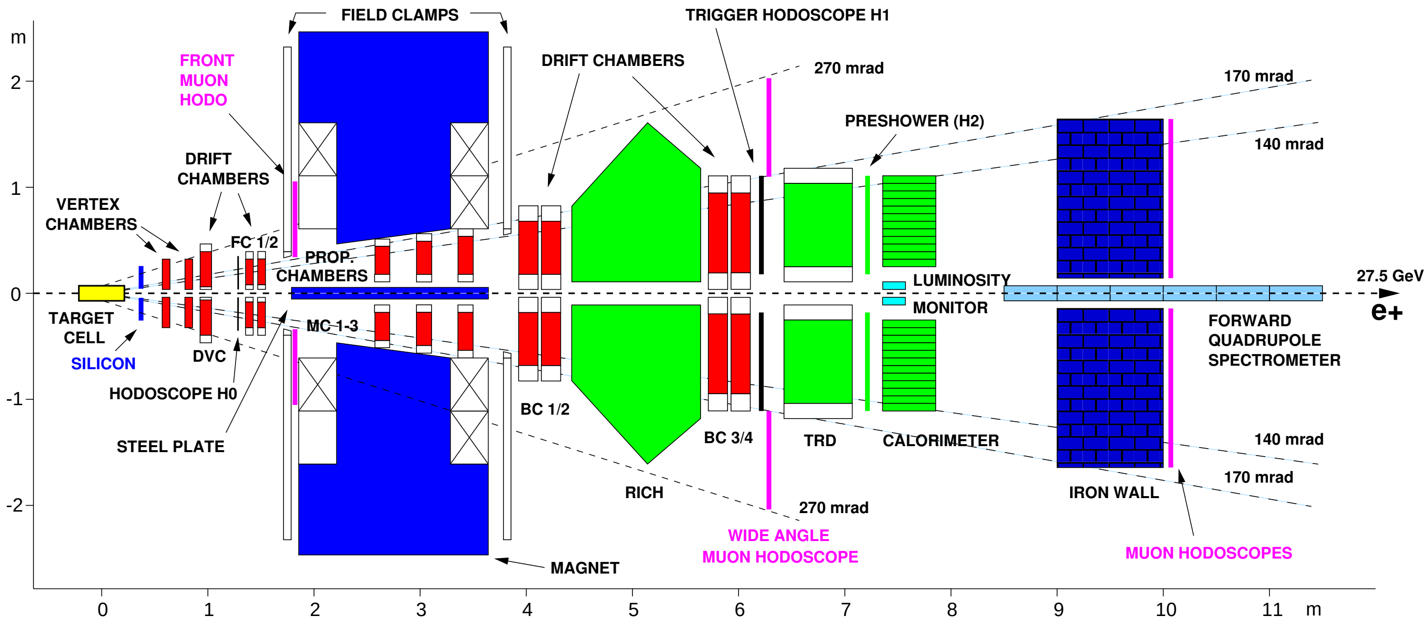
$(\Delta\, q_f)\; q_f$	:	(Polarised) quark distributions,
$D_f^h(z,Q^2)$	:	Fragmentation functions
$\mathcal{C}$	:	$\frac{1+R(x,Q^2)}{1+\gamma^2}$

Assuming g_2 = 0:
The virtual photon nucleon asymmetry A_1^h is related to the *measured lepton nucleon asymmetry* $A_{\|}^h$ by

$$A_1^h = \frac{A_{\|}^h}{D\,(1+\eta\gamma)}$$

D: Virtual photon depolarisation factor

The HERMES Experiment



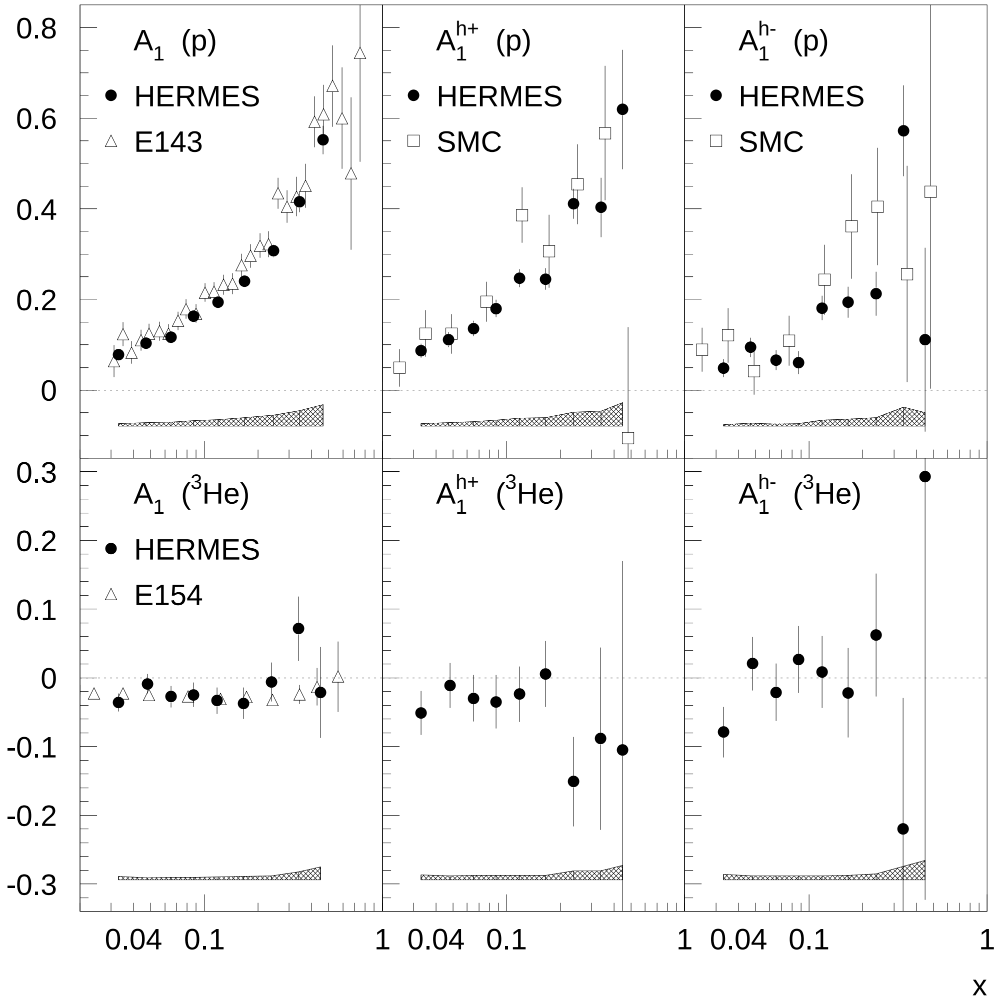
- Threshold Čerenkov detector replaced by a RICH detector in 1998.

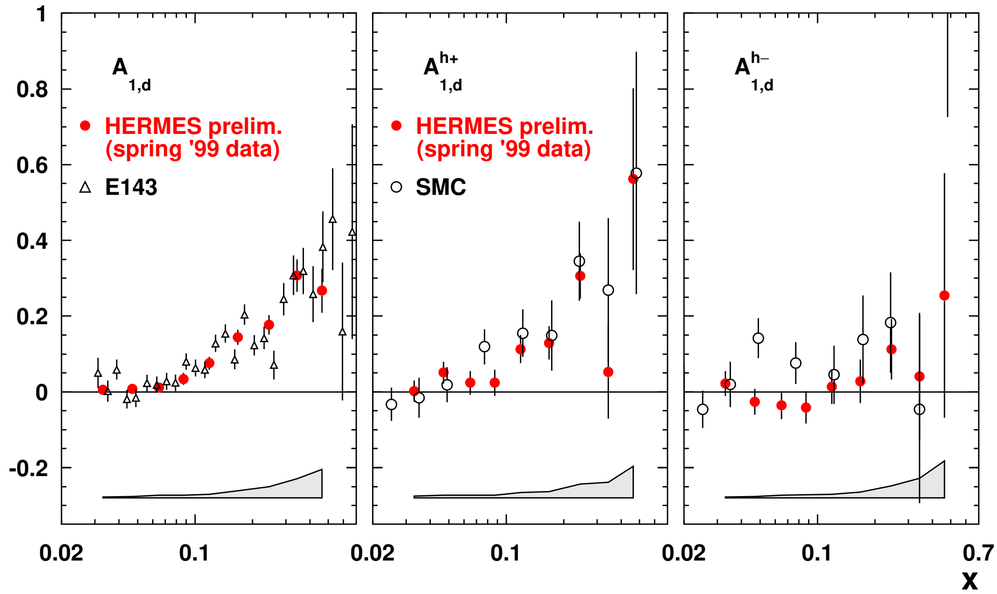
- Lepton identification with average efficiency of 98% and hadron contamination of $\leq$ 1%.

HERMES polarised data taking programme:

Year	'95	'96 - '97	'98 - Spring '99	'99 - '00
Target	$^3\vec{\mathrm{He}}$	$\vec{\mathrm{H}}$	$\vec{\mathrm{D}}$	
DIS ($\times 10^6$)	2.2	2.2	1.0	7.0

Semi inclusive Asymmetries





Inclusive and semi inclusive asymmetries on $^3\vec{\mathrm{He}}$, $\vec{\mathrm{H}}$ and $\vec{\mathrm{D}}$ targets. Data shown at mean measured Q^2 in each bin.

$\Delta\, q$-Extraction

- Rewrite Photon-Nucleon asymmetry

$$A_1^h(x) = \mathcal{C} \cdot \sum_f \underbrace{\frac{e_f^2\; q_f(x) \int \mathrm{d}z\, D_f^h(z)}{\sum_{f'} e_{f'}^2\; q_{f'}(x)\ \int \mathrm{d}z\, D_{q_{f'}}^h(z)}}_{\equiv\, \mathcal{P}_f^h(x)} \cdot \frac{\Delta q_f(x)}{q_f(x)}$$

- *Purity* $P_f^h(x)$ gives probability that a hadron $h(z)$ originates from an event with struck quark f.

- Define

$$\vec{A} = \begin{pmatrix} A_1^{h_1}(x) \\ \ldots \\ A_1^{h_m}(x) \end{pmatrix}, \quad \vec{Q} = \begin{pmatrix} \Delta q_1(x)/q_1(x) \\ \ldots \\ \Delta q_n(x)/q_n(x) \end{pmatrix}, \quad \mathcal{P} = \mathcal{C} \cdot \left[P_f^h(x)\right]$$

- To extract quark polarisations solve

$$\vec{A} = \mathcal{P} \cdot \vec{Q}$$

In Particular...

- Use inclusive and $h^{\pm}$ asymmetries only
- Assume: Symmetric sea polarisation

$$\frac{\Delta q_s(x)}{q_s(x)} \equiv \frac{\Delta u_s(x)}{u_s(x)} = \ldots = \frac{\Delta \bar{s}(x)}{\bar{s}(x)}$$

Two different schemes for the decomposition:

- Flavour Decomposition (FDC)

$$\vec{Q}_{\mathrm{FDC}} = \left(\frac{\Delta u(x) + \Delta \bar{u}(x)}{u(x) + \bar{u}(x)}, \frac{\Delta d(x) + \Delta \bar{d}(x)}{d(x) + \bar{d}(x)}, \frac{\Delta s(x)}{s(x)} \right)$$

- Valence Decomposition (VDC)

$$\vec{Q}_{\mathrm{VDC}} = \left(\frac{\Delta u(x) - \Delta \bar{u}(x)}{u(x) - \bar{u}(x)}, \frac{\Delta d(x) - \Delta \bar{d}(x)}{d(x) - \bar{d}(x)}, \frac{\Delta q_s(x)}{q_s(x)} \right)$$

χ^2-minim. of the overconstrained SoE:

$$\vec{A}_{\text{meas}} = \mathcal{P}_{\mathrm{FDC}} \cdot \vec{Q}_{\mathrm{FDC}}$$

- $\mathcal{P}_{\mathrm{FDC}}$ is an effective purity matrix
- Analogous for VDC

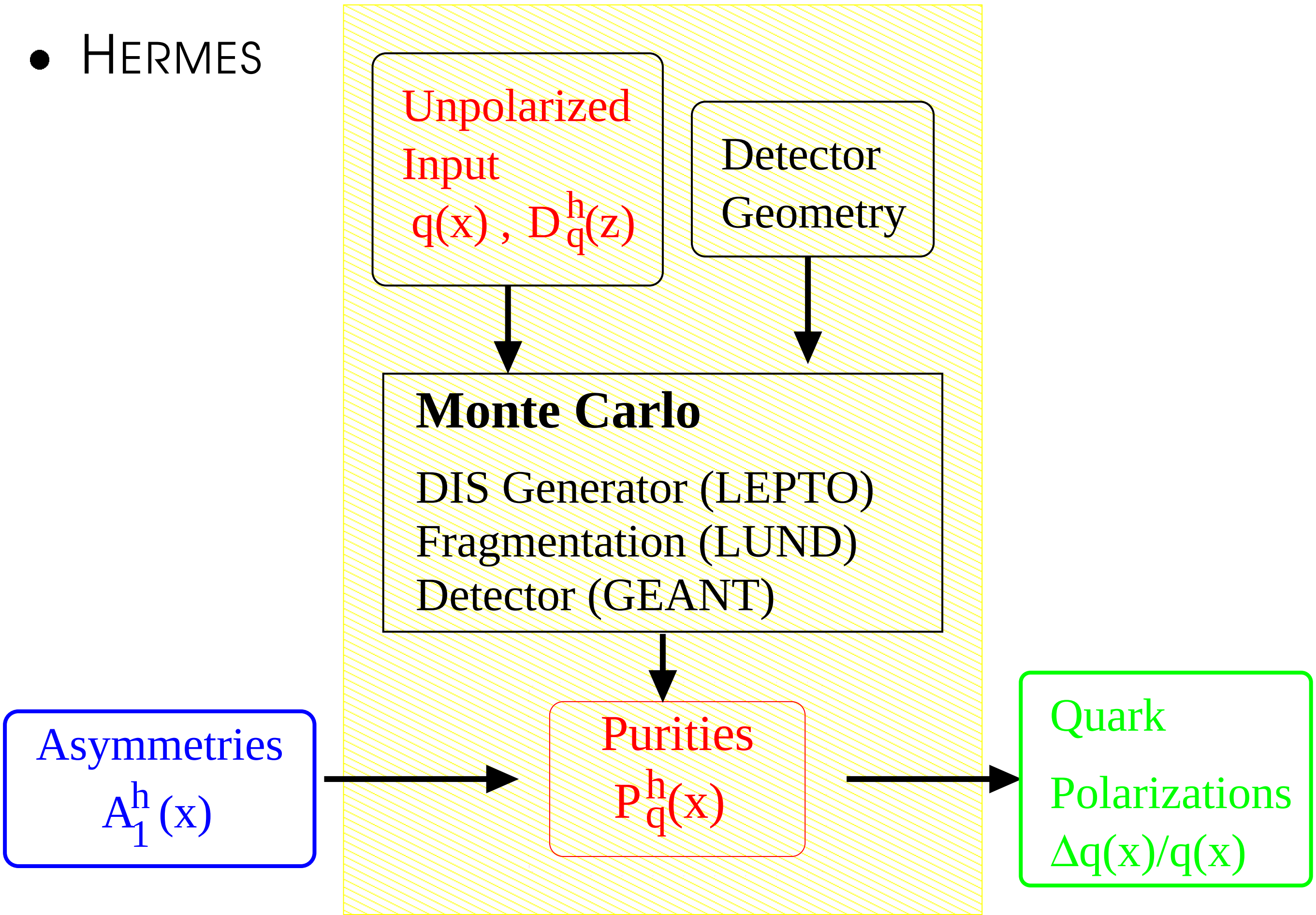
Where do the Purities come from?

- Purities

$$P_f^h(x) = \frac{e_f^2\, q_f(x) \int \mathrm{d}z\, D_f^h(z)}{\sum_{f'} e_{f'}^2\, q_{f'}(x)\ \int \mathrm{d}z\, D_{q_{f'}}^h(z)}$$

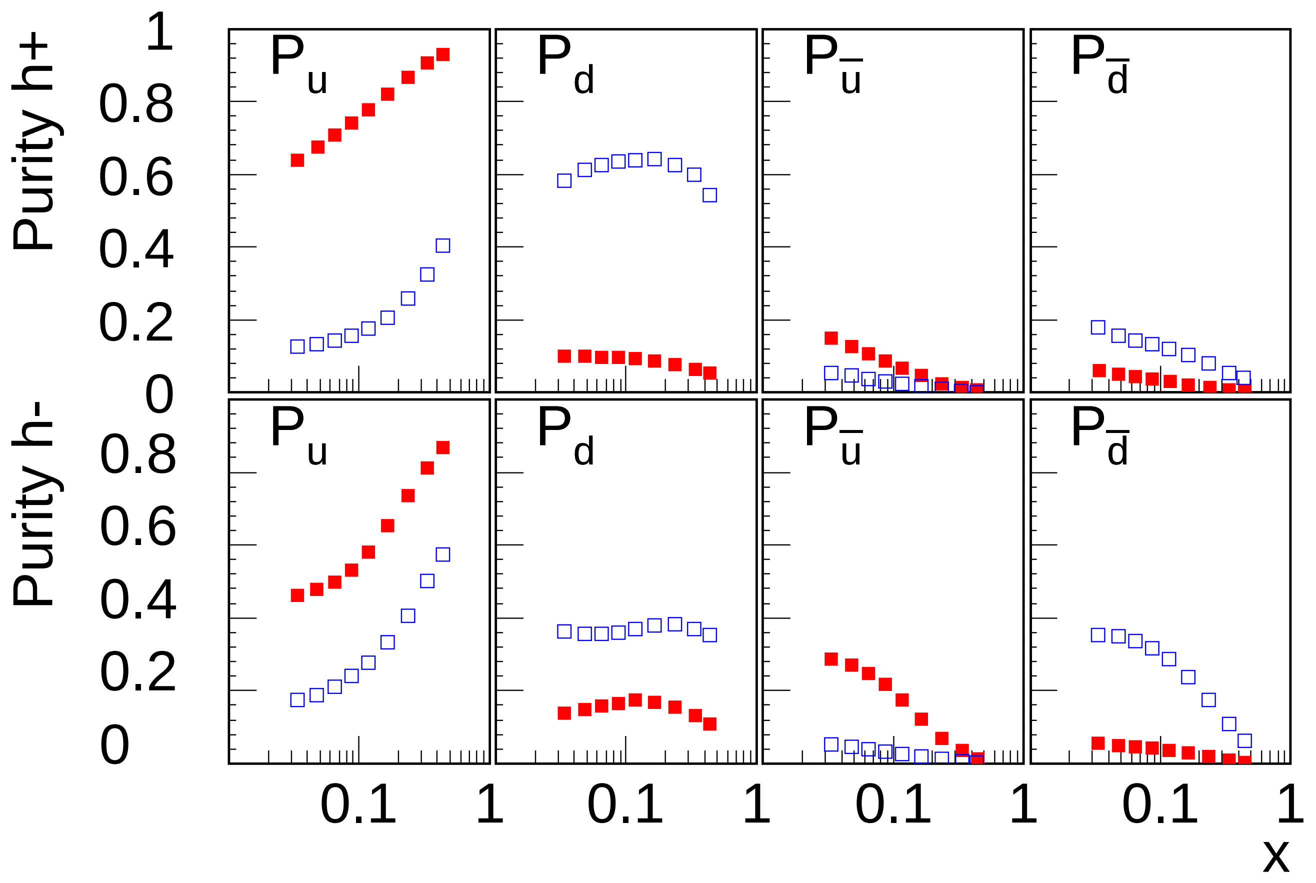
are derived from tuned fragmentation model *(LUND)* and parametrisations of $q_f(x)$ *(CTEQ4LQ)*

- HERMES



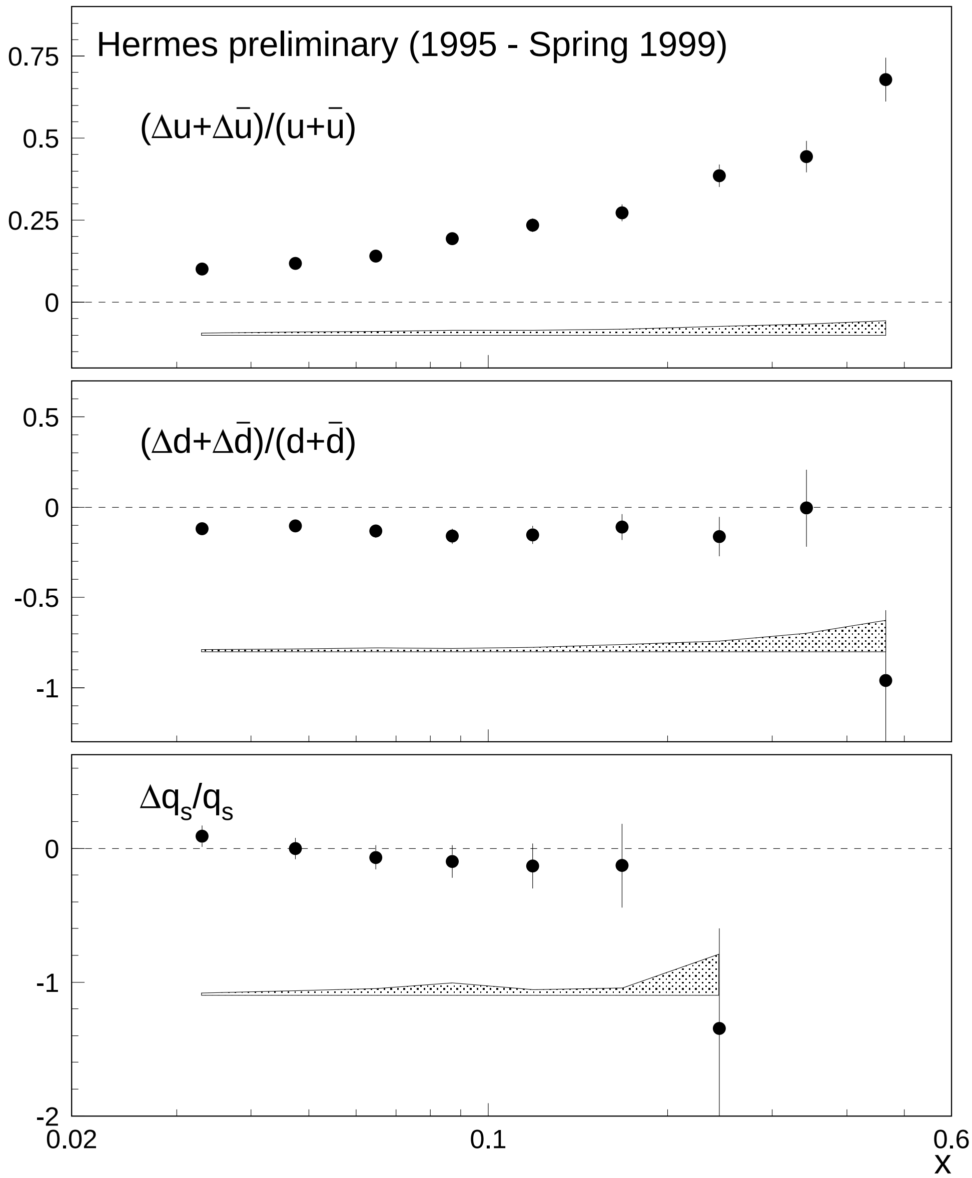
Purities

Purities $P^{h^{\pm}}_{u,d,\bar{u},\bar{d}}(x)$ for a *proton* and *neutron* target:



- h^+, h^- asymmetries on the proton dominated by $\Delta\, u(x)$
- h^+, h^- asymmetries on the neutron sensitive to $\Delta d(x)$
- Sensitivity to $\Delta\bar{u}(x)$ & $\Delta\bar{d}(x) \geq$ 10% for $x\ \leq\ 0.2$

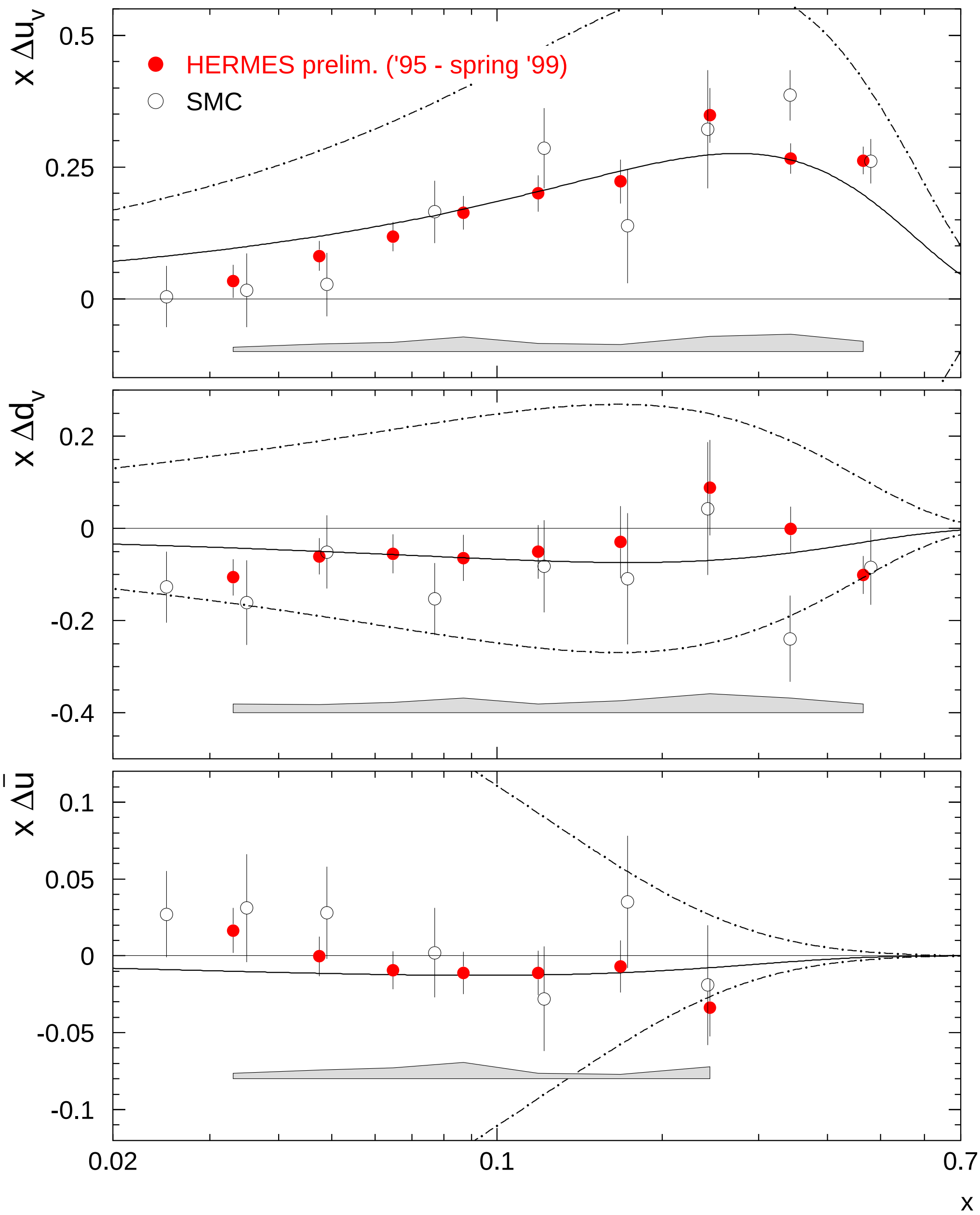
Extracted Quark Polarisations



Flavour decomposition of quark polarisations as a function of x at measured Q^2.
Assume: Symmetric sea polarisation:

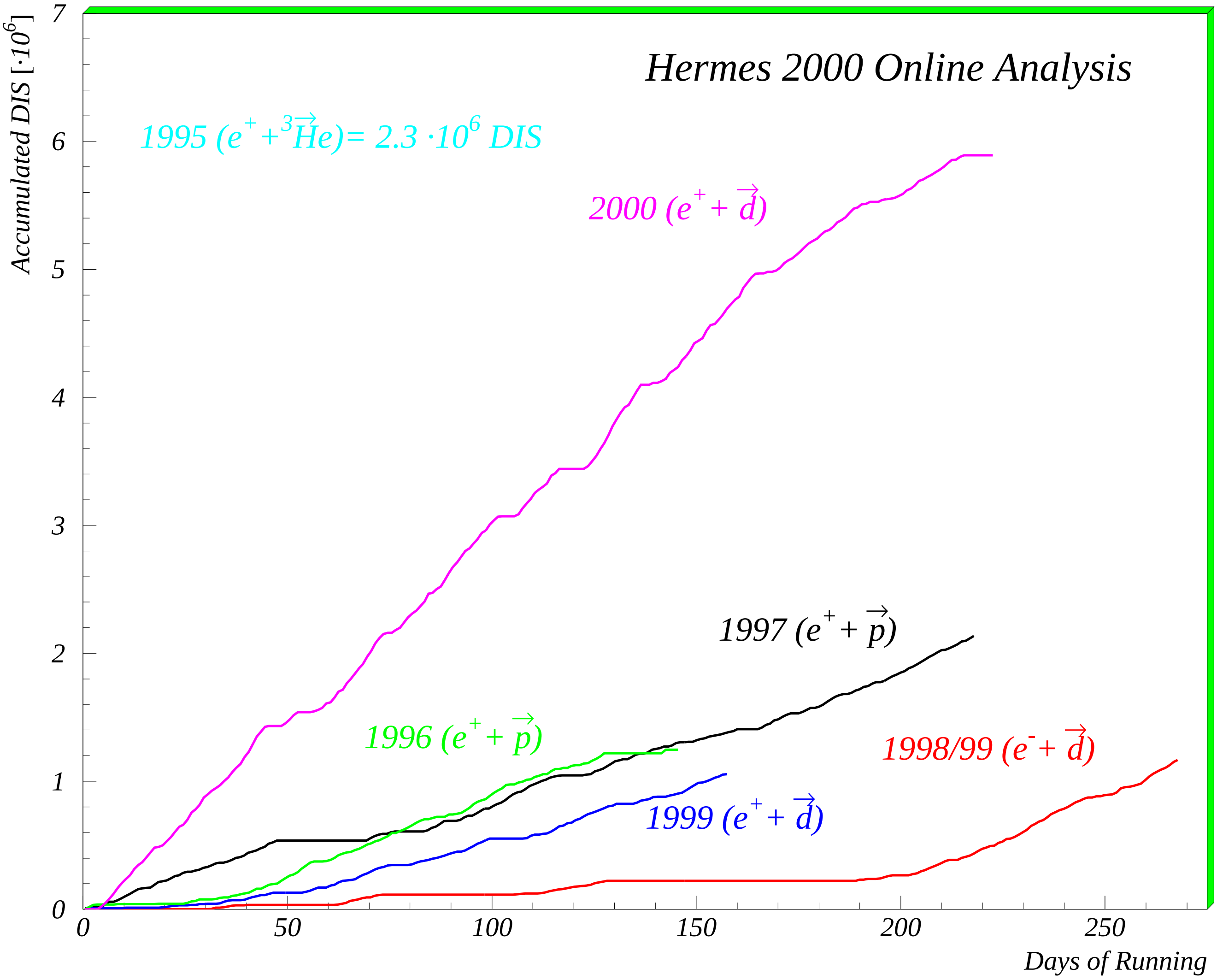
$$\frac{\Delta q_s(x)}{q_s(x)} \equiv \frac{\Delta u_s(x)}{u_s(x)} = \ldots = \frac{\Delta \bar{s}(x)}{\bar{s}(x)}$$

Pol. Valence and Sea Quark Distributions



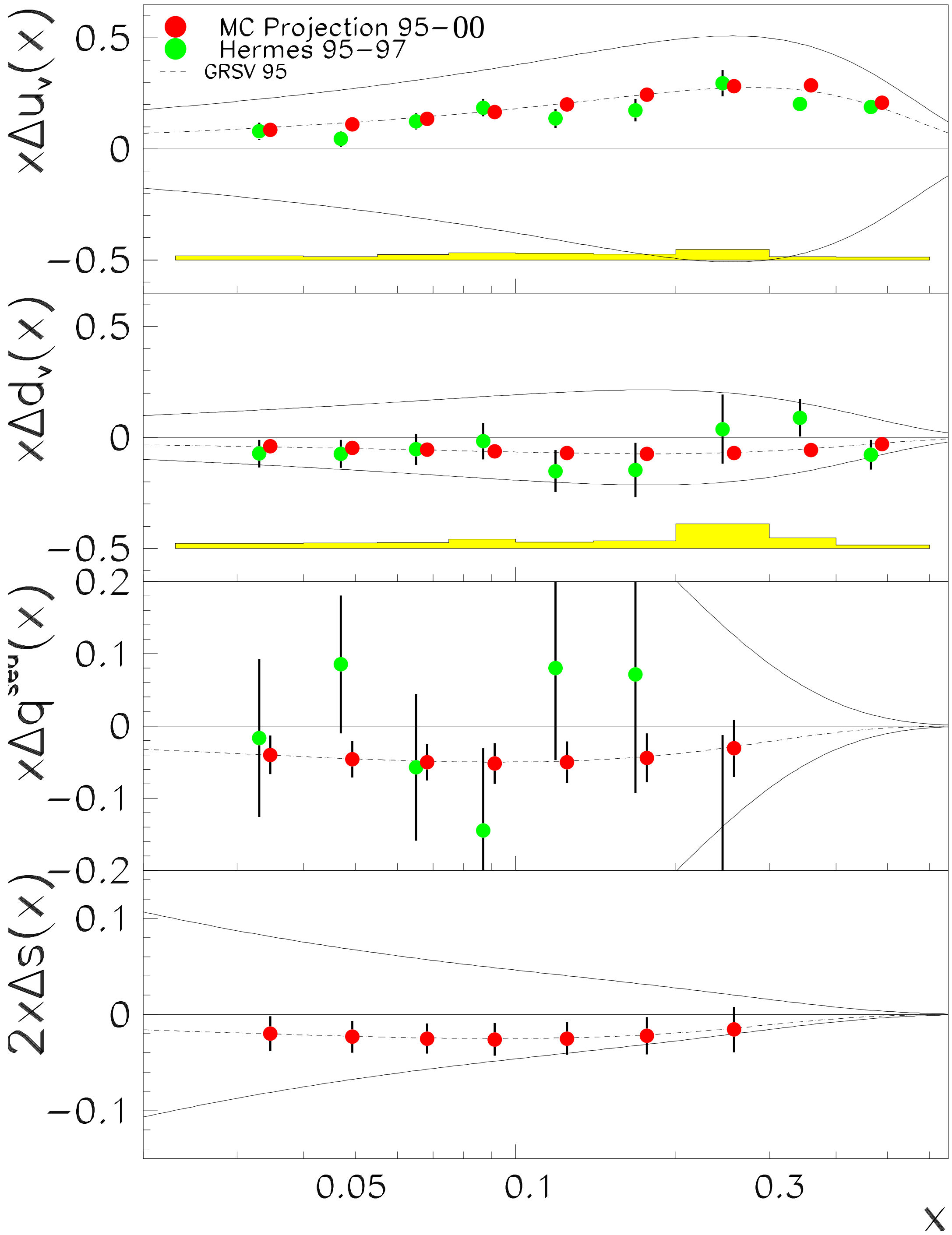
- Data points evolved to Q^2 = 2.5 GeV^2
- Solid lines: Gehrmann-Stirling ("Gluon A", LO)
- Dashed lines: positivity limits

More data to analyse...



- 7 Million DIS events from polarised $\vec{D}$ on tape are currently being analysed.

Monte Carlo projection up to 2000



Prediction based on 8 x 10^6 DIS events with semi inclusive $K^{\pm}$ asymmetries; $\langle P_{target} \rangle$ = 0.88 and $\langle P_{beam} \rangle$ = 0.5

Summary and Outlook

- $A_1^{(h)}$ measured on ${}^3\vec{\mathrm{He}}$, $\vec{\mathrm{H}}$ and $\vec{\mathrm{D}}$ targets

- Quark polarisations extracted for up and down quarks with good statistic, and for valence and sea quarks

- Polarisation of up quarks positive, of down quarks negative, and of sea quarks compatible with zero

- In the near future
  - Large statistics on polarised $\vec{\mathrm{D}}$ target
    $\Rightarrow$ Largely improved statistical precision on polarisation of up and down quarks.
  - Test alternative models on the sea polarisation
  - Semi inclusive asymmetries for pions and kaons using the RICH detector
    $\Rightarrow$ Separation of sea polarisation into light and strange sea contributions