Measurement of Polarised Quark Distributions of the Nucleon

at hermes

Marc Beckmann

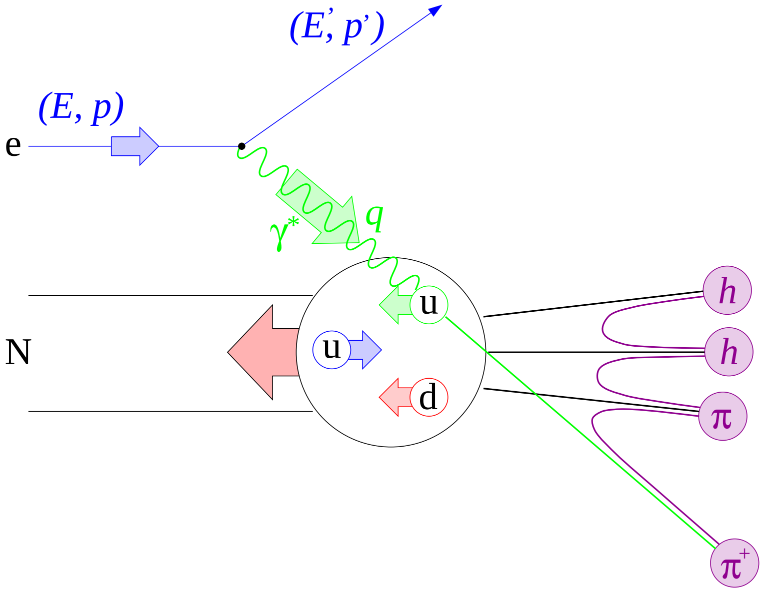
Fakultät für Physik,
Universität Freiburg i. Brsg., Germany

Outline:

- Polarised Semi Inclusive DIS
- The HERMES Experiment
- Measured Semi Inclusive Asymmetries
- Results
  - The Polarisation of Quark Flavours
  - Polarised Valence and Sea Quark Distributions
  - Moments of the Extracted Distributions
- New Data and Expected Accuracies
- Outlook

Polarised Semi Inclusive DIS

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



Flavour tagging:

- Select hadrons from the current fragmentation by minimum cuts on $z = E_h/\nu > 0.2$ and $x_{\mathrm{F}} \simeq 2p_{\|}/W > 0.1$
- Measure cross section asymmetry $A_1 \propto \dfrac{1}{D} \dfrac{\sigma^{\uparrow\Downarrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\uparrow\Downarrow} + \sigma^{\uparrow\Uparrow}}$
- In LO QCD

$$A_1^h(x, Q^2) \overset{g_2^h=0}{\simeq} \frac{\sum_f e_f^2\, \Delta q_f(x, Q^2) \int_{z_{\min}}^1 \mathrm{d}z\, \mathcal{D}_f^h(z, Q^2)}{\sum_f e_f^2\, q_f(x, Q^2) \int_{z_{\min}}^1 \mathrm{d}z\, \mathcal{D}_f^h(z, Q^2)} \times \underbrace{\frac{1 + R(x, Q^2)}{1 + \gamma^2}}_{=:\,\mathcal{C}}$$

Polarised PDFs: $\Delta q_f(x, Q^2) = q^{\uparrow\uparrow}(x, Q^2) - q^{\uparrow\downarrow}(x, Q^2)$,
Fragmentation function: $\mathcal{D}_f^h(z, Q^2)$

The "Purity" Extraction Formalism

- Introducing the **unpolarised** purities

$$P_f^h(x) \;=\; \frac{e_f^2\, q_f(x)\; \int_{z_{\min}}^1 D_f^h(z)\mathrm{d}z}{\sum_{f'} e_{f'}^2\, q_{f'}(x)\; \int_{z_{\min}}^1 D_{f'}^h(z)\mathrm{d}z}\,,$$

  the semi inclusive asymmetry can be rewritten as

$$A_1^h(x) \simeq \mathcal{C}\cdot\sum_f P_f^h(x)\,\frac{\Delta q_f}{q_f}(x)$$

- Given a set of asymmetries $\vec{A}$ solve the system of linear equations

$$\vec{A}(x) \;=\; \mathcal{C}\cdot\mathbf{P}(x)\cdot\vec{Q}(x)$$

  for a set of quark polarisations:

$$\vec{Q} = \left(\frac{\Delta u + \Delta\bar{u}}{u+\bar{u}}, \frac{\Delta d + \Delta\bar{d}}{d+\bar{d}}, \frac{\Delta q_\mathrm{s}}{q_\mathrm{s}}\right) \text{ or } \vec{Q} = \left(\frac{\Delta u_\mathrm{v}}{u_\mathrm{v}}, \frac{\Delta d_\mathrm{v}}{d_\mathrm{v}}, \frac{\Delta q_\mathrm{s}}{q_\mathrm{s}}\right)$$

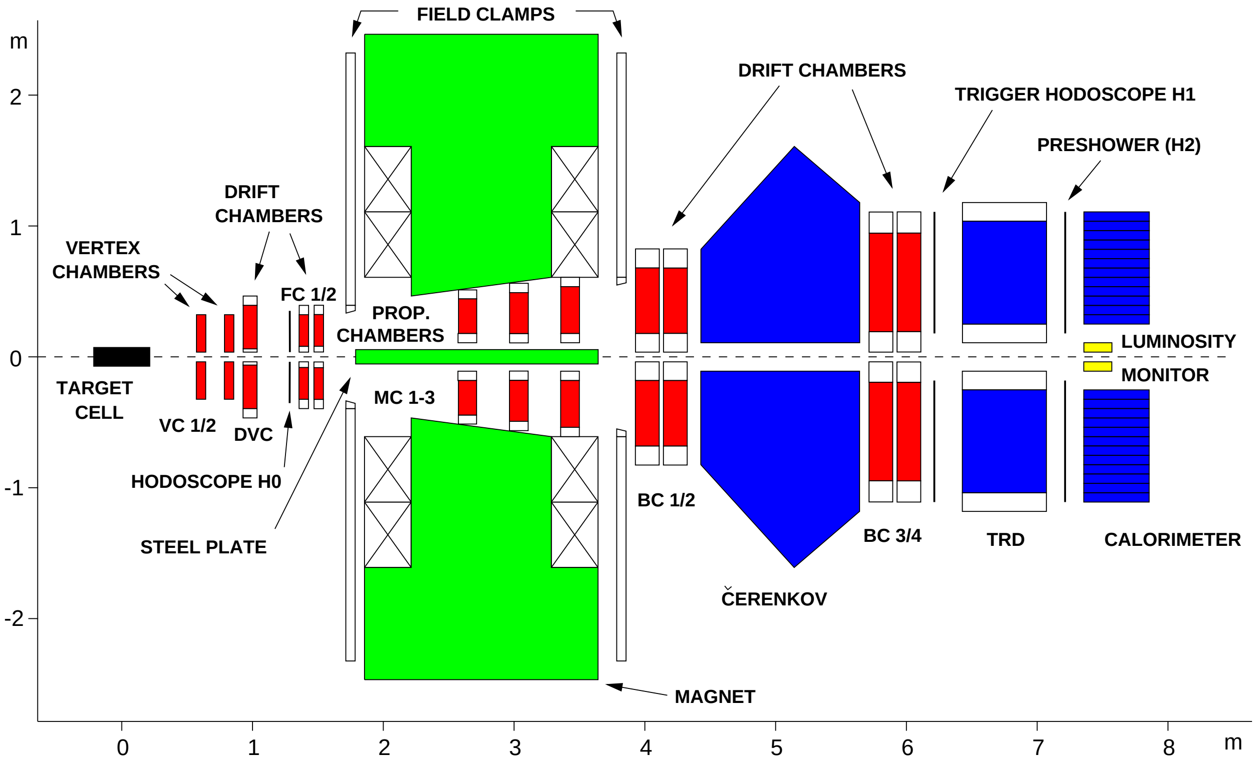
- Symmetry assumptions on the sea:

$$\frac{\Delta q_\mathrm{s}}{q_\mathrm{s}} \equiv \frac{\Delta u_\mathrm{s}}{u_\mathrm{s}} = \frac{\Delta\bar{u}}{\bar{u}} = \frac{\Delta d_\mathrm{s}}{d_\mathrm{s}} = \frac{\Delta\bar{d}}{\bar{d}} = \frac{\Delta s}{s} = \frac{\Delta\bar{s}}{\bar{s}}$$

$$\Delta q_\mathrm{s} \equiv \Delta u_\mathrm{s} = \Delta\bar{u} = \Delta d_\mathrm{s} = \Delta\bar{d} = \Delta s = \Delta\bar{s}$$

The HERMES Experiment

- Polarised HERA positron beam + polarised internal gas target
- Open geometry spectrometer

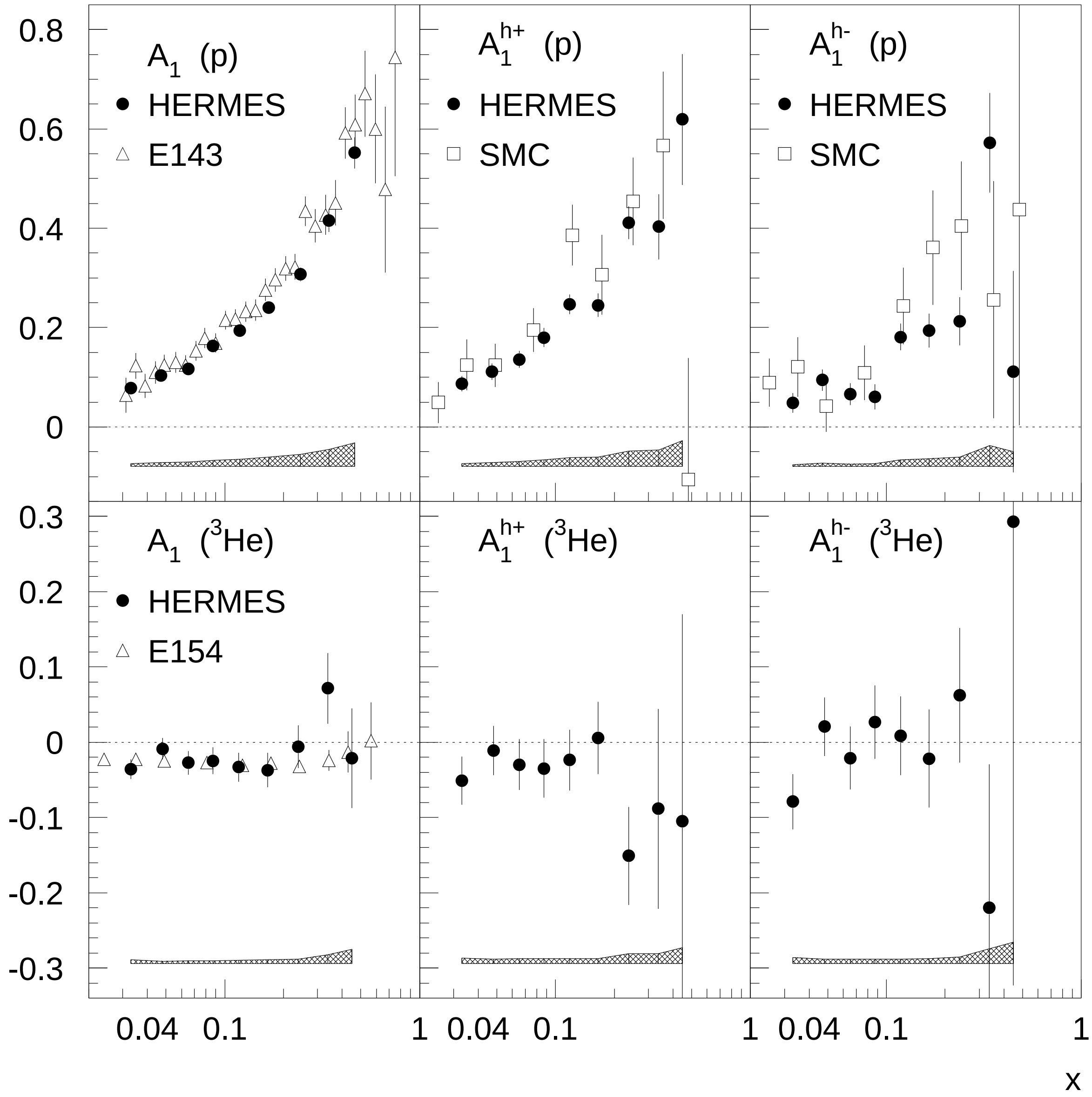


- The HERMES polarised data taking programme:

Year	1995	1996	1997	1998	1999	2000
Target	$^3\overrightarrow{\mathrm{He}}$	$\overrightarrow{\mathrm{H}}$		$\overrightarrow{\mathrm{D}}$		
DIS events $(\times 10^6)$	2.2	0.7	1.6	1.2	1.1	3.4

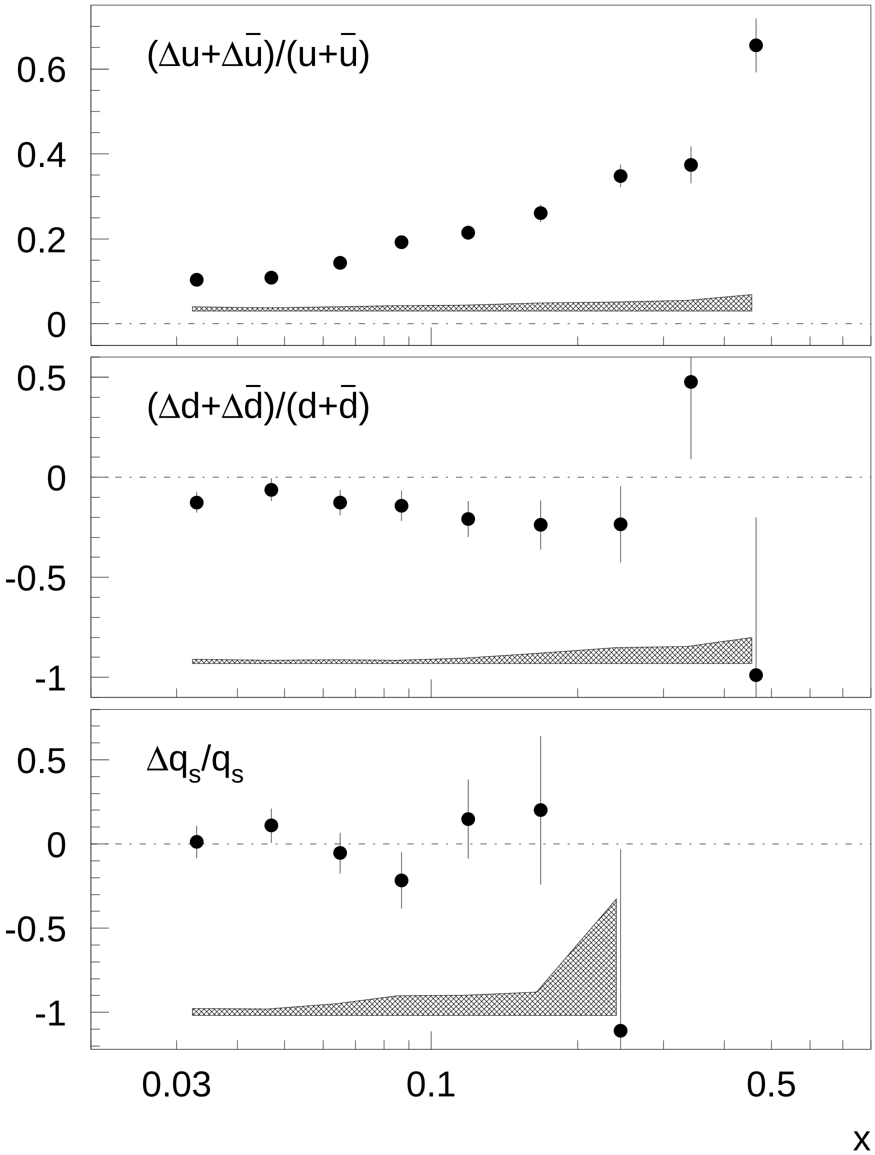
- Threshold Čerenkov detector replaced by a RICH detector in 1998

Semi inclusive asymmetries



- Inclusive and semi inclusive asymmetries from 2.2×10^6 (2.3×10^6) DIS events on a $^3\overrightarrow{\mathrm{He}}$ ($\overrightarrow{\mathrm{H}}$) target
- Data shown at mean measured Q^2 in each bin
- Error bars of HERMES (SLAC and SMC) are statistical (total) uncertainties, bands are HERMES systematic uncertainty

Extracted Quark Polarisations

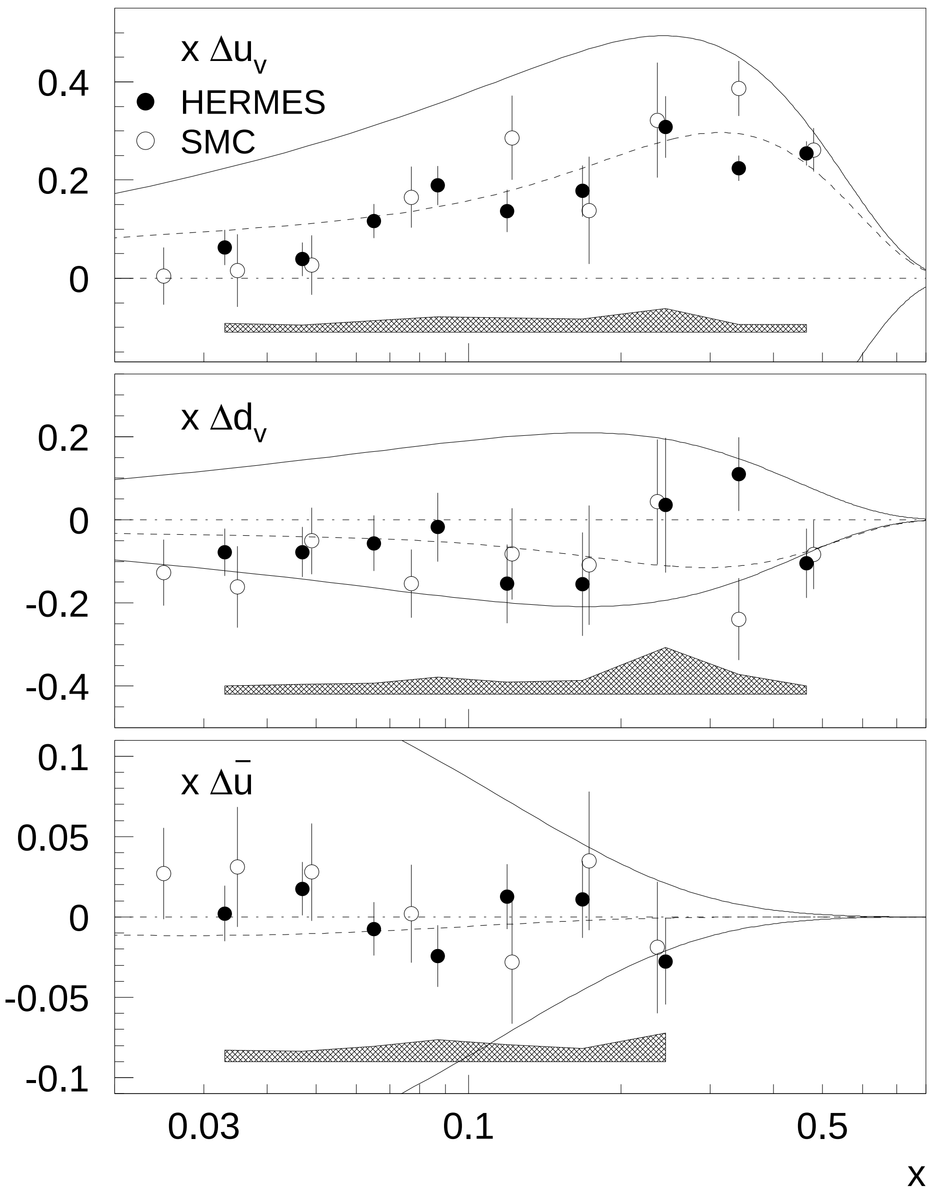


- Result insensitive to choice of sea model:

$$\frac{\Delta q_s}{q_s} \equiv \frac{\Delta u_s}{u_s} = \frac{\Delta \bar{u}}{\bar{u}} = \frac{\Delta d_s}{d_s} = \frac{\Delta \bar{d}}{\bar{d}} = \frac{\Delta s}{s} = \frac{\Delta \bar{s}}{\bar{s}}$$

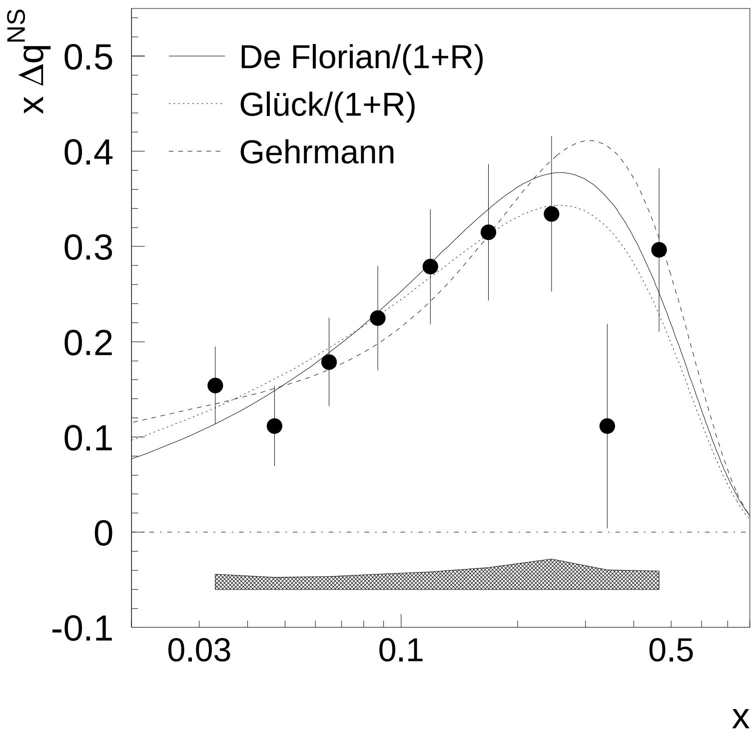
$$\Delta q_s \equiv \Delta u_s = \Delta \bar{u} = \Delta d_s = \Delta \bar{d} = \Delta s = \Delta \bar{s}$$

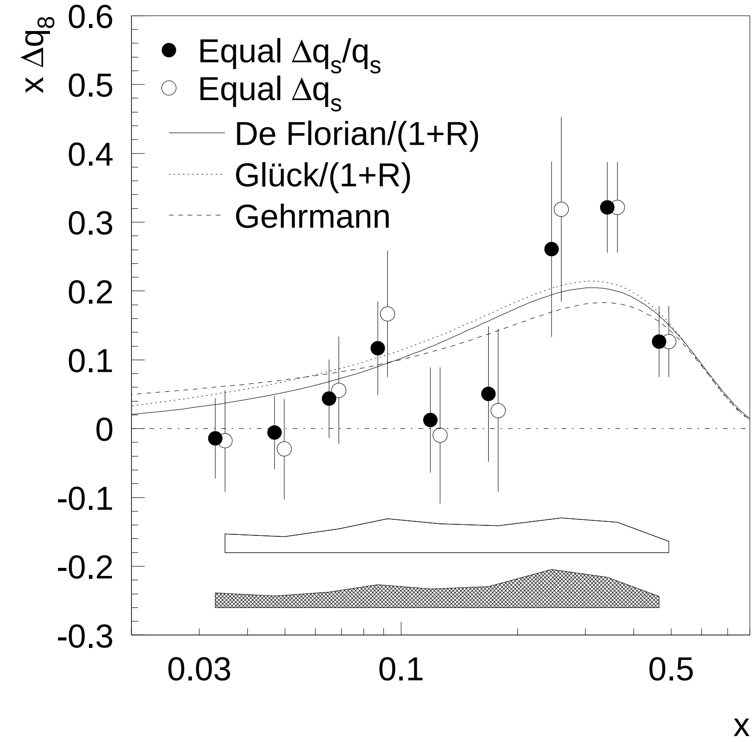
Polarised Valence and Sea Quark Distributions



- SMC data points evolved to $Q^2 = 2.5$ GeV^2
- Dashed lines: Gehrmann–Stirling param. (“Gluon A”, LO)
- Solid lines: positivity limits

Non–singlet Quark Distributions





- Only small sensitivity on model for sea polarisation

First Moments

- Integration in the measured region

+ Low–x extrapolation by Regge parametrisation

+ High–x extrapolation by GRSV parametrisation

- HERMES flavour decomposition (all values at $Q^2 = 2.5$ GeV^2)

	total integral	prediction
$\Delta u + \Delta\bar{u}$	0.57 ± 0.04	0.66 ± 0.04 $SU(3)$[1]
$\Delta d + \Delta\bar{d}$	−0.25 ± 0.08	−0.35 ± 0.04 $SU(3)$[1]
$\Delta s + \Delta\bar{s}$	−0.01 ± 0.05	−0.08 ± 0.03 $SU(3)$[1]

- HERMES singlet and non–singlet distributions:

$$\begin{array}{rrcl} \text{singlet} & \Delta q_0 & = & \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s} \\ \text{triplet} & \Delta q_3 & = & \Delta u + \Delta\bar{u} - (\Delta d + \Delta\bar{d}) \\ \text{octet} & \Delta q_8 & = & \Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} - 2(\Delta s + \Delta\bar{s}) \end{array}$$

(all values at $Q^2 = 2.5$ GeV^2)

	total integral	prediction
Δq_0	0.30 ± 0.10	0.23 ± 0.04 $SU(3)$[1]
Δq_3	0.84 ± 0.09	1.01 ± 0.05 $\lvert g_A/g_V \rvert$
Δq_8	0.32 ± 0.15	0.46 ± 0.03 $(3F - D)$

[1] J. Ellis, M. Karliner, Phys. Lett. **B 341** (1995) 397.

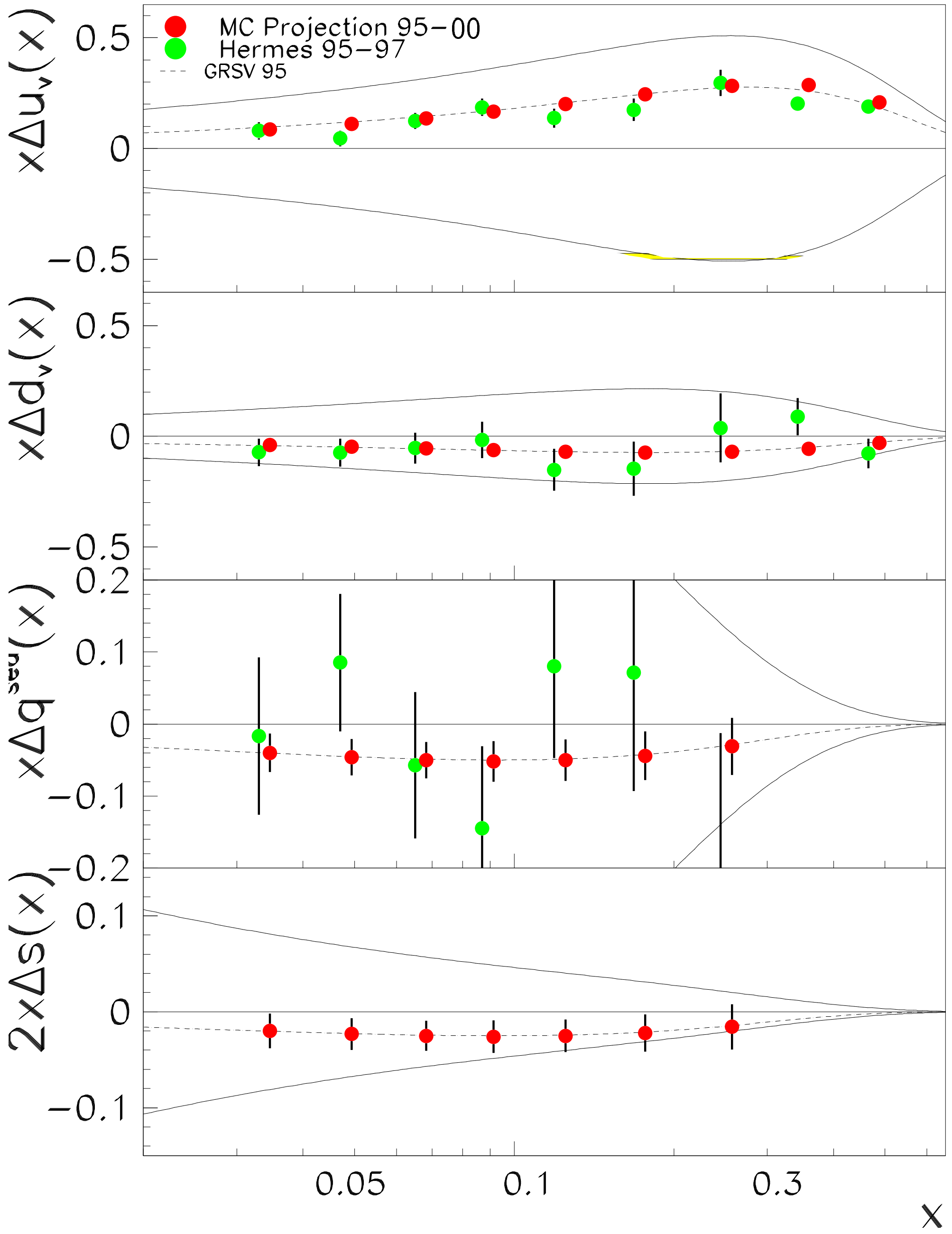
. . . and Second Moments

- HERMES valence distributions ($Q^2 = 2.5$ GeV^2) vs. lattice QCD calculations

	total integral	prediction	Q^2/GeV^2
Δu_v	0.57 $\pm$ 0.09	0.84 $\pm$ 0.05 [1]	5
Δd_v	-0.22 $\pm$ 0.17	-0.25 $\pm$ 0.02 [1]	5
$x\,\Delta u_v$	0.13 $\pm$ 0.01	0.20 $\pm$ 0.01 [2]	4
$x\,\Delta d_v$	-0.02 $\pm$ 0.03	-0.05 $\pm$ 0.01 [2]	4

[1] M. Göckeler *et al.*, Phys. Rev. **D 53** (1996) 2317.
[2] M. Göckeler *et al.*, Phys. Lett. **B 414** (1997) 340.

Monte Carlo projection up to 2000



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

Summary & Outlook

- Polarised quark distributions from 2.2×10^6 (2.3×10^6) DIS events on a polarised $^3\overrightarrow{\mathrm{He}}$, $(\overrightarrow{\mathrm{H}})$ target
- Good agreement with previous SMC measurement, improved statistics
- Good agreement with parametrisations
- Results consistent with analyses assuming $SU(3)_f$ symmetry

- In the **near** future:
  - Semi inclusive asymmetries for pions, kaons, and protons
  - Large statistics on a polarised $\overrightarrow{\mathrm{D}}$ target

  ⇒ Largely improved statistical precision on polarisation of up– and $down$–flavours

  ⇒ Separation of sea polarisation into light and strange sea contributions possible using the RICH: