Measurements of Polarized Quark Distributions at hermes

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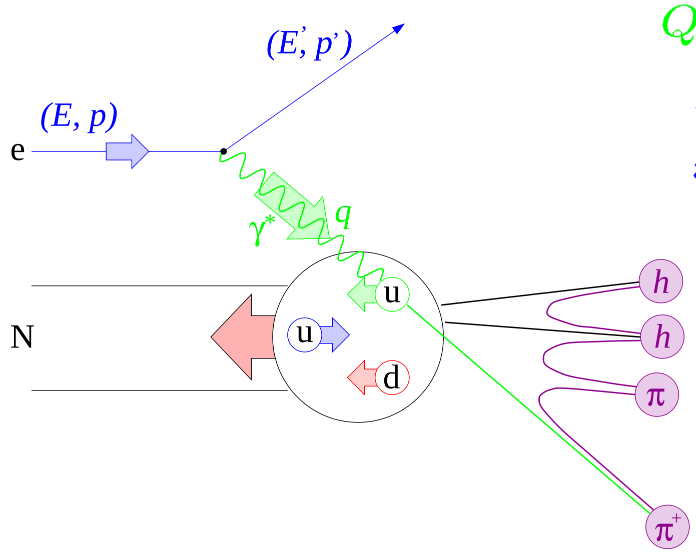
Outline:

- Polarized Semi Inclusive DIS
- The HERMES Experiment
- Measured Semi Inclusive Asymmetries
- The *Purity* Extraction Formalism
- Results
  - The Polarization of Quark Flavours
  - Polarized Valence and Sea Quark Distributions
- New Data and Expected Accuracies
- Outlook

Polarized Semi Inclusive DIS

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



$$\begin{aligned} Q^2 &\stackrel{\text{lab}}{=} 4EE'\sin^2(\theta/2) \\ \nu &\stackrel{\text{lab}}{=} E - E' \\ x &= Q^2/2M\nu \end{aligned}$$

Target fragments

Current fragments

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

$$A_{\|}^{h} = \frac{(N^h/L)^{\uparrow\Downarrow} - (N^h/L)^{\uparrow\Uparrow}}{(\langle P_B\, P_T\rangle N^h/L)^{\uparrow\Downarrow} + (\langle P_B\, P_T\rangle N^h/L)^{\uparrow\Uparrow}},$$

N^h : Number of DIS events
L : Dead time corrected luminosity
P_B, P_T : Beam and target polarizations

- Virtual photon nucleon asymmetry

$$A_1^h \stackrel{g_2=0}{=} \frac{A_{\|}^h}{D(1+\eta\gamma)}$$

The Virtual Photon Asymmetry A_1

- A_1 relates to the nucleon structure functions

$$A_1(x,Q^2) \overset{g_2=0}{\approx} \frac{g_1(x,Q^2)}{F_1(x,Q^2)} \overset{\text{LO QCD}}{=} \frac{\sum_q e_q^2\,\Delta q(x,Q^2)}{\sum_q e_q^2\,q(x,Q^2)}$$

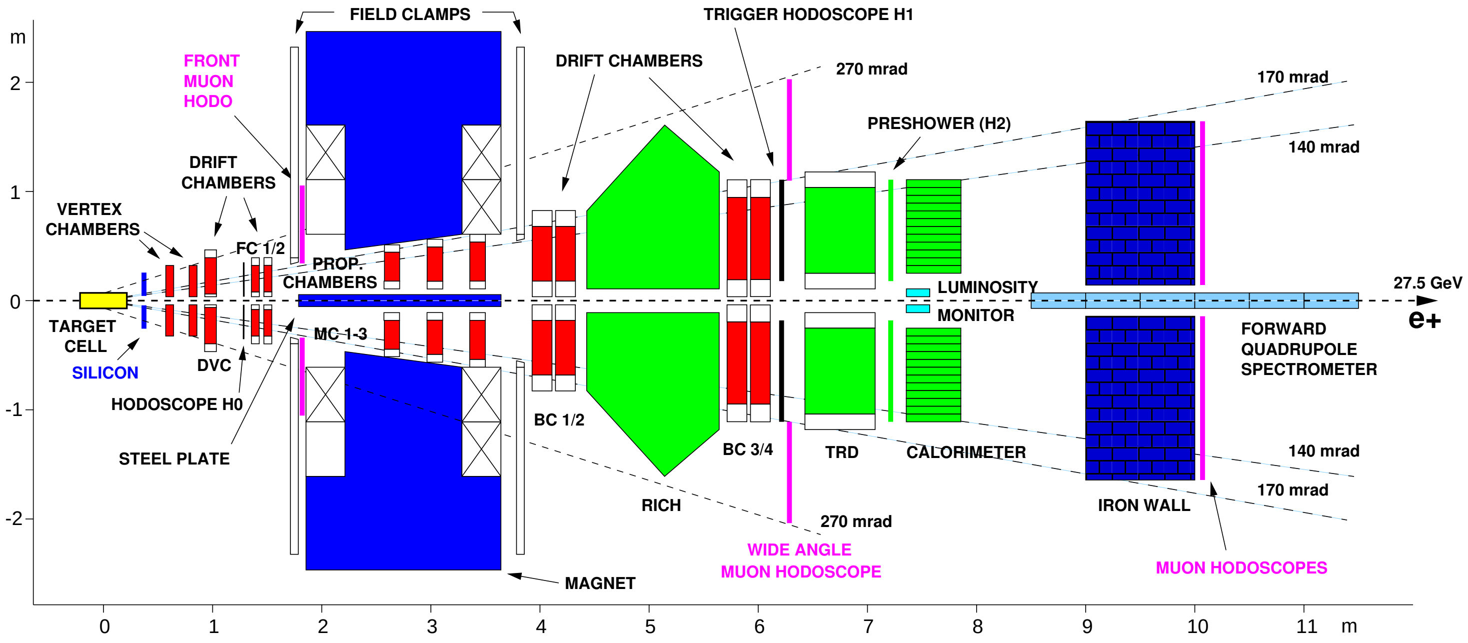
- Write semi inclusive asymmetries in LO QCD:

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

- Polarized PDFs: $\Delta q(x,Q^2) = q^{\uparrow\Uparrow}(x,Q^2) - q^{\uparrow\Downarrow}(x,Q^2)$
- Fragmentation functions: $\mathcal{D}_q^h(z,Q^2)$

How Do we Measure? — The Experiment

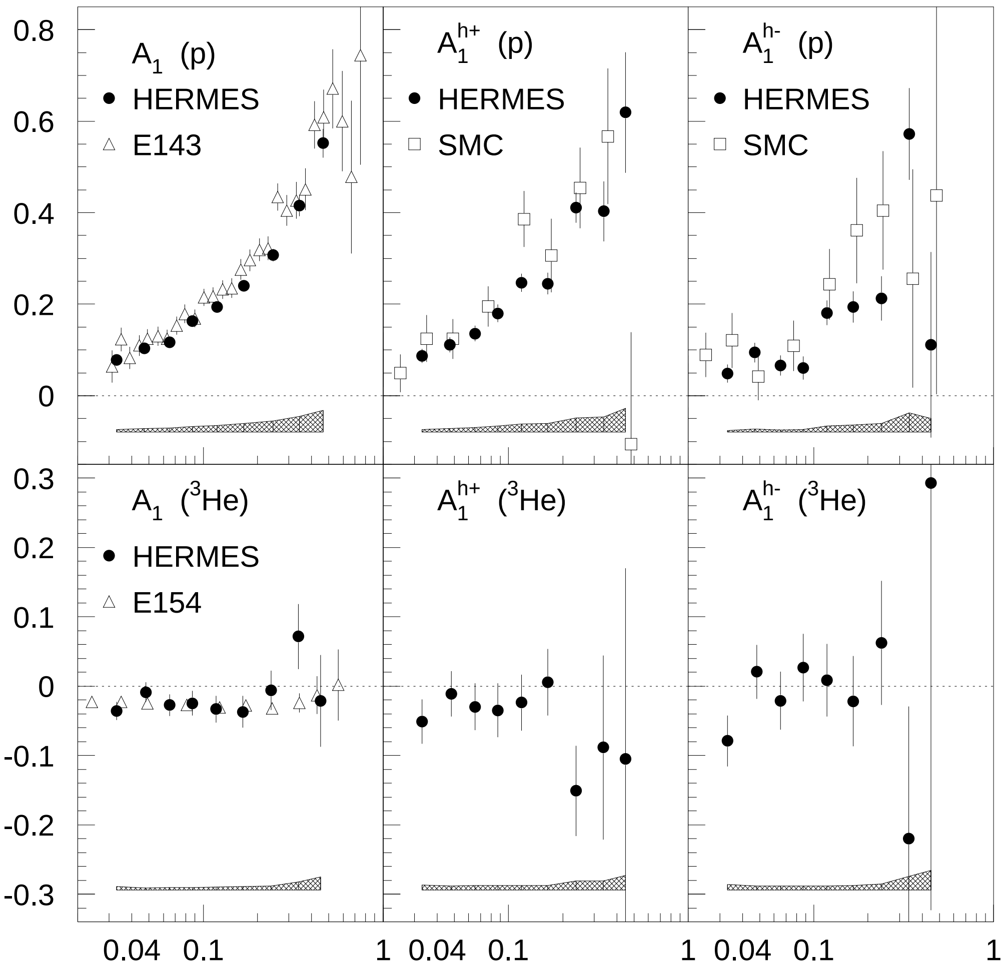
- Use polarized HERA positron beam + polarized internal gas target

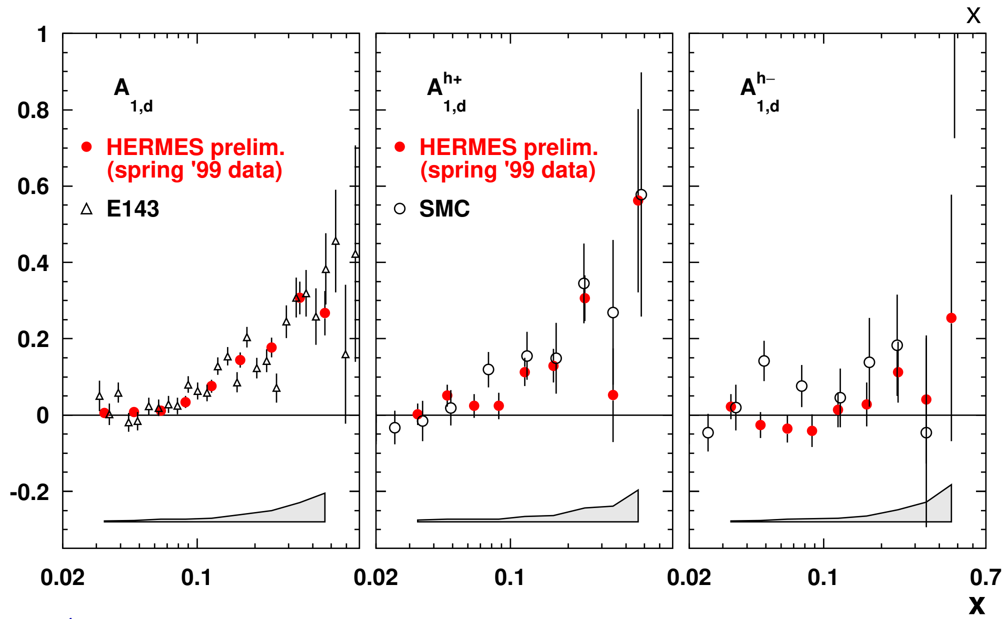


- Threshold Čerenkov detector replaced by a RICH detector in 1998
- Good lepton identification with an average efficiency of 98% at a hadron contamination of $\leq 1\%$.
- The HERMES polarized data taking program up to 2000:

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	1.5	1.0	1.1	5.5

What Did we Measure? — Asymmetries





The "Purity" Extraction Formalism

- Rewrite the virtual photon nucleon asymmetry

$$A_1^h(x) = \mathcal{C} \cdot \sum_q \underbrace{\left(\frac{e_q^2\, q(x) \int_{z_{\min}}^1 D_q^h(z)\mathrm{d}z}{\sum_{q'} e_{q'}^2\, q'(x) \int_{z_{\min}}^1 D_{q'}^h(z)\mathrm{d}z} \right)}_{\equiv P_q^h(x)} \cdot \frac{\Delta q(x)}{q(x)}$$

- The *purity* $P_q^h(x)$ gives the probability that a hadron h originates from scattering off a quark $q(x)$.
- Given a set of asymmetries $\vec{A}$ solve the system of linear equations

$$\vec{A}(x) = \mathcal{C} \cdot \mathbf{P}(x) \cdot \vec{Q}(x) \qquad (1)$$

for a set of quark polarizations:

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

- Symmetry assumptions on the sea:

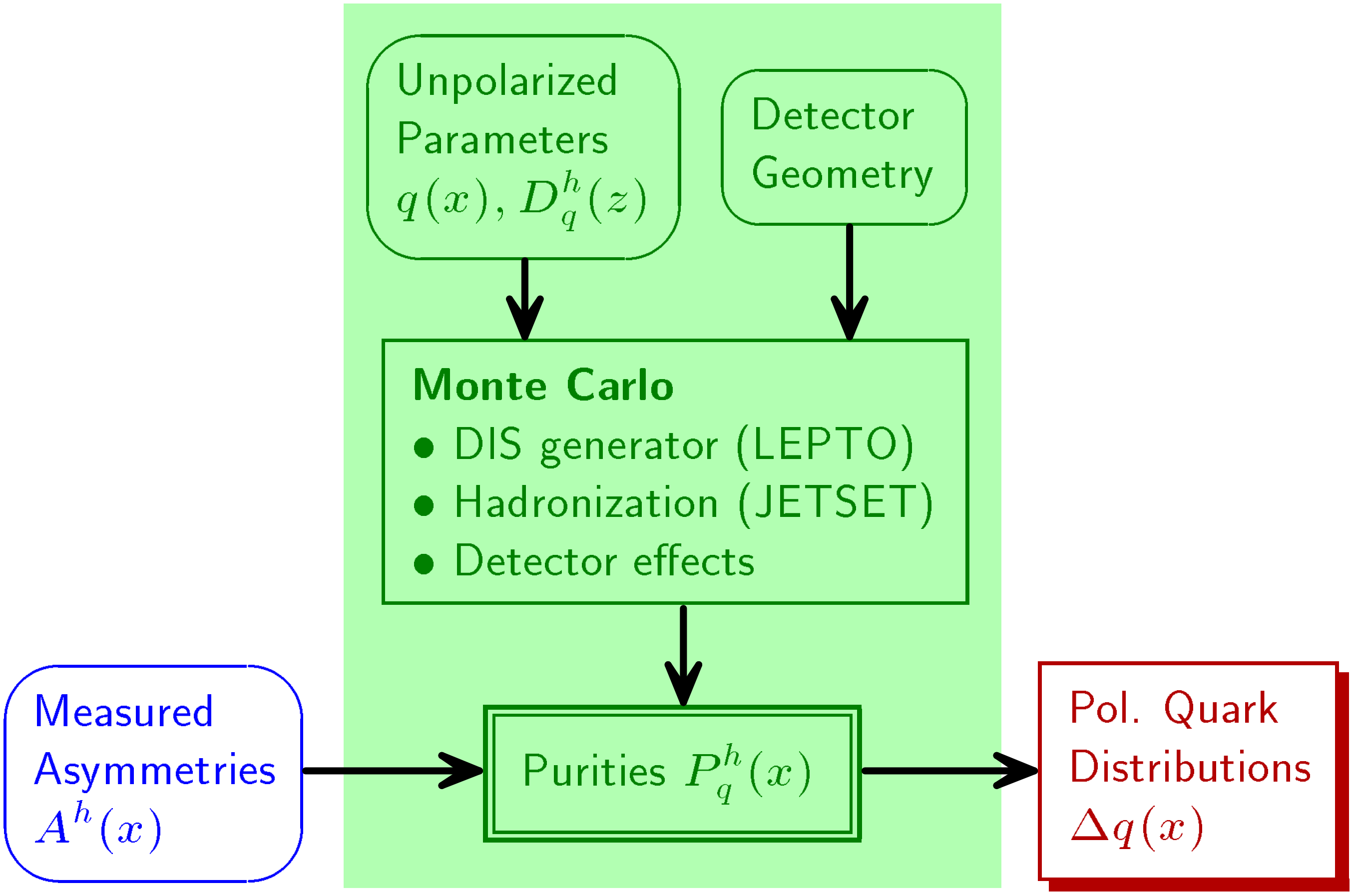
$$\frac{\Delta q_{\mathrm{s}}}{q_{\mathrm{s}}} \equiv \frac{\Delta u_{\mathrm{s}}}{u_{\mathrm{s}}} = \frac{\Delta \bar{u}}{\bar{u}} = \frac{\Delta d_{\mathrm{s}}}{d_{\mathrm{s}}} = \frac{\Delta \bar{d}}{\bar{d}} = \frac{\Delta s}{s} = \frac{\Delta \bar{s}}{\bar{s}}$$

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

- Solve overconstrained system of equations (1) by a χ^2-minimization

Where do the Purities come from?

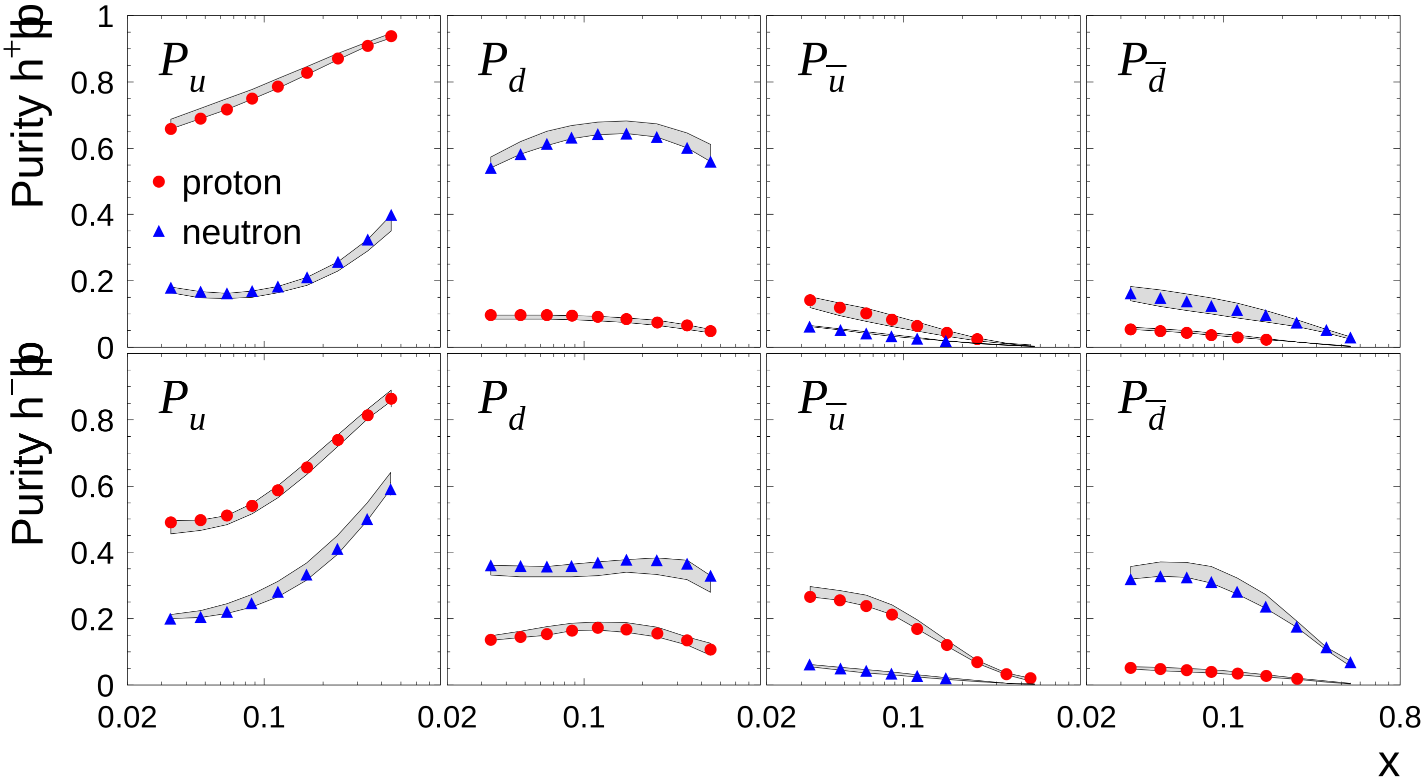
- Use Monte Carlo to generate the purities from parameterizations of $q(x, Q^2)$ (CTEQ4LQ) and tuned fragmentation model (LUND).
- Schematically:



- Estimate the systematic uncertainties by varying fragmentation parameters and using different sets of unpolarized PDFs (GRV98 LO).

Purities for pos. and neg. hadrons

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

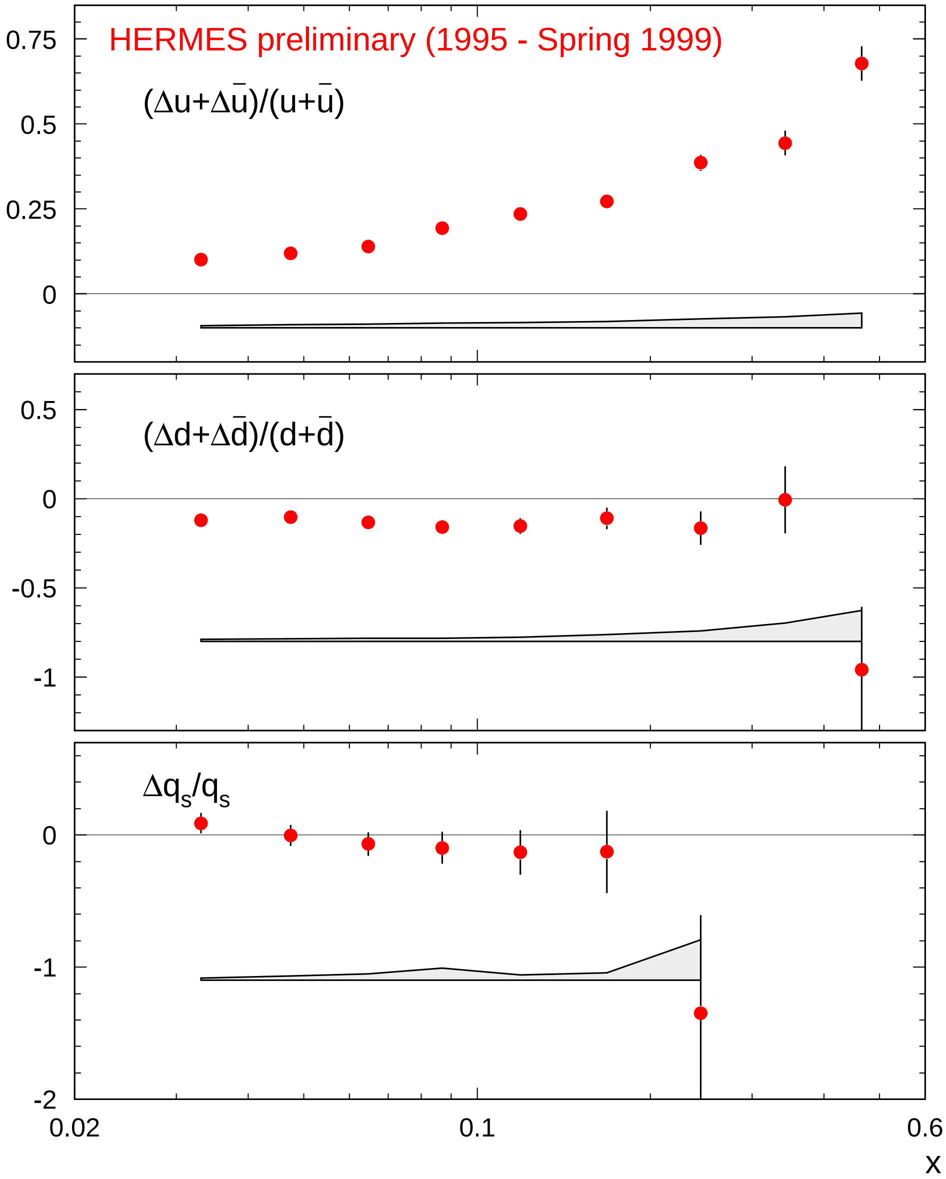


Shaded bands show the systematic uncertainties.

- Semi inclusive hadron asymmetries $h^\pm$ on the proton dominated by $\Delta u(x)$.
- Semi inclusive hadron asymmetries $h^\pm$ on the neutron sensitive to $\Delta d(x)$.
- Sensitivity to $\Delta\bar{u}(x)$ and $\Delta\bar{d}(x) \gtrsim 10\%$ for $x \leq 0.2$.

$\Rightarrow$ Necessity to combine data from proton and "neutron" (deuterium, ^{3}He) targets to extract other flavours than $\Delta\bar{u}(x)$.

Extracted Quark Polarizations

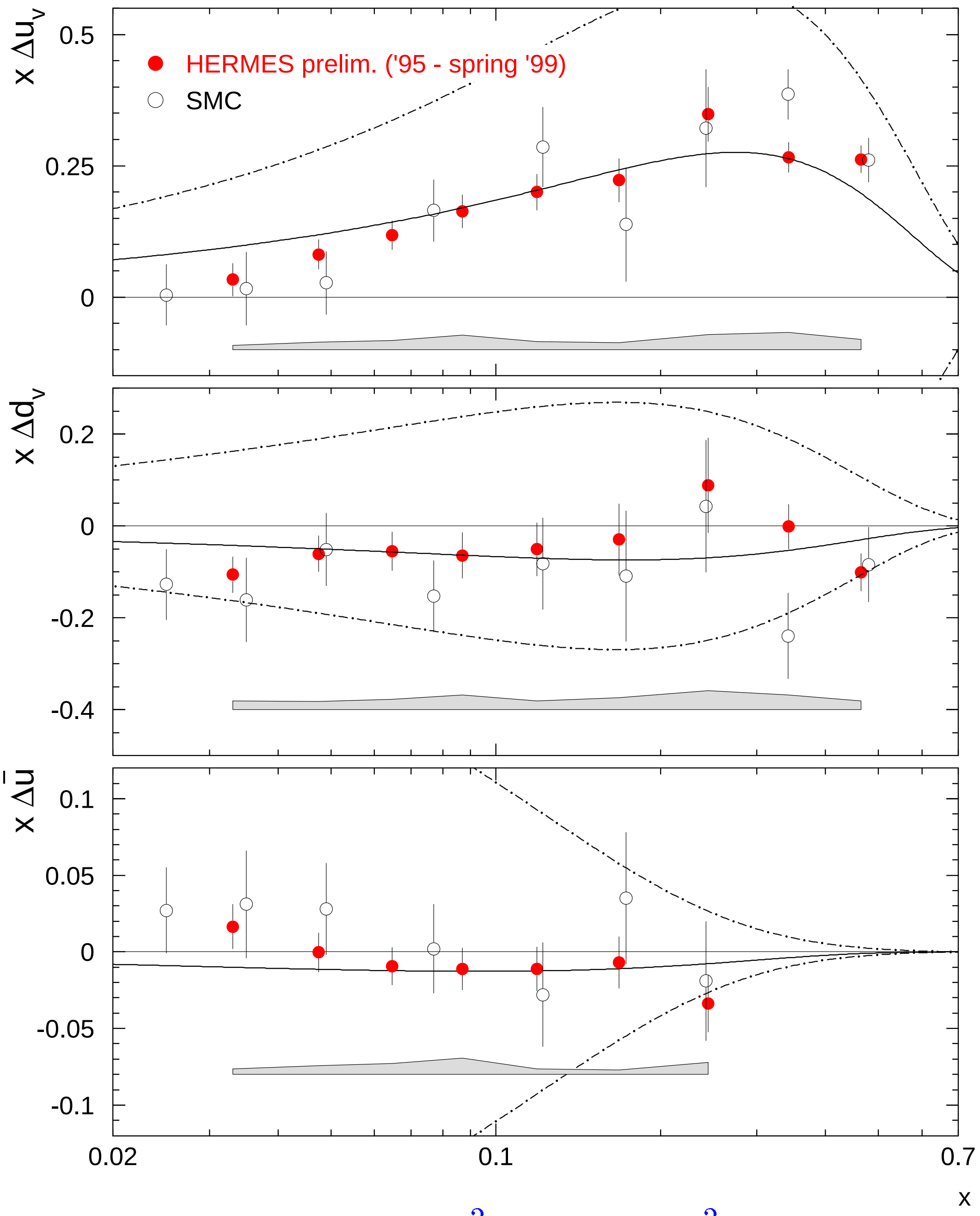


- Result insensitive to the choice of sea model:

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

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

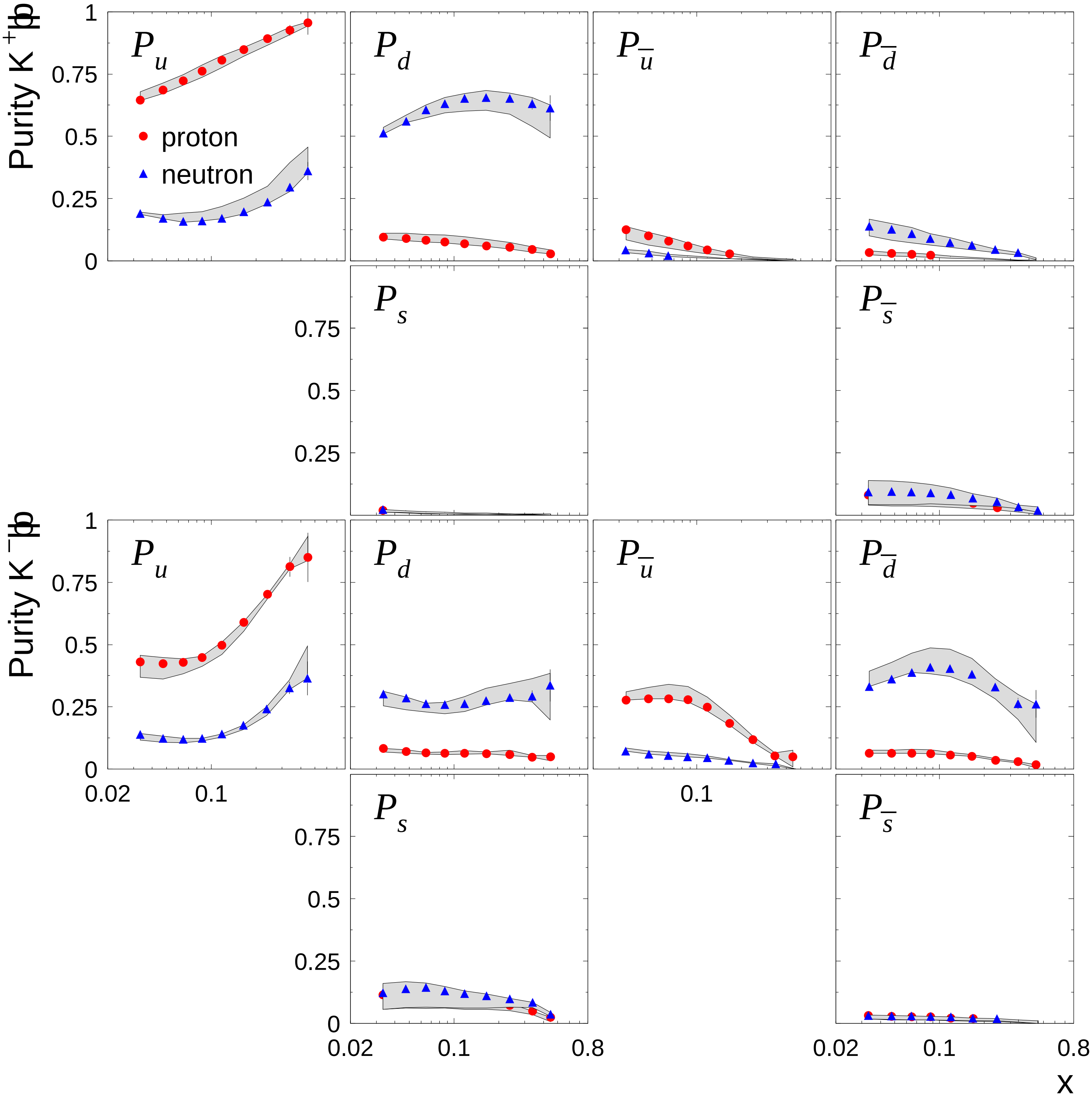
Polarized Valence and Sea Quark Distributions



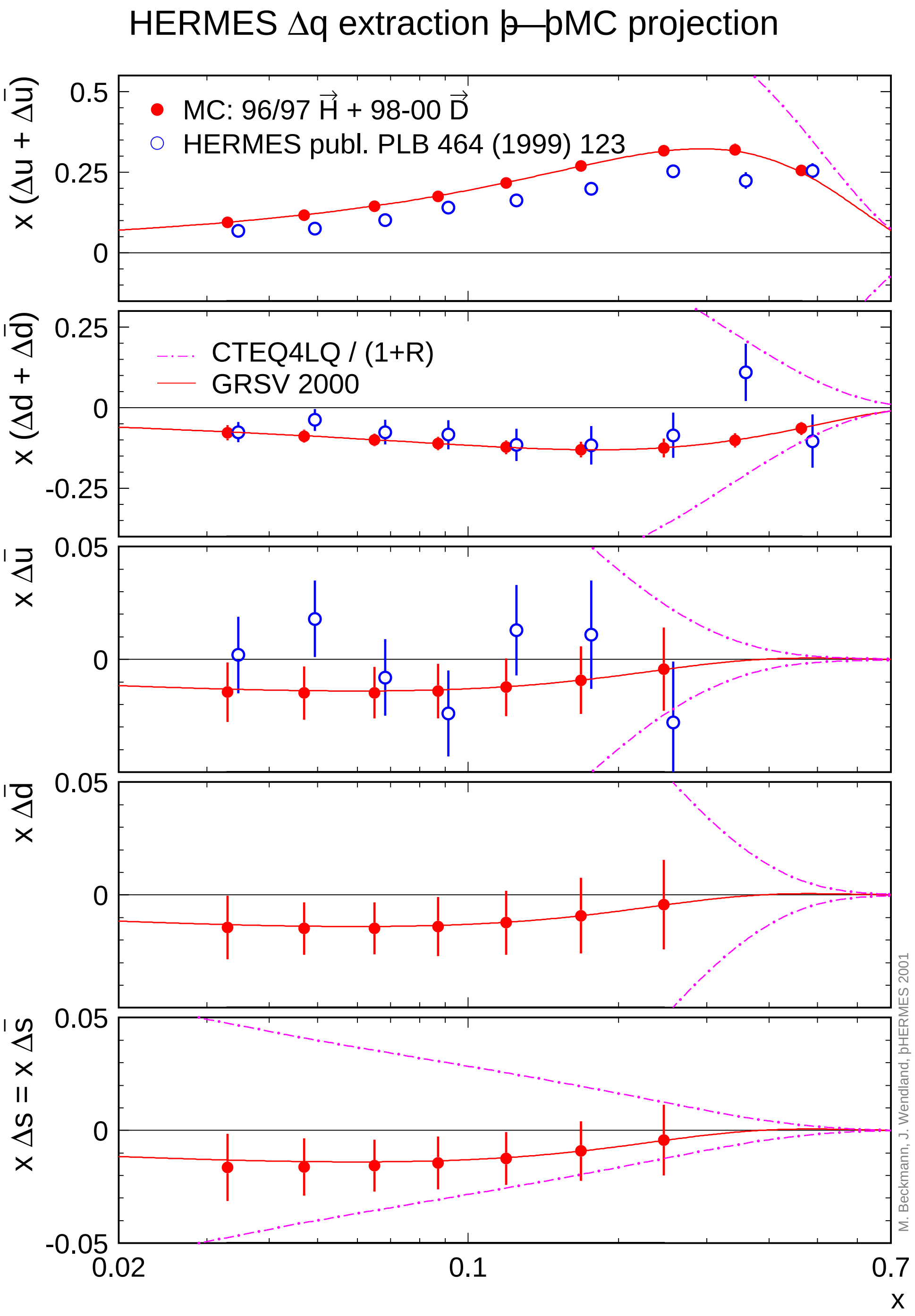
- SMC data points evolved to $Q^2 = 2.5$ GeV^2
- Solid lines: Gehrmann–Stirling param. ("Gluon A", LO)
- Dashed lines: Positivity limits

How kaons will help to measure $\Delta s(x)$

- $K^{\pm}$ identification with the RICH over a wide momentum range.
- $K^{\pm}$ provide enhanced sensitivity on $\Delta s(x)/\Delta \bar{s}(x)$ for $x \lesssim 0.2$:



What to expect in the near future?



Prediction based on 7.5×10^6 DIS events on a polarized deuterium target with semi inclusive $h^{\pm}$, $\pi^{\pm}$, $K^{\pm}$–asymmetries,
$\langle P_T \cdot P_B \rangle = 0.45$

Summary & Outlook

- $\oplus$ Polarized quark distributions from a LO analysis of 2.2×10^6 (2.2×10^6) $[1.0 \times 10^6]$ DIS events on polarized $^3\overrightarrow{\mathrm{He}}$, $(\overrightarrow{\mathrm{H}})$, $[\overrightarrow{\mathrm{D}}]$ targets.
- $\oplus$ Good agreement with previous SMC measurement, improved statistics.
- $\oplus$ Good accuracy for polarized non–sea quark densities $\Delta u(x)$ and $\Delta d(x)$
- $\oplus$ Good agreement with parametrizations
- $\ominus$ Results insensitive to sea model assumptions.

- In the **near** future:
  - Semi inclusive asymmetries for pions, kaons, and protons
  - Large statistics on a polarized $\overrightarrow{\mathrm{D}}$ target
  - $\Rightarrow$ Largely improved statistical precision on polarization of up– and $down$–flavours
  - $\Rightarrow$ Separation of polarized quark densities for all sea flavours without symmetry assumptions feasible.
  - $\Rightarrow$ Tests of $SU(3)_f$ symmetry and the χQSM model possible . . .