FLAVOR DECOMPOSITION OF POLARIZED QUARK DISTRIBUTIONS IN THE NUCLEON

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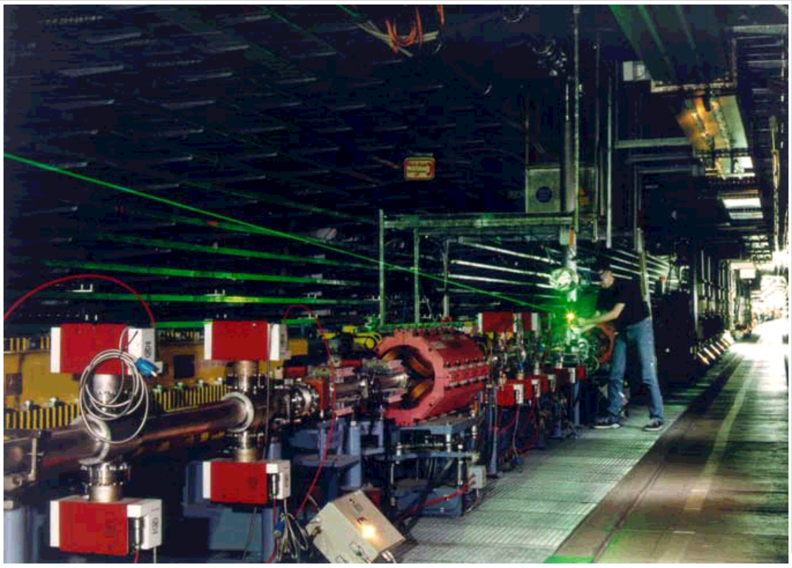
On behalf of the HERMES Collaboration

HERMES(HERA Measurement of Spin)

Laser polarimeter in the HERA tunnel
HERMES uses the polarized electrons from HERA to find out how the different quarks and gluons account for the "spin" (the intrinsic angular momentum) of the protons. During HERA operation, the green laser beam is directed inside the beam pipe against the electron beam, to observe to what extent the electrons are polarized, i.e. how their spins are aligned preferring a forward or backward direction. In this picture, the laser beam is outside the beam pipe for adjustment.



hermes

A second generation experiment designed to study the spin structure of the nucleon at HERA

Alberta
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Erlangen
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Regensburg
St. Petersburg
Tokyo
TRIUMF
Warsaw
Yerevan

ANL:

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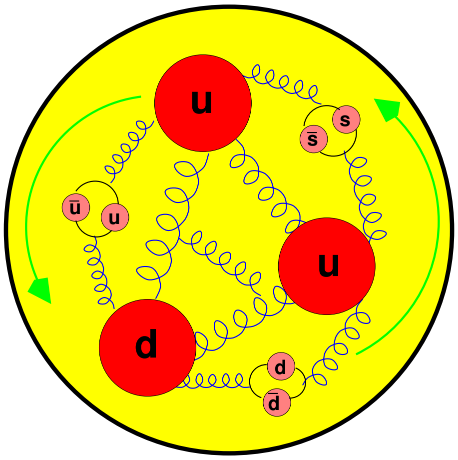
PhD students: A. El Alaoui, Y. Sanjiev

The Spin of the Nucleon



$$< {s^N}_z >= \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \Delta L_z$$

Early History of $\Delta\Sigma = \Delta u + \Delta d + \Delta s$

Non-relativistic Quark Model

Pure valence description of constituent quarks:

$$\Delta u = +4/3, \qquad \Delta d = -1/3 \quad \rightarrow \quad \Delta\Sigma = 1$$

Relativistic Quark Model *Jaffe, Manohar, NP B337(1990)509*

Relativistic current quarks with light masses: orbital angular momentum is important, and accounts for the deficit of $\Delta\Sigma$.

$$\Delta\Sigma \approx 0.60 - 0.75, \qquad L_q = \frac{1}{2}(1 - \Delta\Sigma)$$

SPIN CRISIS-DIS at SLAC/CERN('90's)-

$$\Delta\Sigma \approx 0$$

POLARIZATION OF THE QUARK SEA

The flavor decomposition of the polarized quark distributions, Δq_f, is one of the major missions of HERMES.

From early analysis of $\int g_1(x, Q^2)dx$ by SMC,SLAC:

$$\Delta u = +0.78 \pm 0.06$$

$$\Delta d = -0.47 \pm 0.06$$

$$\Delta s = -0.19 \pm 0.06$$

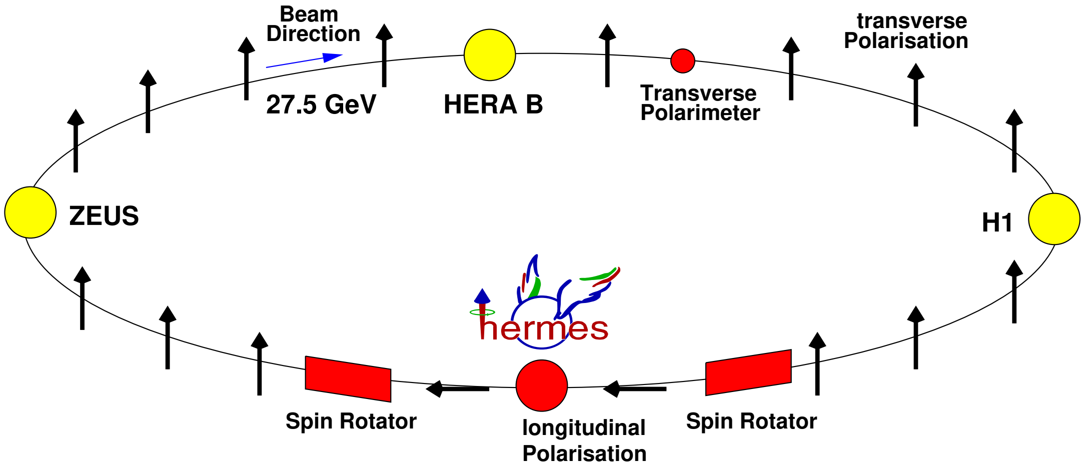
With flavor tagging in DIS, individual spin contributions, $\Delta q_f(x)$ can be determined directly from the spin asymmetries

$$A_{\|}^{(h)} = \frac{N_{(h)}^{\uparrow\downarrow} - N_{(h)}^{\uparrow\uparrow}}{N_{(h)}^{\uparrow\downarrow} + N_{(h)}^{\uparrow\uparrow}}, \quad A_1^h = \frac{A_{\|}^h}{D(1+\eta\gamma)}$$

Can rewrite in terms of a purity matrix:

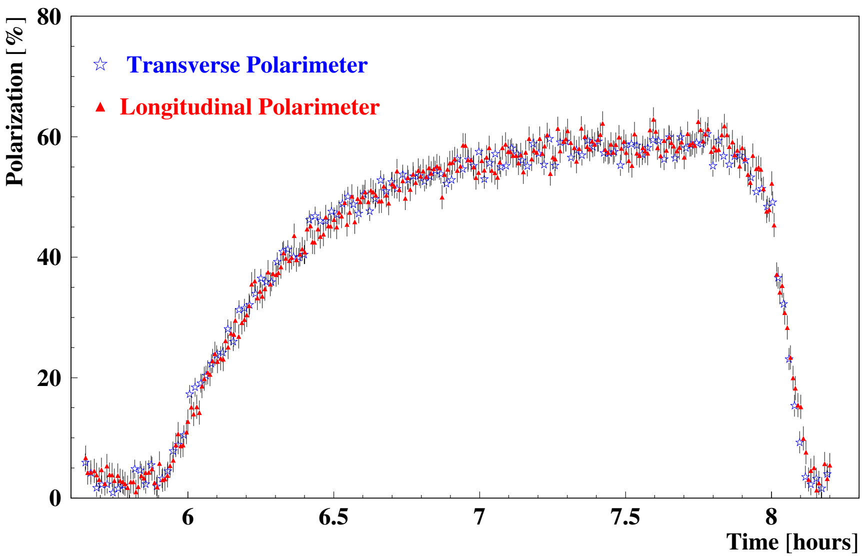
$$A_1^h(x,z) = \sum_q P_q^h(x,z)\frac{\Delta q(x)}{q(x)}$$

Polarized Electrons in Hera



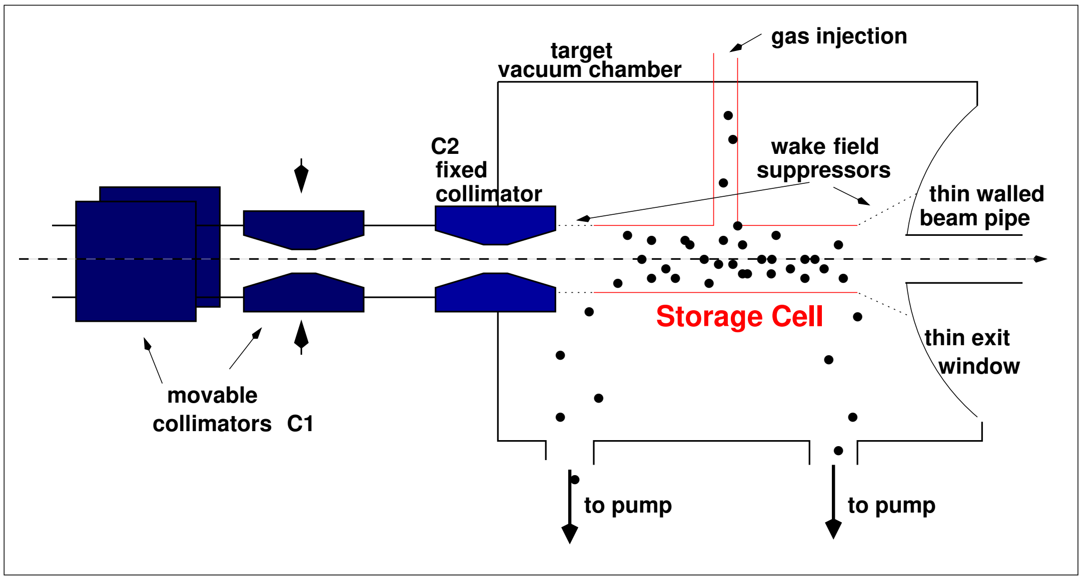
Sokolov-Ternov-Effect:

$$P(t) = \frac{8\sqrt{3}}{15}\left(1 - \mathrm{e}^{-\frac{t}{\tau_P}}\right)$$



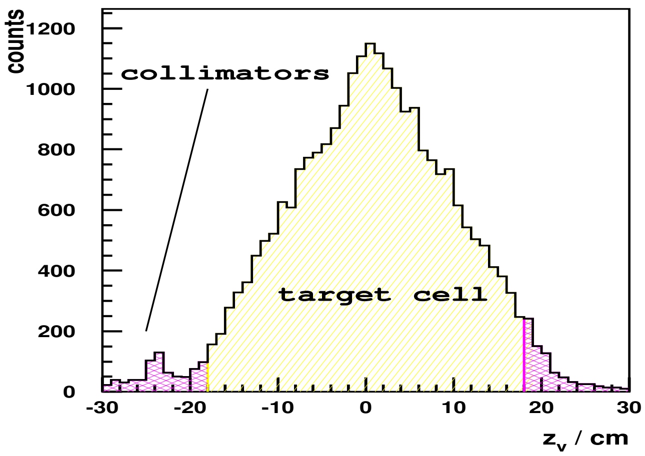
Polarization measured by two Compton polarimeters. $< P >= (55 \pm 2_{sys})\%$

Internal Polarized Gas Target

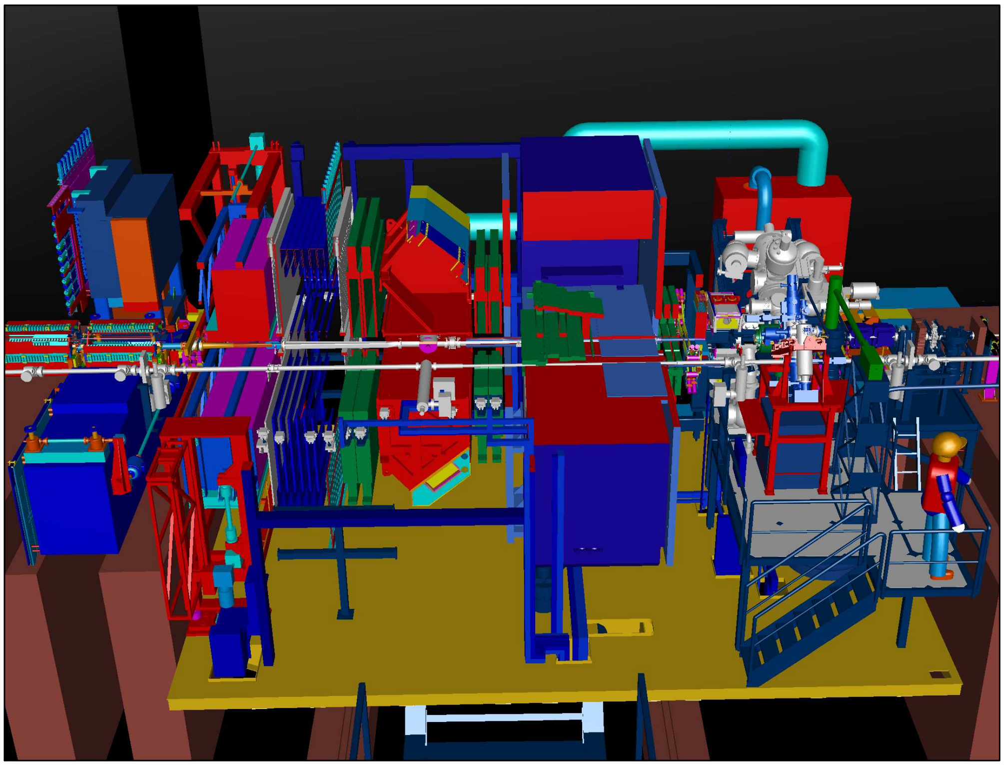


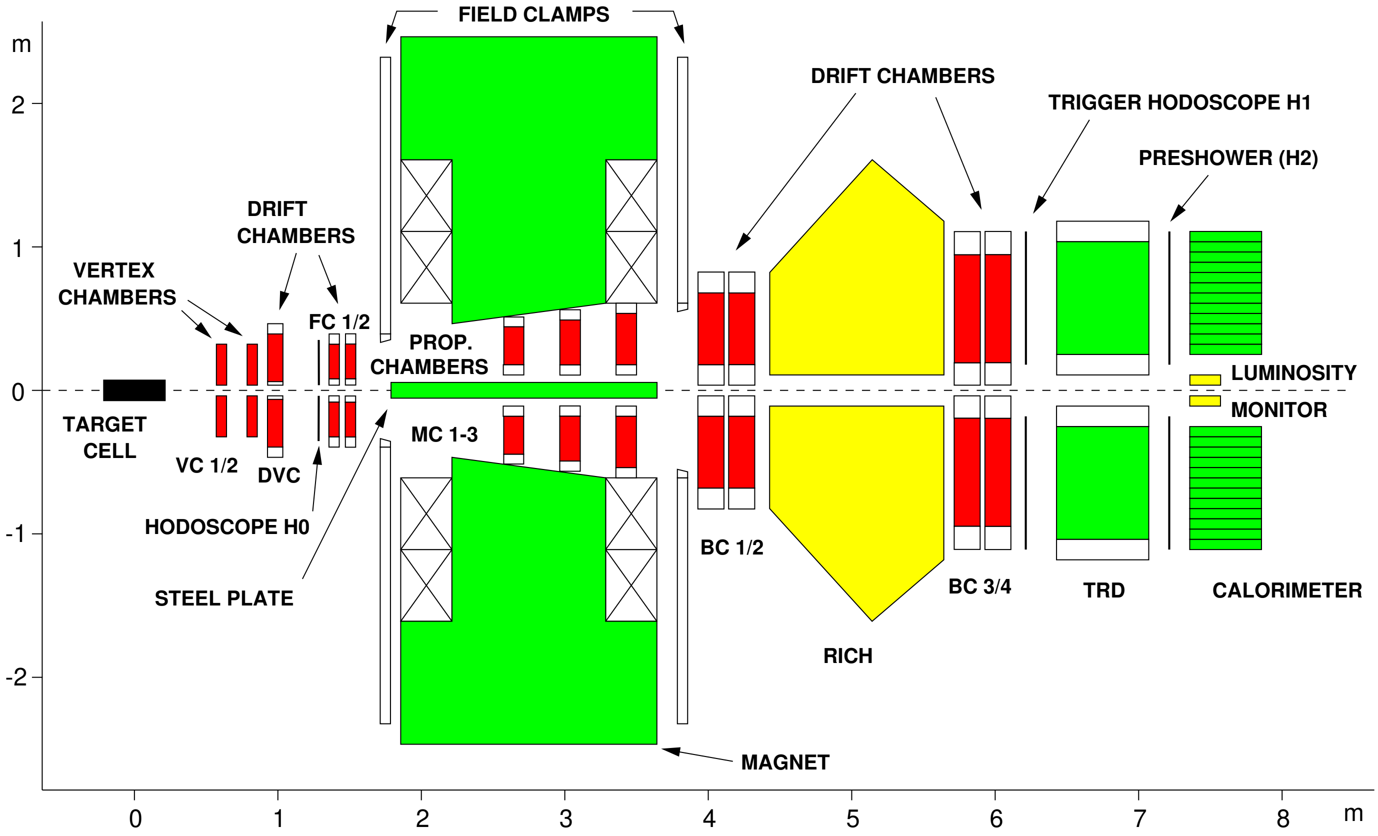
H,D target: atomic beam source based on Stern-Gerlach separation
high target density: $7.6 \cdot 10^{13}$ atoms/cm^2

polarization measured with a Breit-Rabi-polarimeter. $< P >= (88 \pm 4_{sys})\%$



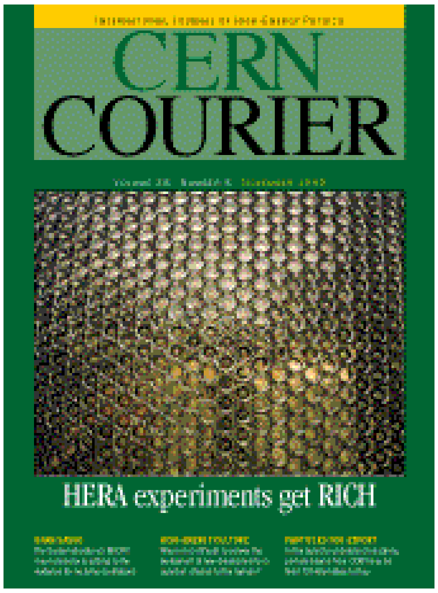
SPECTROMETER

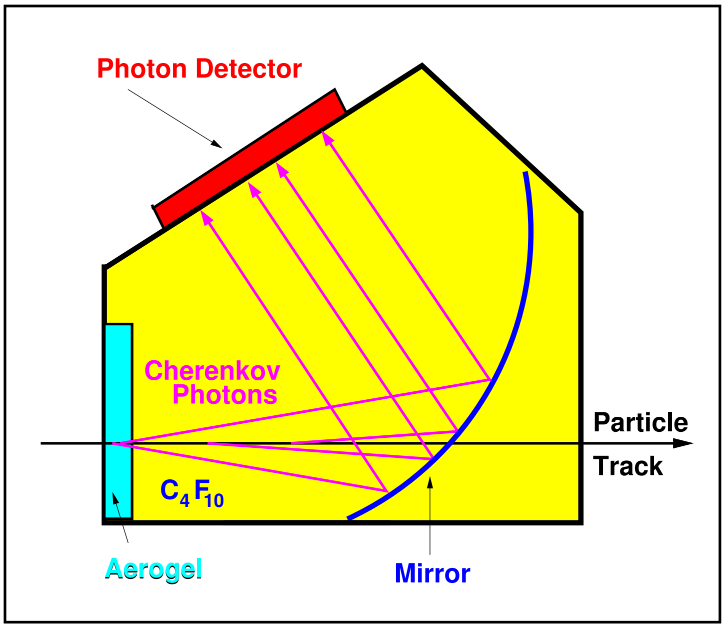


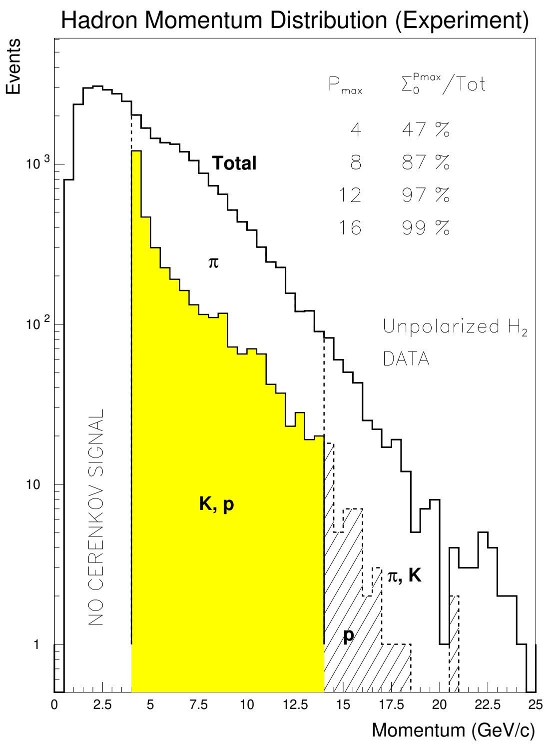


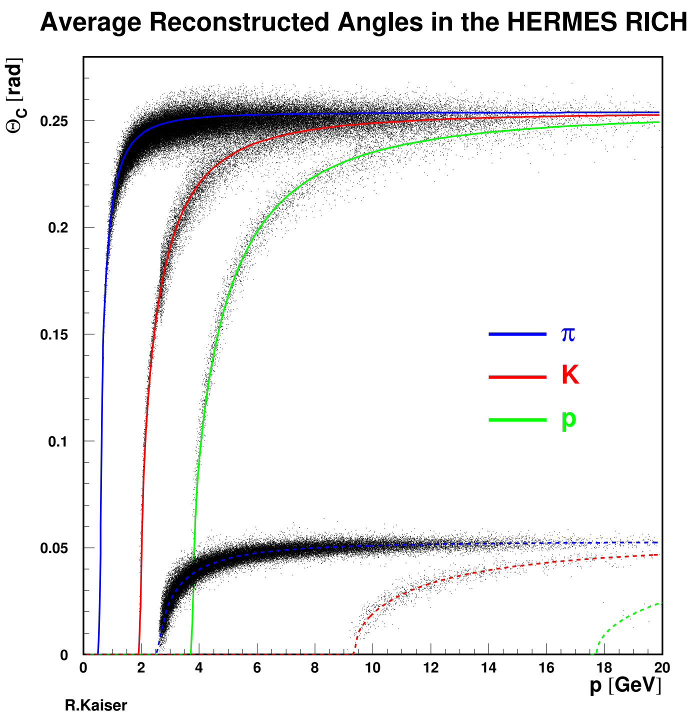
The RICH Detector

Installed in 1998, the RICH detector employs a dual radiator system and an array of 4000 PMT's to allow separation of π, K, and p across the full momentum range of 1 - 20 GeV/c.



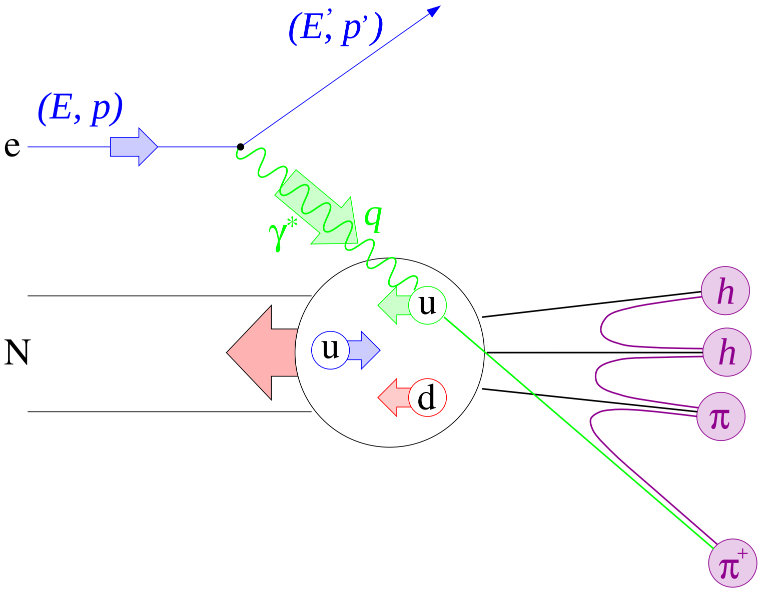






Polarized Semi-Inclusive DIS

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



$$Q^2 = 4EE' sin^2(\Theta/2)$$
$$\nu = E - E'$$
$$x = Q^2/2M\nu$$

Typical Kinematics:
$E_{e^+} = 27.5 GeV$
$x > 0.02,\ W^2 > 10 GeV^2$
$1.0 GeV^2 < Q^2 < 15 GeV^2$
$\nu < 24 GeV$

Cuts for Current fragmentation:
$z = E_h/\nu > 0.2$
$x_F \approx 2p_{\parallel}/W > 0.1$

Flavor Tagging

The flavor content of the final state hadrons is related to the flavor of the struck quark through the agency of the fragmentation functions $D_q^h(z, Q^2)$. In LO QCD:

$$A_1^h(x, Q^2) = \frac{\int_{z_{min}}^{1} dz \sum_q e_q^2 \Delta q(x, Q^2) \cdot D_q^h(z, Q^2)}{\int_{z_{min}}^{1} dz \sum_{q'} e_{q'}^2 q'(x, Q^2) \cdot D_{q'}^h(z, Q^2)}$$

Purity Analysis of Asymmetries

- Perform a simultaneous global analysis of all $A_1^h(x,z)'s$
- The photon-nucleon Asymmetry is

$$A_1^h(x,z) = \frac{\int_{z_{min}}^1 dz \sum_q e_q^2 q(x) \cdot D_q^h(z)}{\int_{z_{min}}^1 dz \sum_{q'} e_{q'}^2 q'(x) \cdot D_{q'}^h(z)} \cdot \frac{\Delta q(x)}{q(x)}$$
$$= \sum_q P_q^h(x,z) \frac{\Delta q(x)}{q(x)}$$

- The hadron quark-purity $P_q^h(x,z)$ is the probability that a quark q was struck in an event $l + N \longrightarrow l' + X$
- Purities are spin-independent quantities
- Define

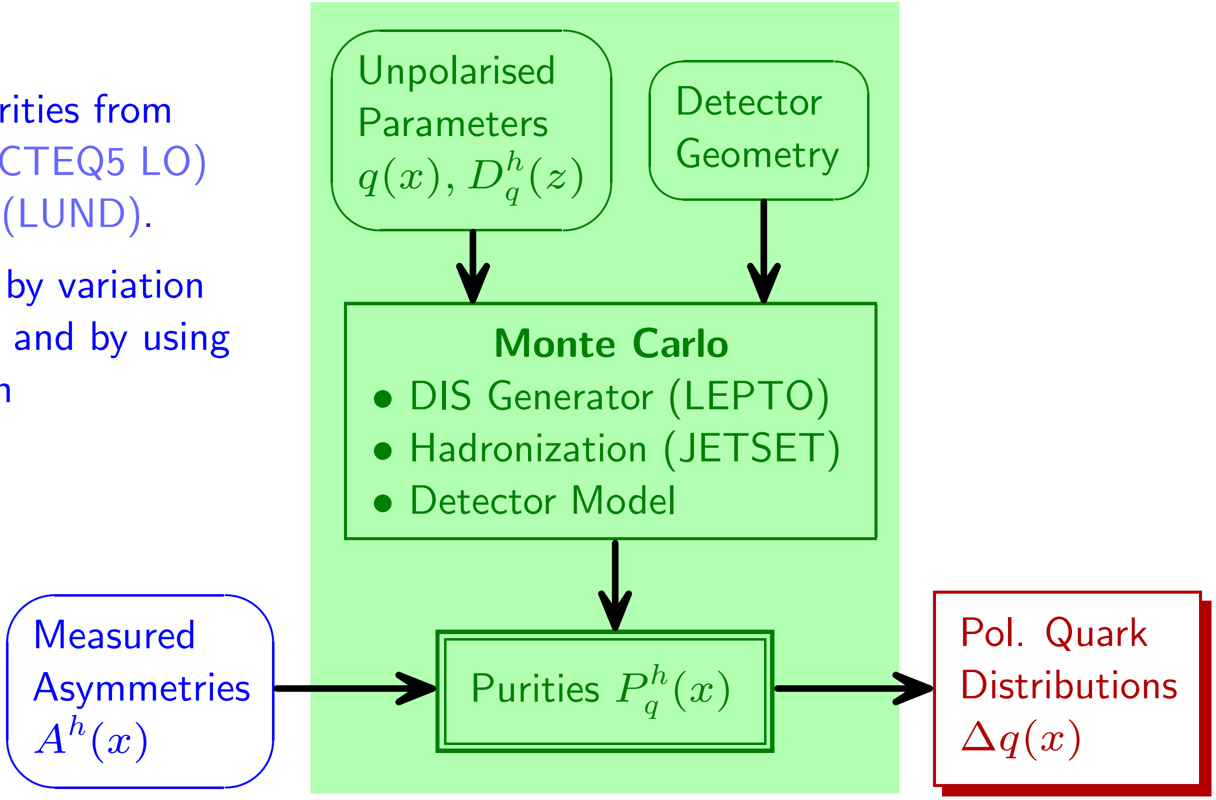
$$\vec{A} = \begin{pmatrix} A^{h_1}(x) \\ \dots \\ A^{h_n}(x) \end{pmatrix}, \vec{Q} = \begin{pmatrix} \Delta q_1(x)/q_1(x) \\ \dots \\ \Delta q_n(x)/q_n(x) \end{pmatrix}, P = [P_q^h(x)]$$

Determine quark polarizations by inverting

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

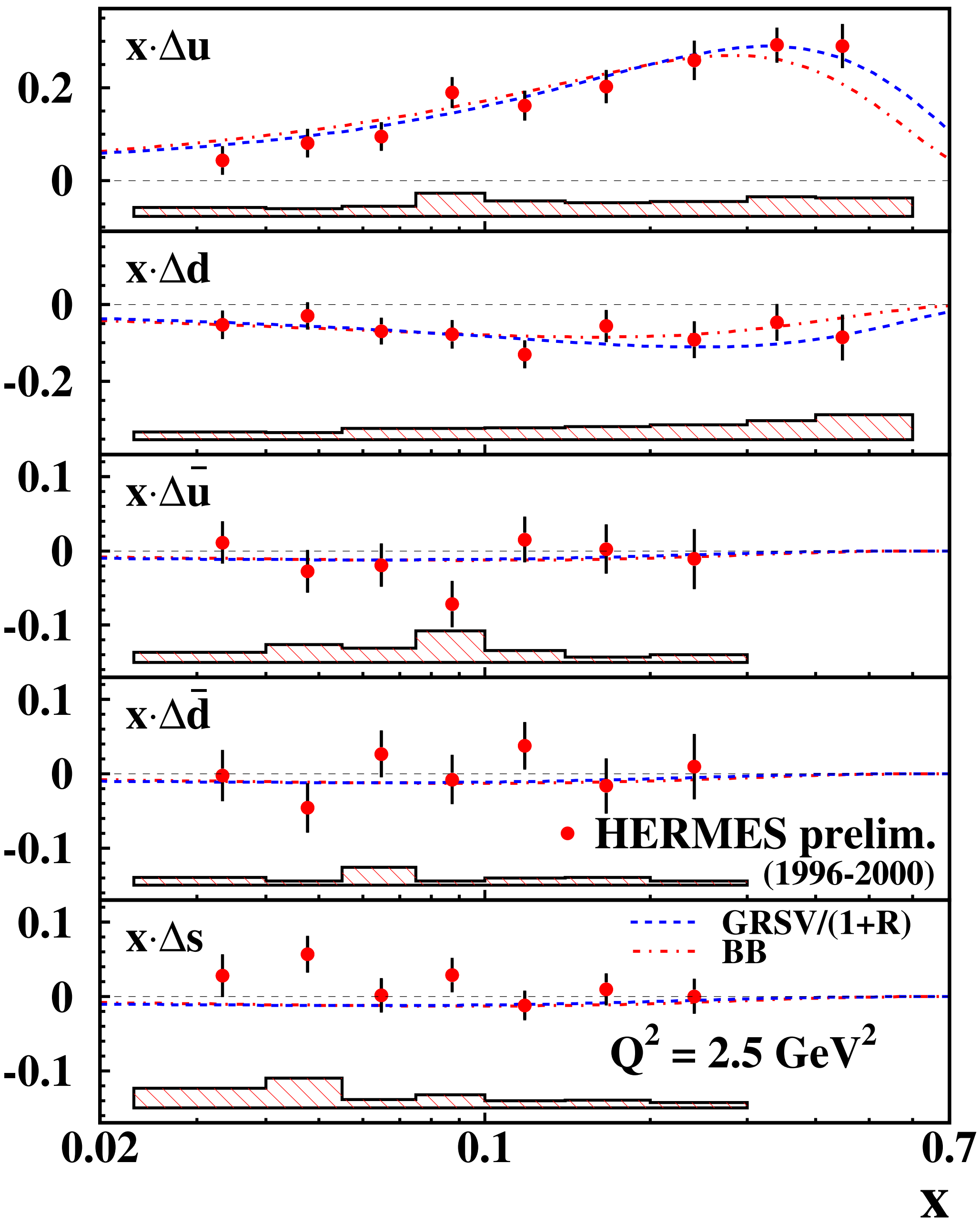
How Do We Obtain the Purities?

- ▷ Use Monte Carlo to generate purities from parameterisations of $q(x, Q^2)$ (CTEQ5 LO) and tuned fragmentation model (LUND).
- ▷ Estimate systematic uncertainty by variation of the fragmentation parameters and by using alternative PDF parameterisation (GRV98 LO).



HERMES Flavor Decomposition

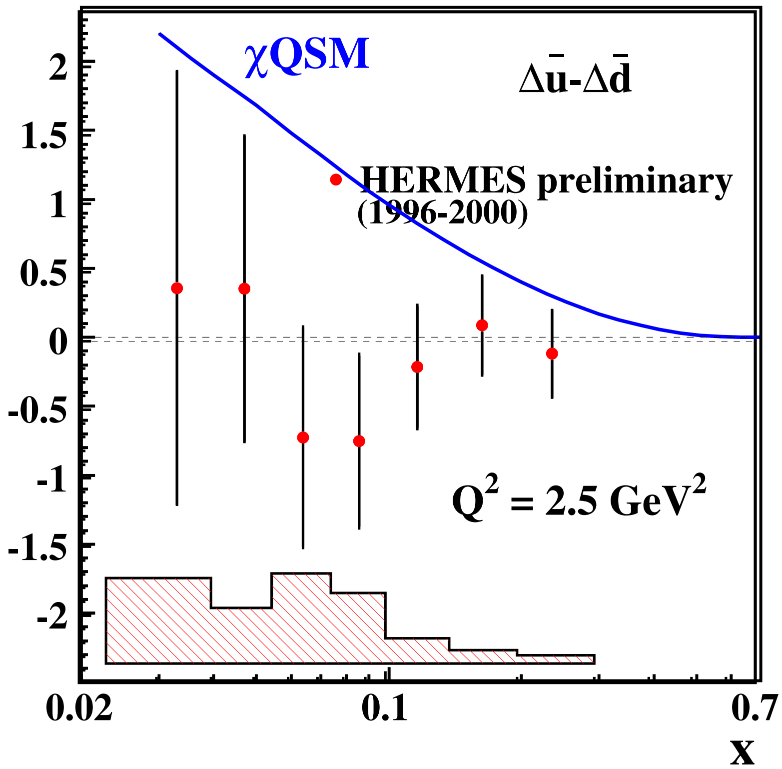
For the first time, a five component, $\Delta u, \Delta\overline{u}, \Delta d, \Delta\overline{d}, \Delta s = \Delta\overline{s}$, decomposition using $\pi's, K's, p's$:



- No evidence for significant polarization of nonstrange sea.
- The strange sea appears to be positively polarized

Remarks and Conclusions

- This is the first "direct" 5 component decomposition of quark helicity distributions using flavor tagging.
- The helicity distributions for u, d, and the nonstrange sea show trends similar to those inferred from inclusive measurements, i.e. $\Delta u >> 0$, $\Delta d < 0$, and $\Delta\overline{u} = \Delta\overline{d} \approx 0$.
- Result $\Delta(s + \overline{s}) > 0$ is unexpected. A challenge to understand since if sea results from gluon splitting, one would expect also $\Delta\overline{u} \approx \Delta\overline{d} > 0$.
- No strong breaking of the flavor symmetry of the light sea.



χQSM prediction from Dressler et al., EPJ **C14**,147 (2000)

Remarks and Conclusions(cont'd)

- The singlet strength, $\Delta q_3 = \Delta u - \Delta d$, agrees to within 1σ with the Bjorken sum rule which states

$$\Delta q_3 = \int_0^1 \Delta q^{NS}(x)dx = |\frac{g_a}{g_v}| \times C_{QCD} = 1.01 \pm 0.05$$

- Can make a measurement of Δs using $A_1^D(x)$ and $A_{1,D}^{K^+ + K^-}$:
  - Use fragmentation functions from e^+e^- collider exp's.
  - Provides an independent check on strange polarization result.
  - Two component analysis also shows $\Delta s > 0$.

- Analysis will continue with a comparison of $\Delta q_8 = \Delta u + \Delta d - 2\Delta s$ with predictions of SU(3) symmetry, i.e.

$$\Delta q_8 = (3F - D) \times C_{QCD} = 0.46 \pm 0.03$$

.

- The explanation of a large negative strange sea polarization as an explanation for the violation of the Ellis-Jaffe sum rule in inclusive scattering is ruled out.