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Experimental Results on Polarized Quark Distributions from HERMES

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‘Flavor Decomposition of the Sea Quark Helicity Distributions in the Nucleon from Semi-inclusive Deep-inelastic Scattering’

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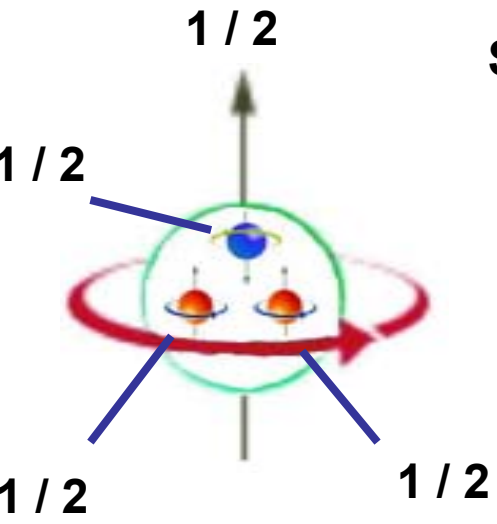
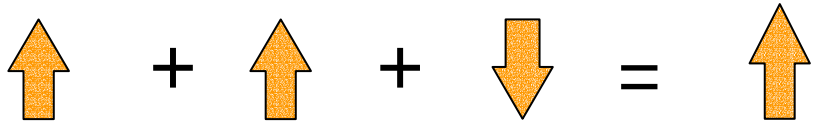
Spin of Proton



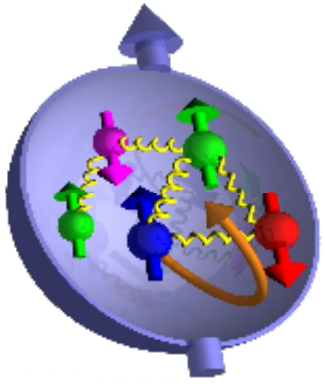
SU(6) Quark Wave Functions of Baryons

Sum of Spins of u u d Quarks = Spin of Proton

$$\frac{1}{2} + \frac{1}{2} + \left(-\frac{1}{2}\right) = \frac{1}{2}$$



EMC Experiment (1988)



$$\frac{1}{2}(\Delta u + \Delta d + \Delta s) = 0.06 \pm 0.047 \pm 0.068 \leq \frac{1}{2}$$
$$(12 \pm 9 \pm 14)\%$$

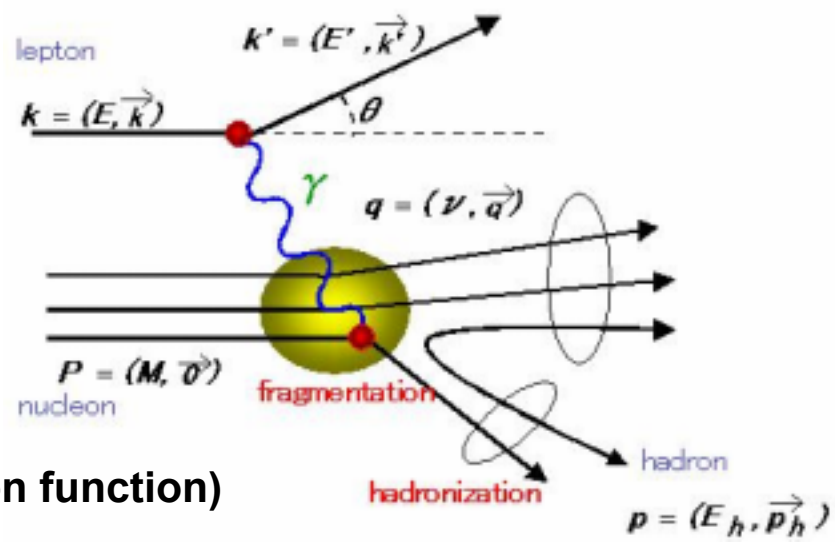
20 – 30 % of Nucleon Spin

$$\frac{1}{2} = \frac{1}{2}\sum_q (\Delta q + \Delta \bar{q}) + \Delta G + L_q + L_G$$

Deep Inelastic Scattering, Semi-inclusive Measurements

Inclusive Measurement, e'

Semi-inclusive Measurement, e' and $\pi, K, p, \bar{p}$ ...



$$\sigma_h(x,z) \propto \sum_q e_q^2 q(x) D_q^h(z)$$

(quark distribution function) * (fragmentation function)

$q(x) = q^{\leftarrow}(x) + q^{\rightarrow}(x)$ **Quark Density Distribution**

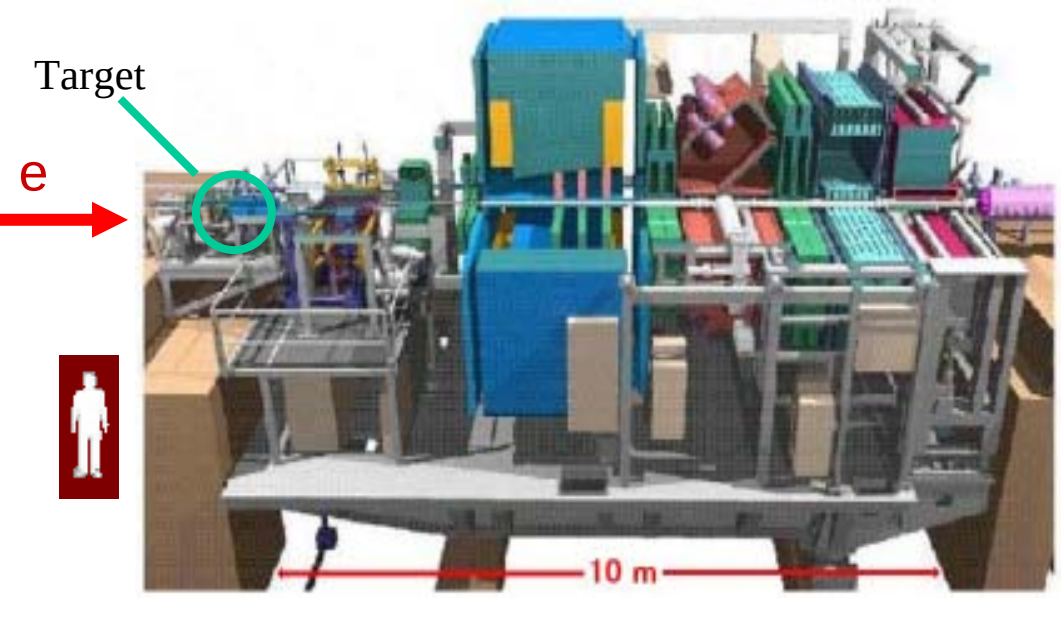
$D_q^h(z)$ **Fragmentation Function**

$\Delta q(x) = q^{\leftarrow}(x) - q^{\rightarrow}(x)$ **Quark Helicity Distribution**

The Detector, Targets, Beam

HERMES at DESY-HERA

- 27.6 GeV Polarized Electron / Positron Beam
- A Wide Acceptance Detector
- Hadron Identification with RICH
- Polarized Gas Internal Targets ^{3}He, H, D, ...



H $P_H = 0.824$ $(\pm 4.2\%)$

D $P_D = 0.844$ $(\pm 4.4\%)$

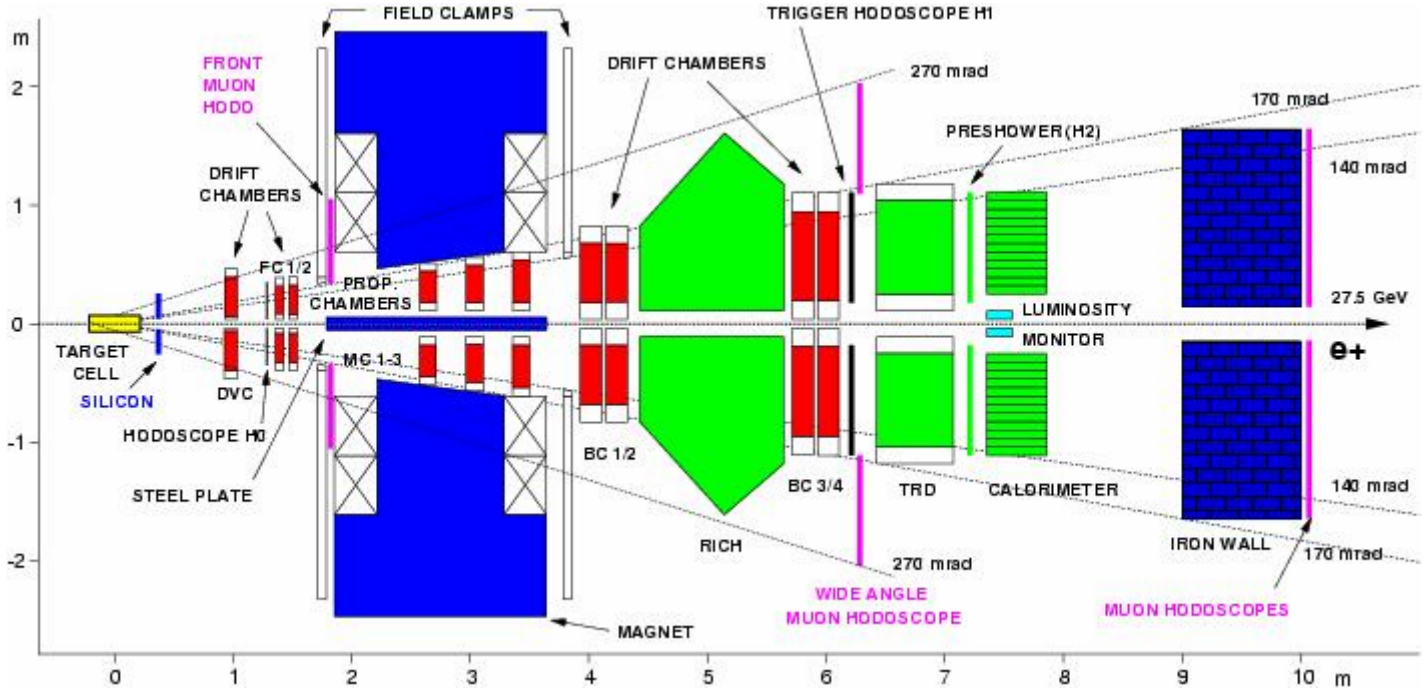
$P_B = 0.53$ $(\pm 3.4\%$ for H)
$(\pm 1.9\%$ for D)

$Q^2 > 1\,\mathrm{GeV}^2$, $W^2 > 10\,\mathrm{GeV}^2$,

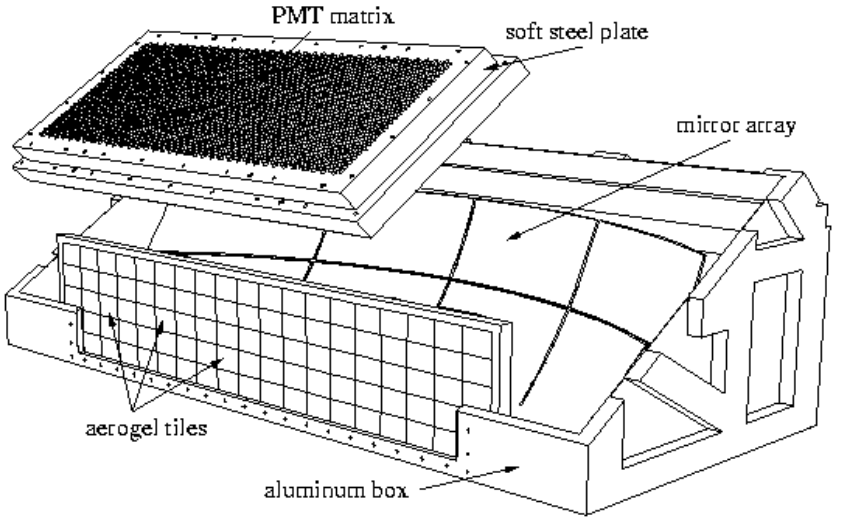
$y = \nu / E < 0.85$, $0.2 < z = E_h / \nu < 0$

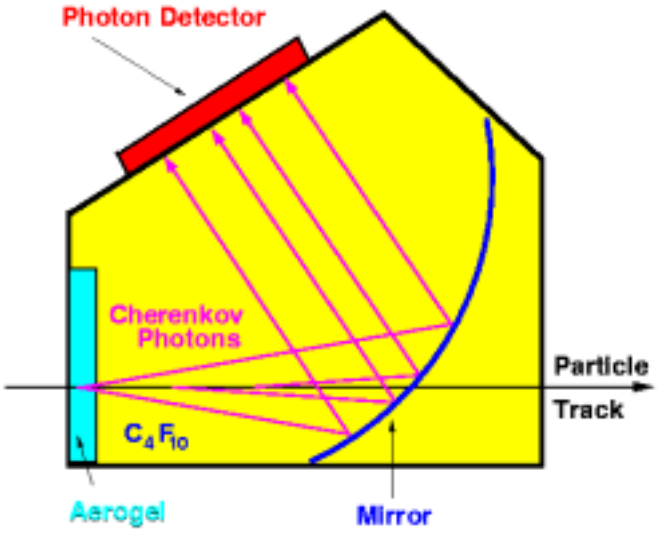
$x_F \approx 2p_L / W > 0.1$

HERMES Spectrometer



RICH with Dual Radiators



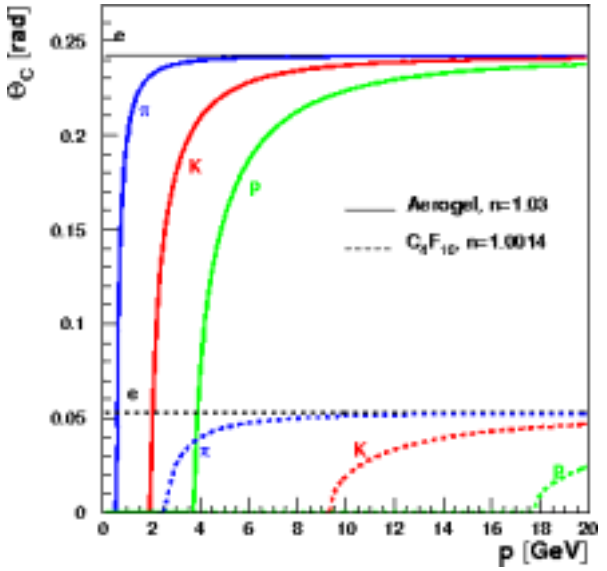


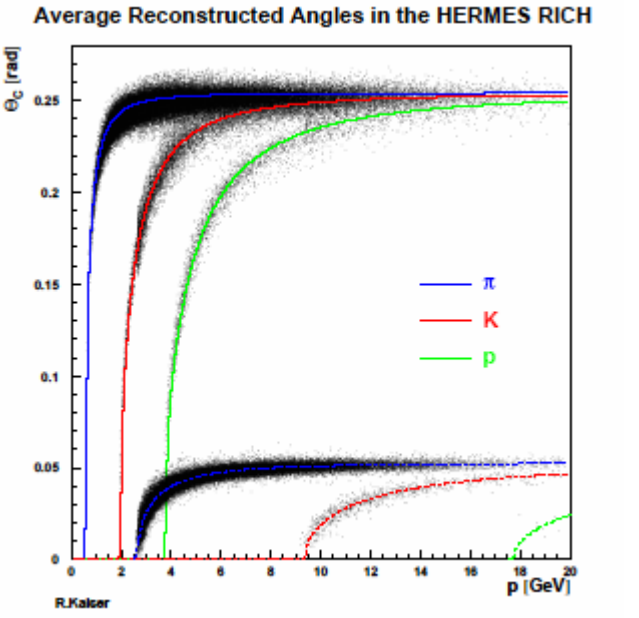
Cherenkov Radiators

Ring Imaging Cherenkov Counter (RICH) of HERMES

Aerogel n = 1.03

C_4F_{10} Gas n = 1.0014

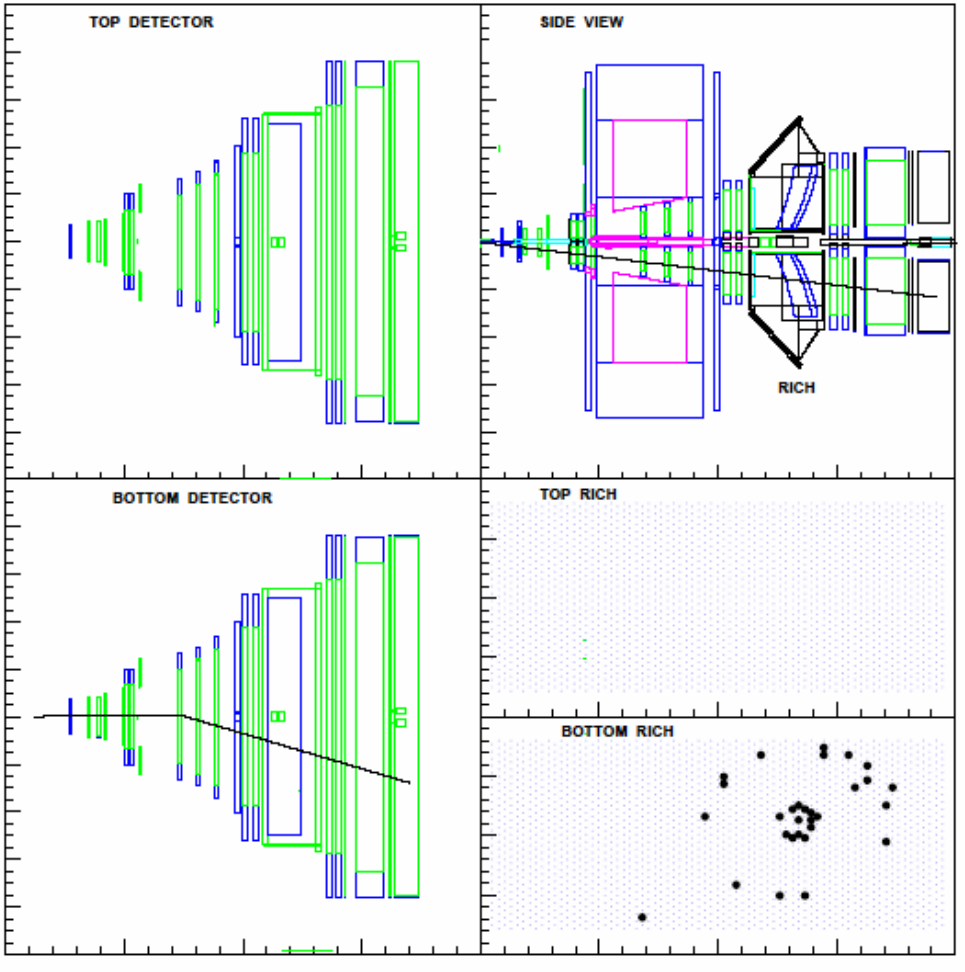




Online Event Display

Top

Side



Bottom

Clean single electron event

Double Spin Asymmetry

$$\vec{e} + \vec{N} \rightarrow e' + m + X$$

Double-Spin Asymmetry

Lepton Scattering Asymmetry $A_{\parallel}^{h}$

Semi-Inclusive Virtual Photon Absorption Asymmetry A_{1}^{h}

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

$$\gamma^2 = Q^2 / \nu^2$$

D Depolarization Factor

Semi-inclusive Virtual Photon Absorption Cross Section (LO)

$$\sigma_h(x,z) \propto \sum_q e_q^2\, q(x) D_q^h(z)$$

$$z = E_h / \nu$$

Flavor Decomposition of Quark Helicity Distributions

Double-Spin Asymmetry

$$A_1^h(x,z) = \frac{\sigma_h^{\uparrow\downarrow}(x,z) - \sigma_h^{\uparrow\uparrow}(x,z)}{\sigma_h^{\uparrow\downarrow}(x,z) + \sigma_h^{\uparrow\uparrow}(x,z)} = \frac{\sum_q e_q^2 \Delta q(x) D_q^h(z)}{\sum_q e_q^2 q(x) D_q^h(z)} \cdot \frac{(1+R(x))}{(1+\gamma^2)}$$

Integrating over *z*,

$$A_1^h(x) = \frac{\sum_q e_q^2 \int D_q^h(z)dz \; \Delta q(x)}{\sum_{q'} e_{q'}^2 q'(x) \int D_{q'}^h(z)dz} \cdot \frac{(1+R(x))}{(1+\gamma^2)}$$

$$= \sum_q P_q^h(x) \cdot \frac{\Delta q(x)}{q(x)} \cdot \frac{(1+R(x))}{(1+\gamma^2)}$$

$$\vec{A}(x) = P(x) \cdot \vec{Q}(x)$$

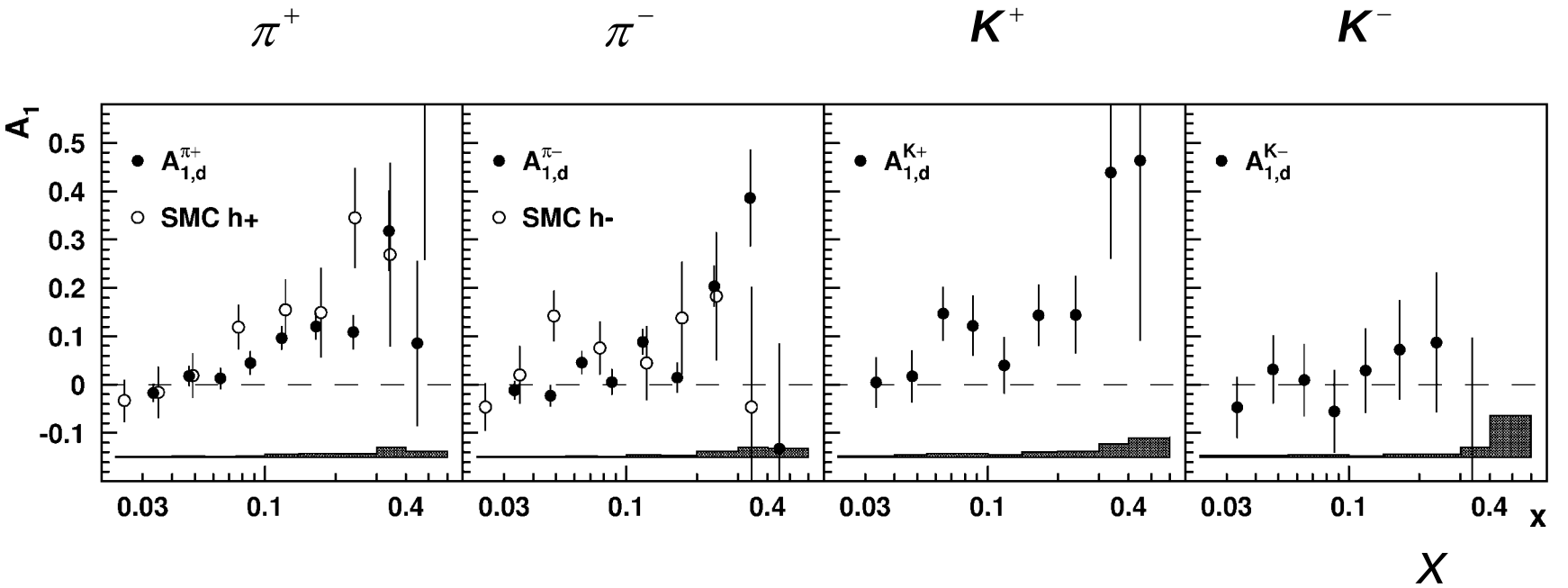
$$\vec{A}(x) = (A_{1p}, A_{1p}^{\pi^+}, A_{1p}^{\pi^-}, A_{1d}, A_{1d}^{\pi^+}, A_{1d}^{\pi^-}, A_{1d}^{K^+}, A_{1d}^{K^-})$$

P: Purity

$$\vec{Q}(x) = \left(\frac{\Delta u}{u}, \frac{\Delta d}{d}, \frac{\Delta \bar{u}}{\bar{u}}, \frac{\Delta \bar{d}}{\bar{d}}, \frac{\Delta s}{s}, \frac{\Delta \bar{s}}{\bar{s}} = 0 \pm \frac{1}{\sqrt{3}}\right)$$

$A_{1,d}^{h}(x)$ Asymmetry

Deuterium Target



A_1 increases with x

$$A_{1,d}^{K^+} > A_{1,d}^{K^-}$$

Purity

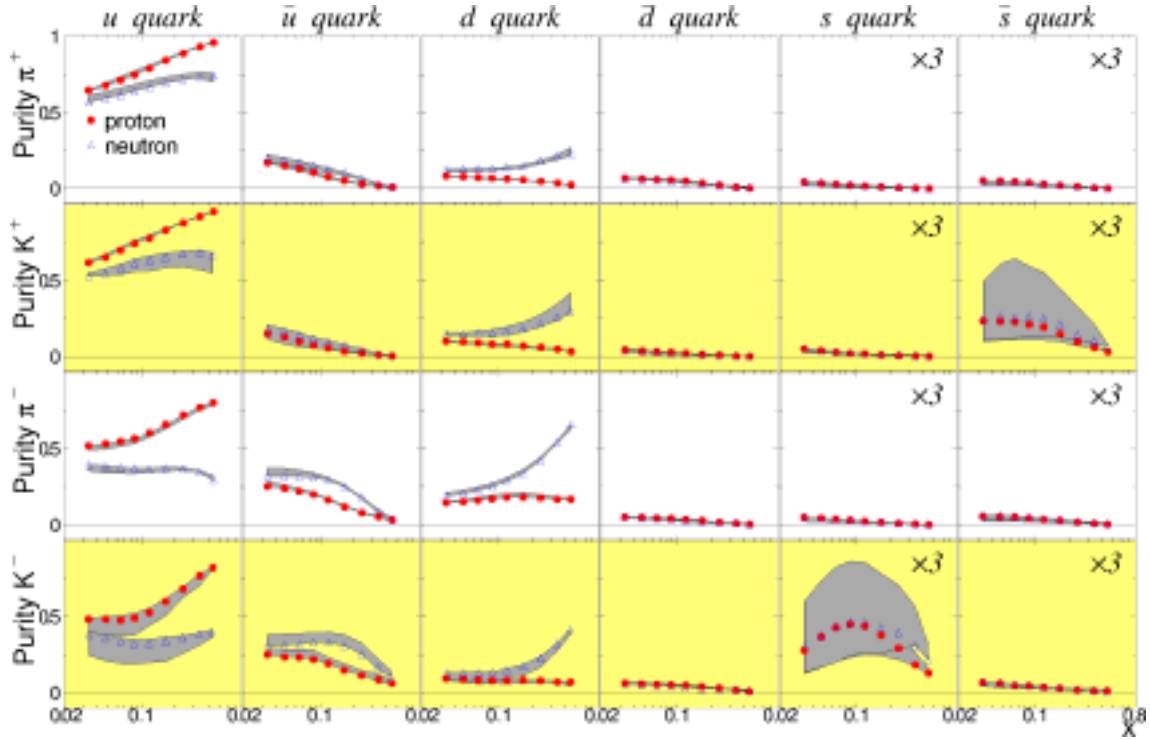
u $\bar{u}$ d $\bar{d}$ s $\bar{s}$

π^+ $(u\bar{d})$

K^+ $(u\bar{s})$

π^- $(\bar{u}d)$

K^- $(\bar{u}s)$



x

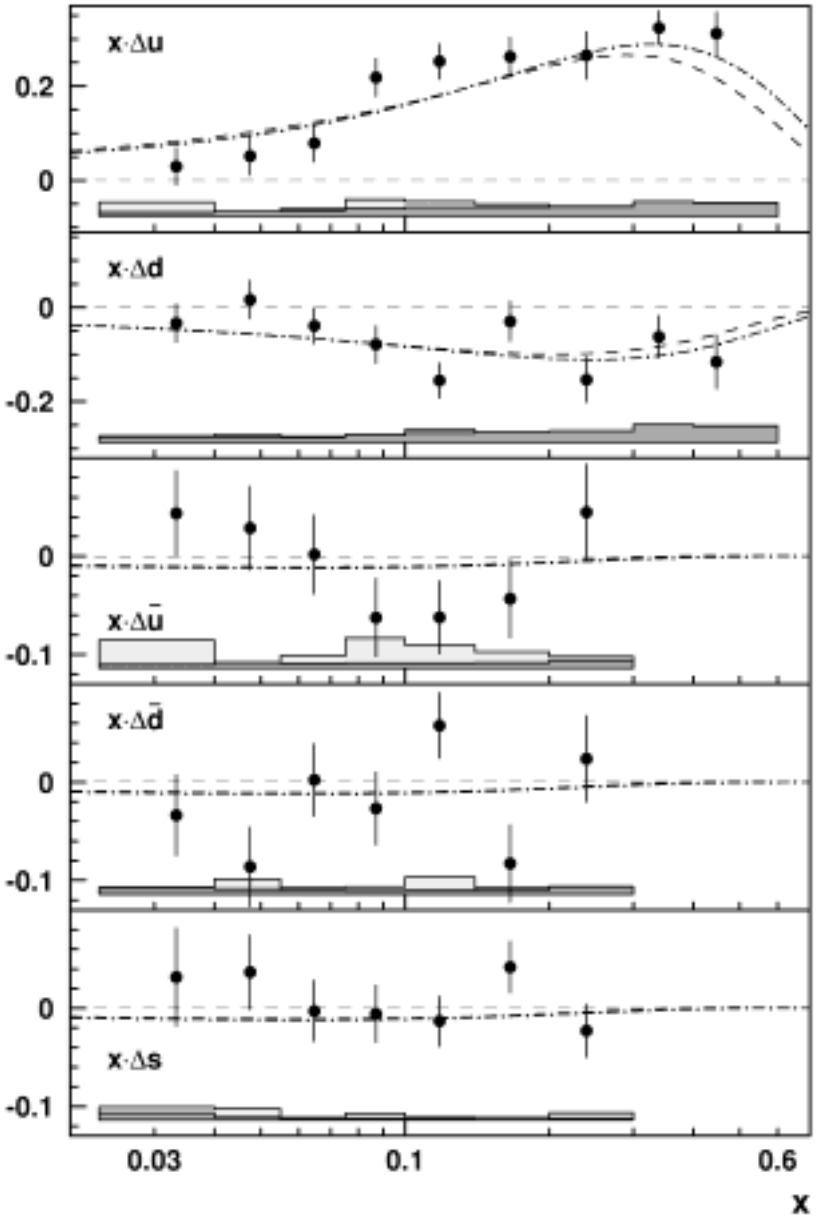
Some Features

No Functional Forms for $\frac{\Delta q(x)}{q(x)}$ need to be assumed.

No first Moments fixed.

SU(3) Symmetry not assumed.

x **bin by bin Analysis except for Smearing Correction**



hermes

Systematic Errors:

Light Error Bar – Fragmentation Model

Dark Error Bar - Asymmetries

Positive	$\Delta u(x)$
Negative	$\Delta d(x)$
Nearly Zero	$\Delta \bar{q}(x)$

Bluemlein and Boettcher (Scenario 1)

Glueck et al. (Standard Scenario)

Strangeness Helicity Distribution

$0.023 < x < 0.3$, x Integral of $\Delta s(x)$, or $\Delta s(x) + \Delta \bar{s}(x)$

This Analysis : $+0.03 \pm 0.03(\text{stat.}) \pm 0.01(\text{syst.})$

Inclusive + SU(3) : -0.02

Hyperon Beta Decay

These Two are not in Contradiction

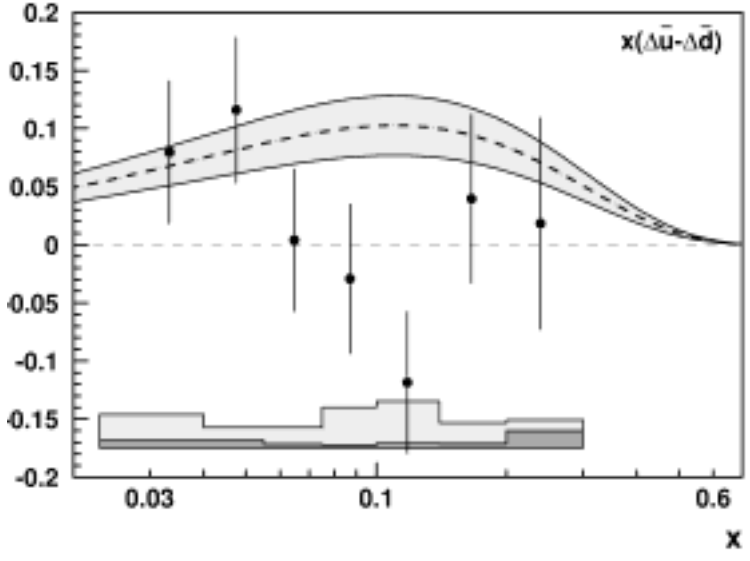
Test of Flavor Symmetry of Sea Quark Helicity Distributions

$$\Delta\bar{u}(x) - \Delta\bar{d}(x)$$

Integration in the measured Region, $0.023 < x < 0.3$

Experiment : $+0.05 \pm 0.06\,(\text{stat.}) \pm 0.03\,(\text{syst.})$

Theory : $+0.21 \pm 0.05$



Flavor Symmetry in Polarized Sea:
No Evidence of Large Asymmetry.

Chiral Quark Soliton Model, B. Dressler et al.

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

Conclusions

- HERMES uses Polarized Positron/Electron Beam of 27.6 GeV and Polarized Gas Internal Targets. For this Analysis, H and D.
- HERMES has a good Particle Identification $(\pi^{\pm}, K^{\pm}, p, \bar{p})$ with RICH of Aerogel and C_4F_{10} Gas
- $A_1^h(x)$ was obtained from Semi-Inclusive Measurements
- Five Component Analysis of $\Delta q(x)$ was carried out for the First Time
- Without Assuming Functional Forms or First Moments, positive $\Delta u(x)$, negative $\Delta d(x)$, and nearly zero $\Delta \bar{q}(x)$ were obtained
- Flavor Asymmetry of the Sea Quark Helicity Distributions was tested for the First Time