Polarized Parton Distributions Measured at the HERMES Experiment

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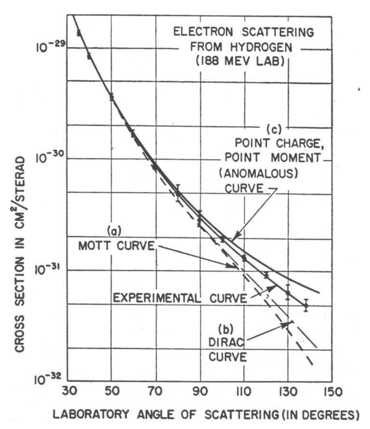
Introduction

McAllister, Hofstadter (1956): Elastic electron scattering experiments indicate structure within the proton.



EMC (1988): Measurements of the polarized nucleon structure show that the quark constituents carry only a small fraction of the nucleon spin.

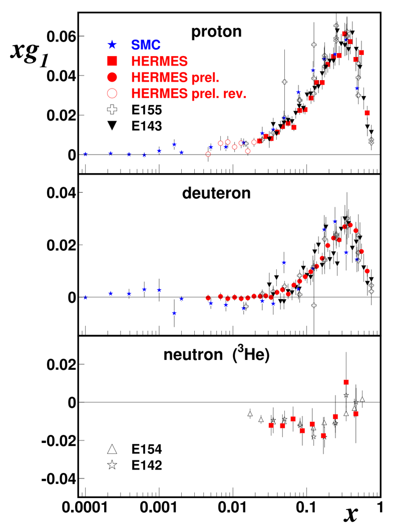
$\int_0^1 g_1^p(x)\mathrm{d}x = 0.114 \pm 0.012 \pm 0.026$

Assuming $\Delta s = 0$:

$\langle S_z \rangle_u = \frac{1}{2}\Delta u = 0.348 \pm 0.023 \pm 0.051$

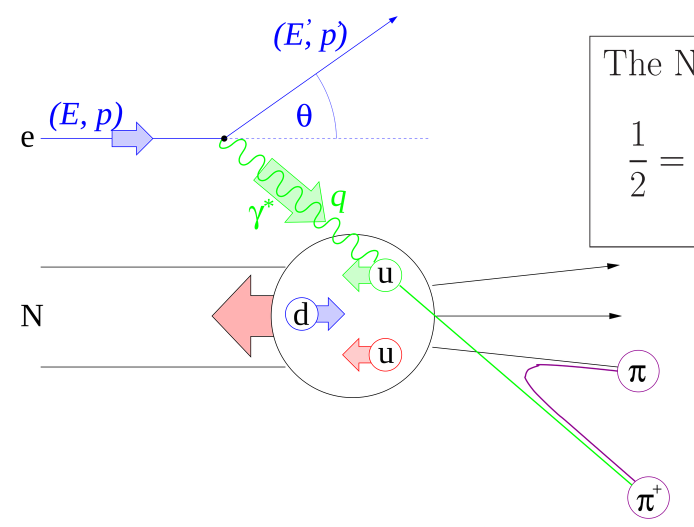
$\langle S_z \rangle_d = \frac{1}{2}\Delta d = -0.280 \pm 0.023 \pm 0.051$

⇨ "Proton spin crisis"



(2002): A wealth of inclusive data describes the polarized nucleon structure function g_1.

Polarized Deep Inelastic Scattering



The Nucleon Spin:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + (L_q + L_g)$$

$Q^2 \stackrel{\text{lab}}{=} 4EE' \sin^2\frac{\theta}{2}$

$\nu \stackrel{\text{lab}}{=} E - E'$

$x = Q^2/(2M\nu)$

$W^2 \stackrel{\text{lab}}{=} M^2 + 2M\nu - Q^2$

Inclusive DIS: $e + N \to e' + X$

Measure $\Delta\Sigma = (\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s})$

Semi-inclusive DIS: $e + N \to e' + h + X$

Measure $\Delta u, \Delta\bar{u}, \Delta d, \Delta\bar{d}, \Delta s, \Delta\bar{s}$

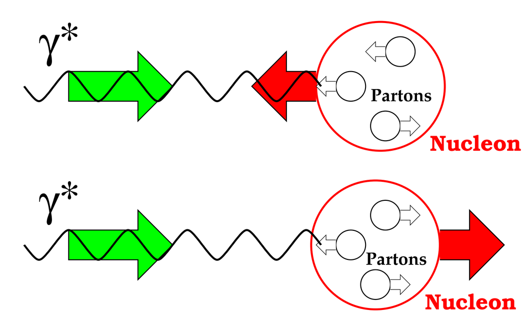
Double Spin Asymmetries

Electron-nucleon asymmetry $A_\parallel$:

$$A_\parallel = \frac{1}{\langle P_B P_T \rangle} \frac{(N/L)^{\uparrow\downarrow} - (N/L)^{\uparrow\uparrow}}{(N/L)^{\uparrow\downarrow} + (N/L)^{\uparrow\uparrow}}$$

Virtual photon-nucleon asymmetry A_1:

$$A_1(x, Q^2) = A_\parallel(x, Q^2) / \left[(1 + \eta\gamma)\, D(x, Q^2)\right]$$



$\Delta q = q_+ - q_-$

$q = q_+ + q_-$

The Purity Formalism

Inclusive asymmetry:

$$A_1(x, Q^2) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \stackrel{g_2=0}{\simeq} \frac{g_1(x, Q^2)}{F_1(x, Q^2)} = \frac{\frac{1}{2}\sum_f e_f^2\, \Delta q_f(x, Q^2)}{\frac{1}{2}\sum_f e_f^2\, q_f(x, Q^2)}$$

Semi-inclusive asymmetry of hadron h:

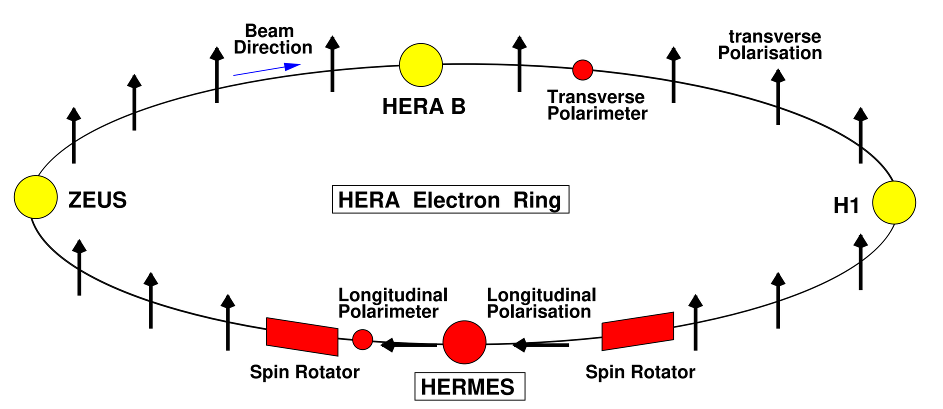
$$A_1^h(x) \stackrel{g_2=0}{\simeq} \frac{\sum_f e_f^2\, \Delta q_f(x) \int \mathrm{d}z\, D_f^h(z)}{\sum_{f'} e_{f'}^2\, q_{f'}(x) \int \mathrm{d}z\, D_{f'}^h(z)}$$

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

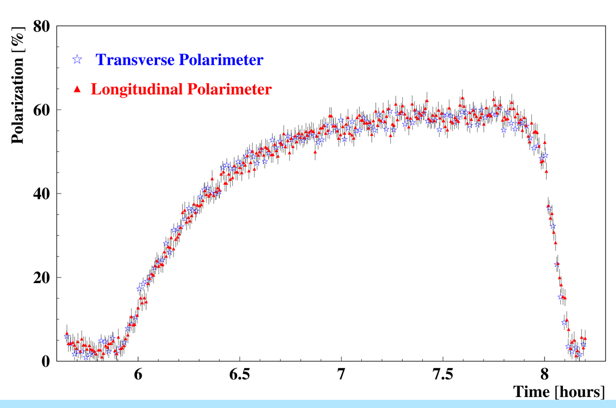
Combine asymmetries on various targets and solve system of linear equations:

$$\vec{A}(x) = \mathbf{P}_f^h(x) \cdot \vec{Q}(x) \qquad \vec{Q} = \left(\frac{\Delta u}{u}, \frac{\Delta d}{d}, \frac{\Delta\bar{u}}{\bar{u}}, \frac{\Delta\bar{d}}{\bar{d}}, \frac{\Delta s + \Delta\bar{s}}{s + \bar{s}}\right)$$

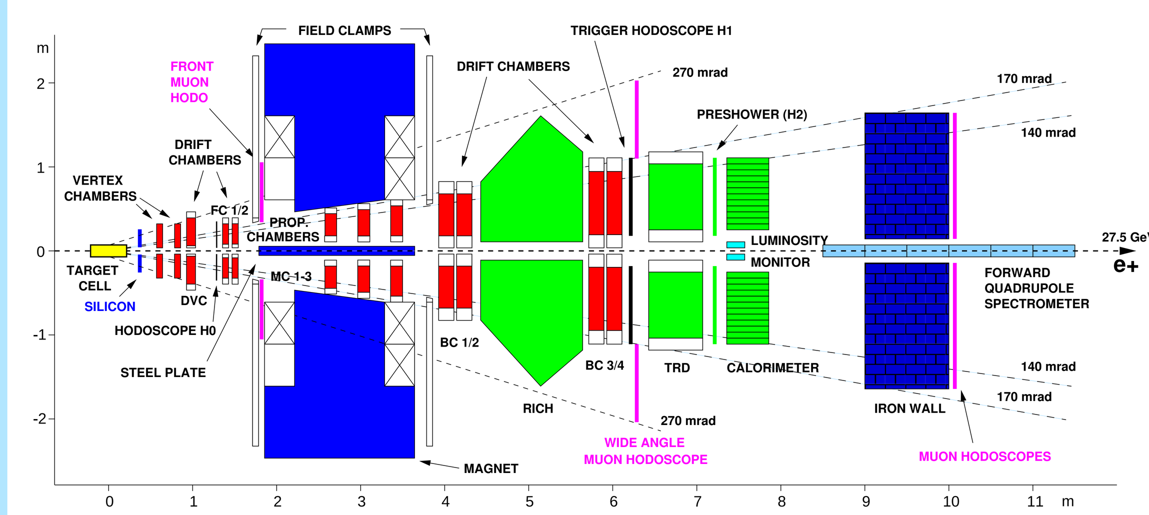
HERA at DESY



- 27.5GeV electron beam [920GeV proton beam]
- e-beam self-polarizing (Sokolov Ternov effect)
- Average polarization: 55%

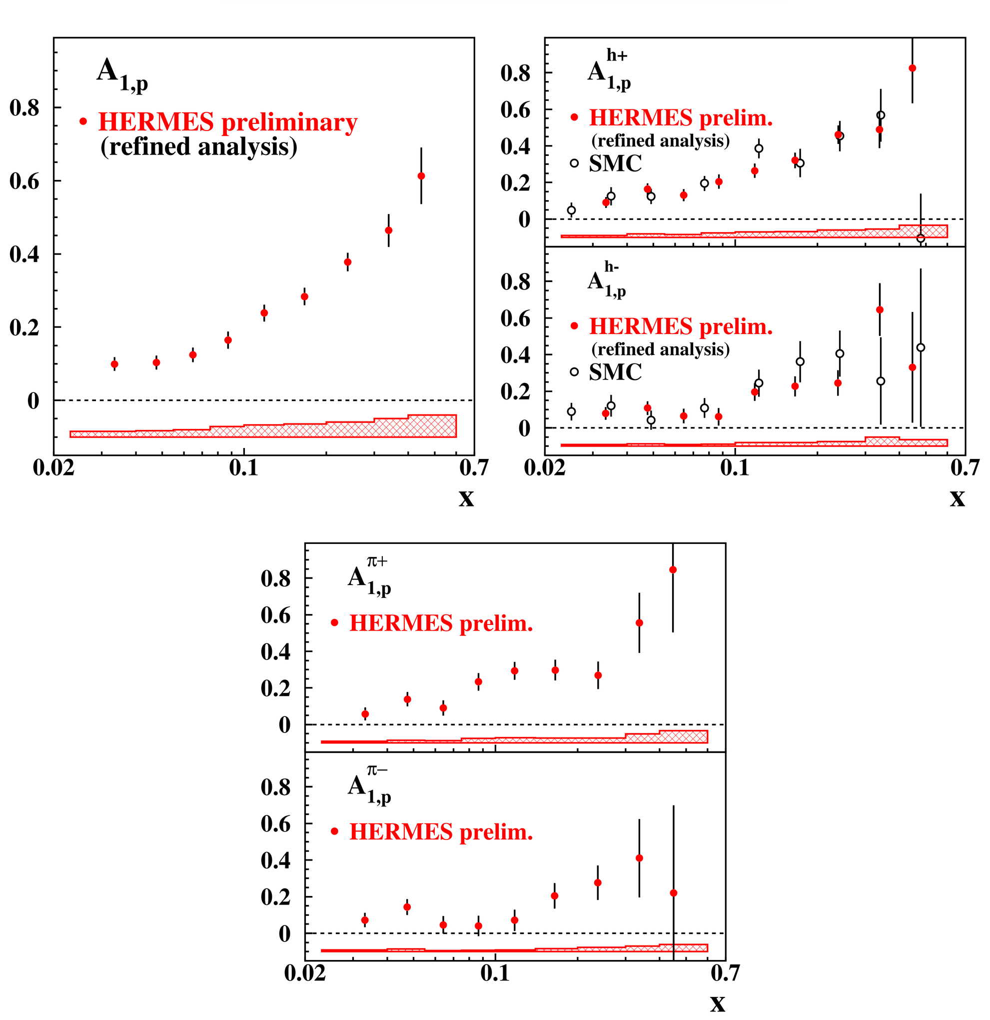


The HERMES Spectrometer

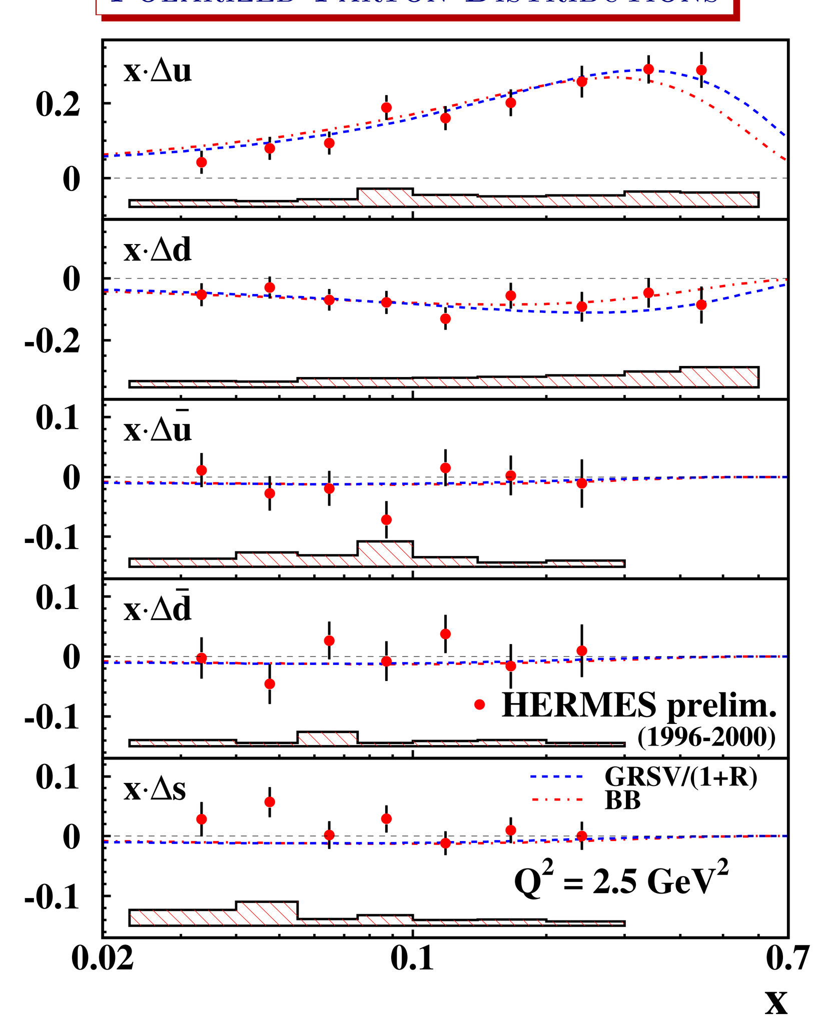


- Angular resolution $\Delta\theta < 0.6$mrad, momentum resolution $\Delta p/p = 0.7 \ldots 1.3\%$
- Lepton identification efficiency $\sim 98\%$ with hadron contaminations $< 1\%$
- Čerenkov counter replaced by a RICH detector in 1998

Asymmetries on the Proton



Polarized Parton Distributions



Asymmetries on the Deuteron