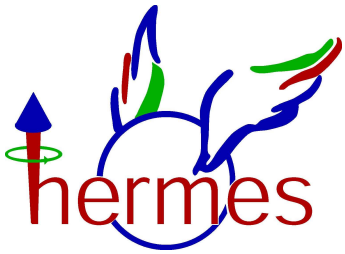
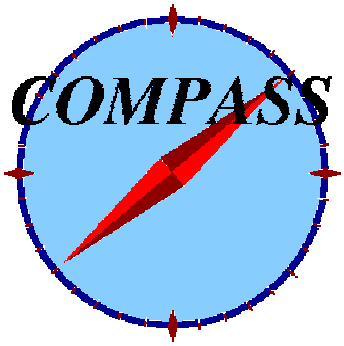
Structure Functions and the Spin of the Nucleon:

From 

to 

Fritz-Herbert Heinsius (Universität Freiburg)

I. Spin of the Nucleon

II. HERMES results

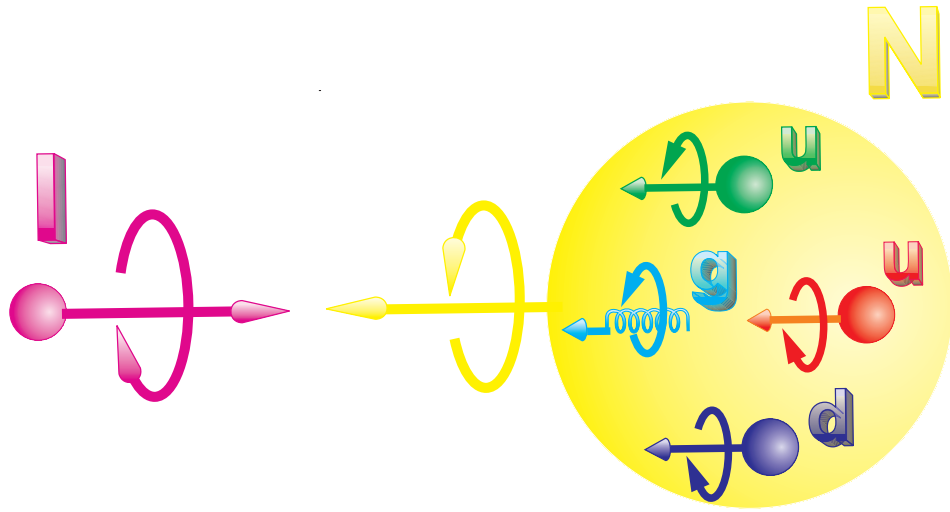
III. COMPASS prospects

XXXVI. Recontres des Moriond, March 2001

bmb+f - Förderschwerpunkt HERMES Großgeräte der physikalischen Grundlagenforschung

bmb+f - Förderschwerpunkt COMPASS Großgeräte der physikalischen Grundlagenforschung

I. Spin of the Nucleon



$$\tfrac{1}{2} = \tfrac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

- $\Delta\Sigma = \Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s}$

  probed in deep inelastic scattering

  HERMES: $\Delta\Sigma$=0.30±0.04±0.09
- $\Delta G \rightarrow$ photon gluon fusion
- J_q=1/2 $\Delta\Sigma$ +L_q

  measure generalized parton distributions

Models for Proton Spin

- Non-relativistic Quark Model
  - Pure valence description of constituent quarks
    no quark sea, no glue
    $\Delta u = +4/3$, $\Delta d = -1/3 \rightarrow \Delta\Sigma = 1$

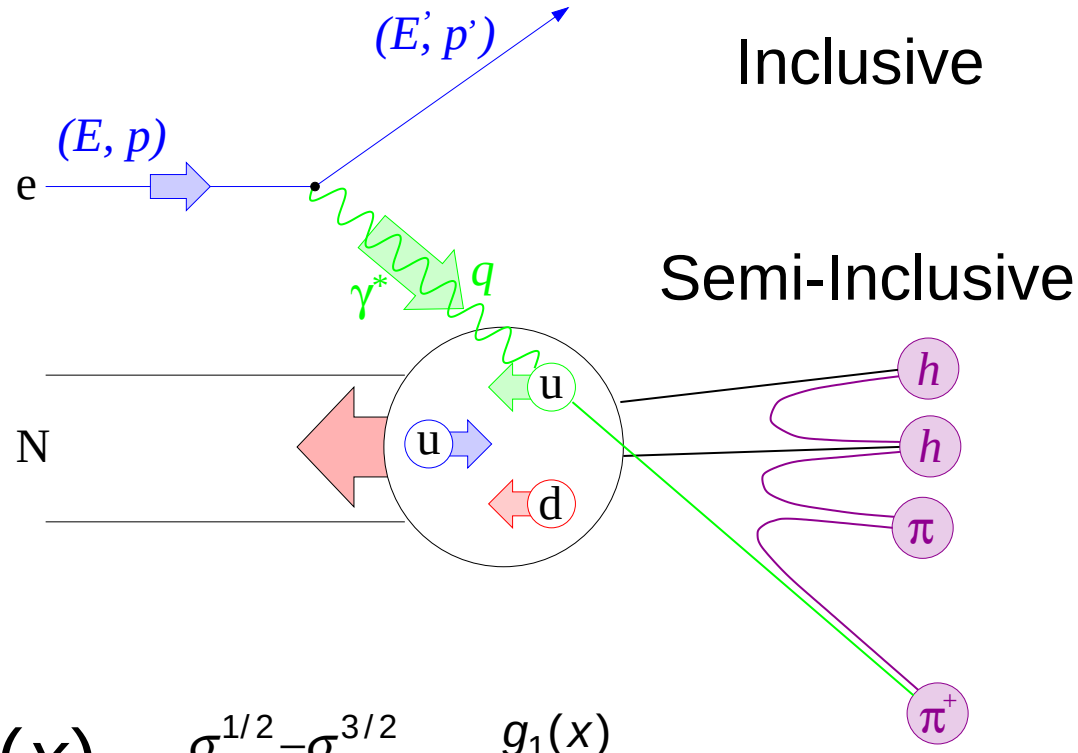
- Relativistic Quark Model — Jaffe, Manohar, NP B337(1990) 509
  - $\Delta\Sigma \approx 0.60 - 0.75$, $J_q = 1/2$ — no glue

- QCD sum rule approach: — Balitski, Ji, PRL 79 (1997) 1225
  - Gauge invariant definition $J_q + J_g = ½$
    $J_q = ½\,\Delta\Sigma + L_q = 0.15$
    $J_g = \Delta G + L_g = 0.35$ — glue large

- Lattice QCD — Güsken et al, PR D59 (1999) 114502
  Full QCD Lattice calculation:
  $\Delta u = 0.62(7)$, $\Delta d = -0.29(6)$, $\Delta s = -0.12(7)$

- Chiral Soliton Model (Instanton Model)
  - Predicts flavor asymmetry of the polarized anti-quark distribution
    Dressler et al, EPJ C14, 147 (2000) 147

Polarized Deep Inelastic Scattering



Inclusive

Semi-Inclusive

$$A_1(x) = \frac{\sigma^{1/2} - \sigma^{3/2}}{\sigma^{1/2} + \sigma^{3/2}} \approx \frac{g_1(x)}{F_1(x)}$$

$$F_1(x) = \tfrac{1}{2} \sum_f e_f^2 q_f(x)$$

$$g_1(x) = \tfrac{1}{2} \sum_f e_f^2 \Delta q_f(x)$$

$$\Delta q_f(x) = q_f^{\uparrow}(x) - q_f^{\downarrow}(x)$$

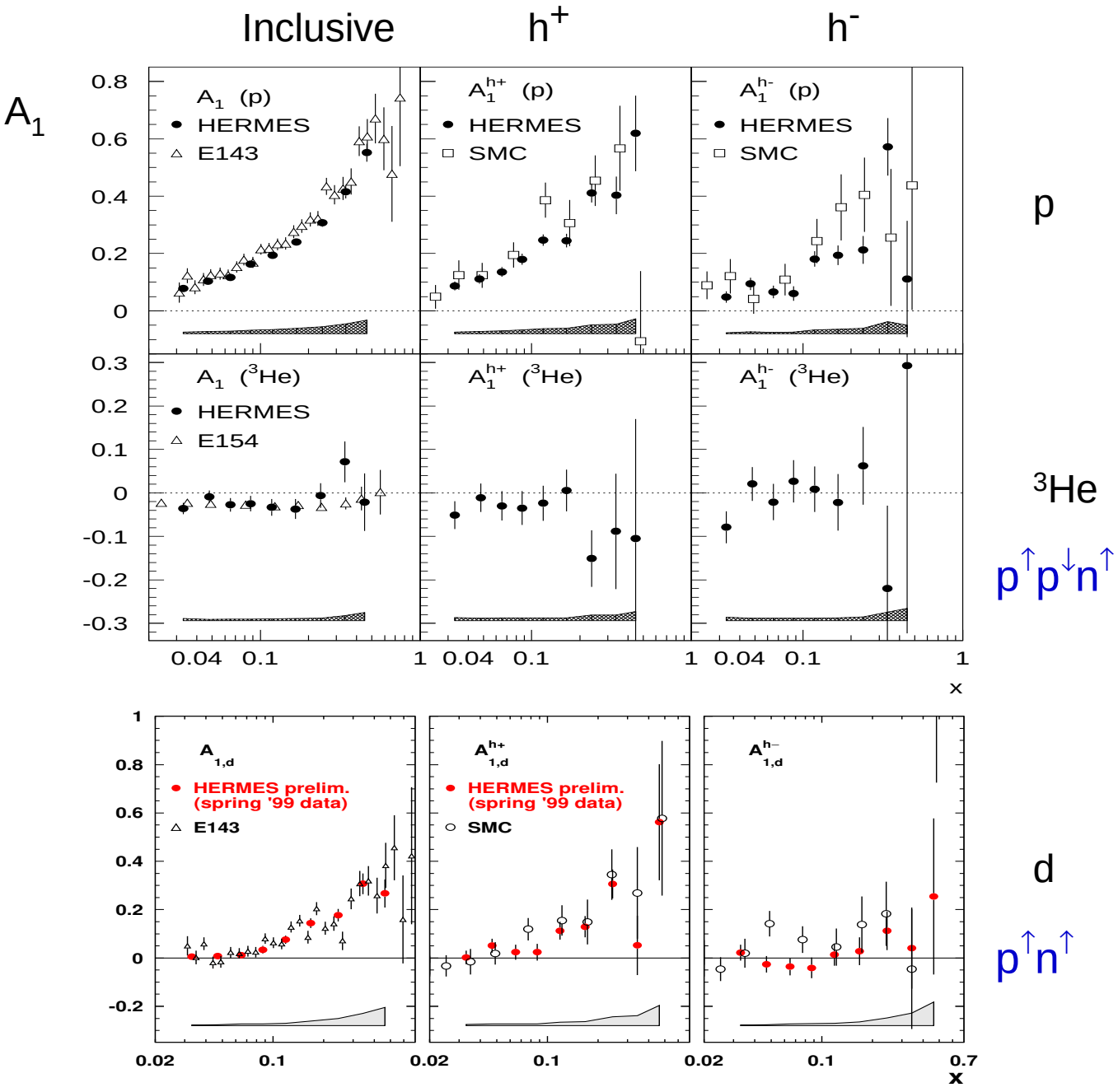
$$Q^2 = -q^2$$

$$x = \frac{Q^2}{2M_N \nu}$$

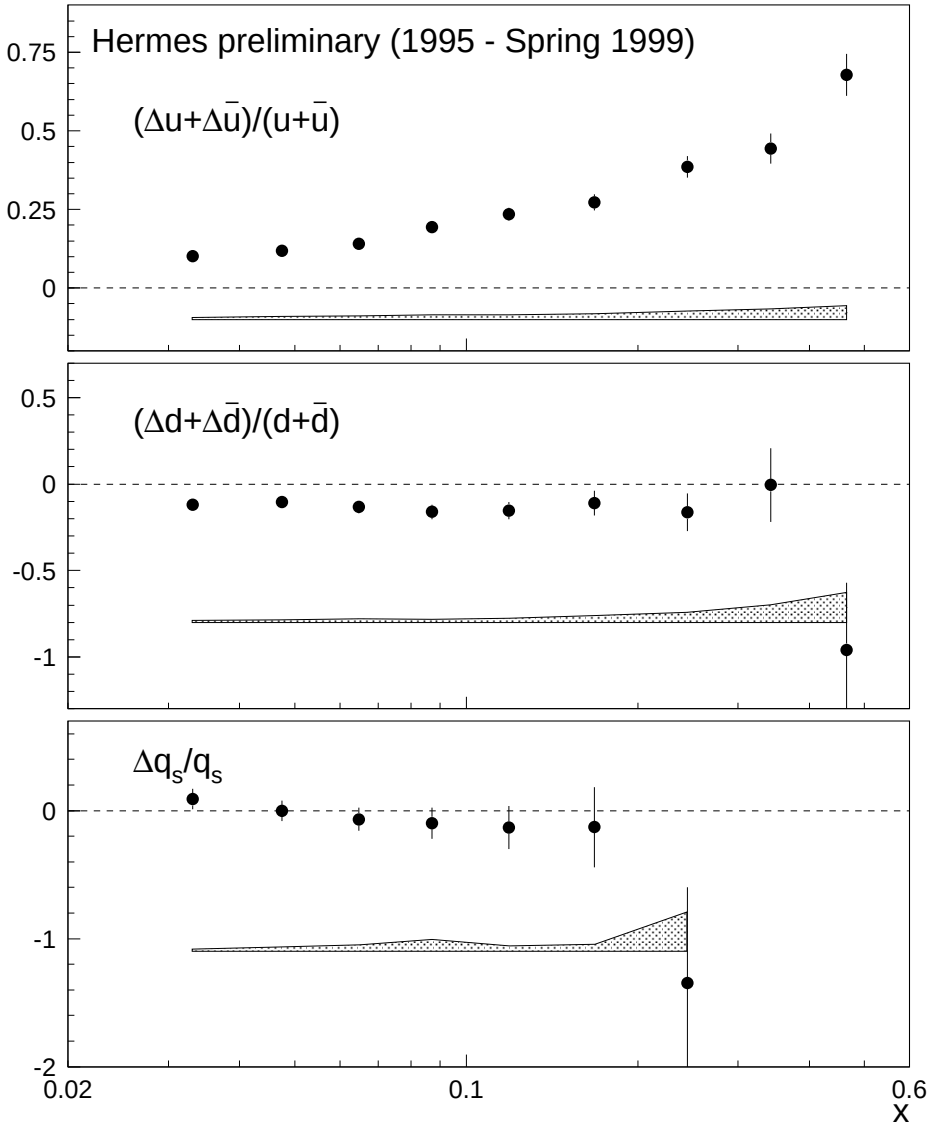
$$\nu = E - E'$$

II. HERMES Results

Inclusive and *semi-inclusive* hadron asymmetries

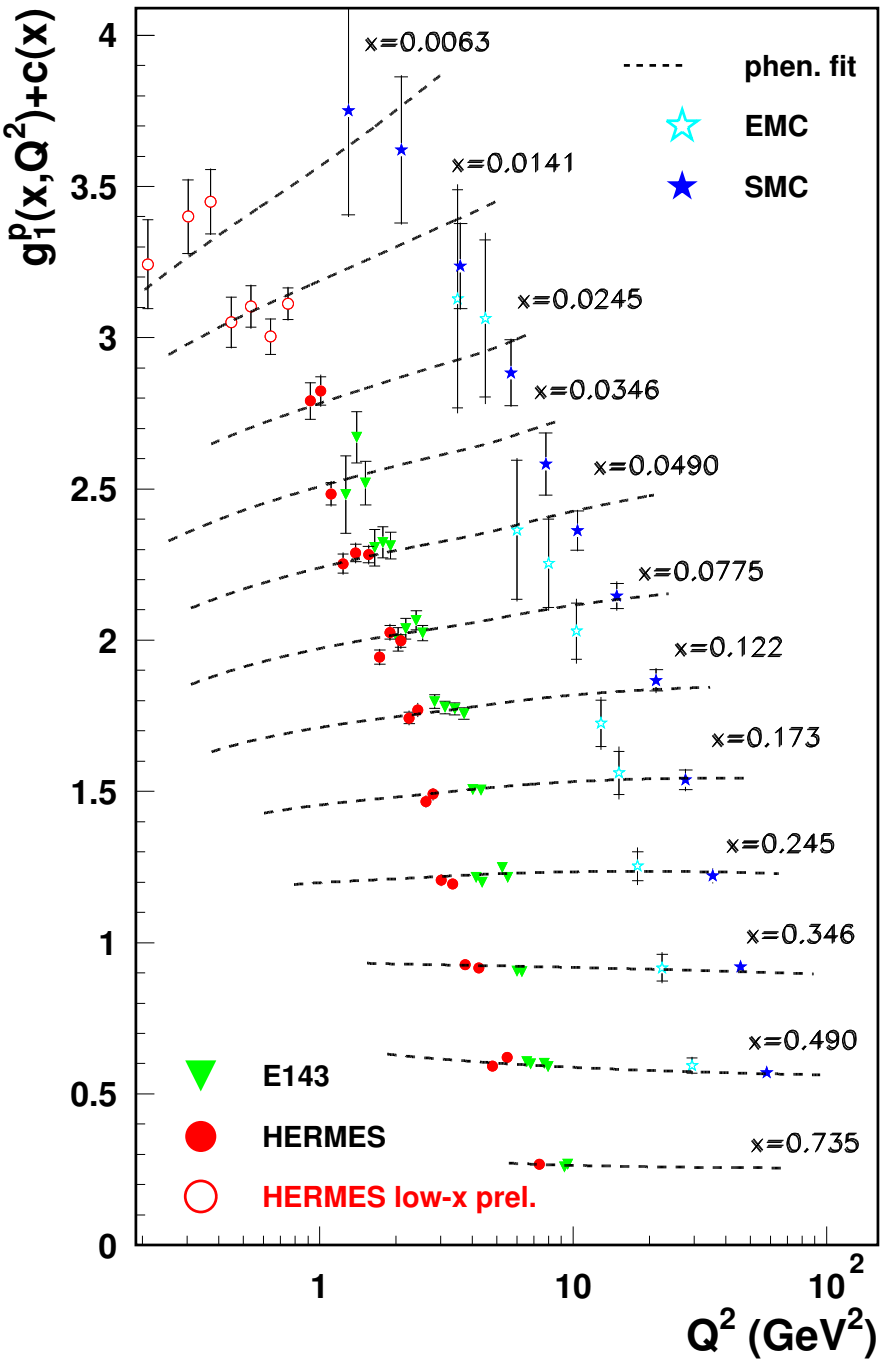


HERMES He + p + d data:



Published HERMES results (PL B464 (1999) 123)
He + p data:
$\Delta\Sigma = 0.30 \pm 0.04 \pm 0.09$
$\Delta q_s = -0.01 \pm 0.03 \pm 0.03$ $Q^2 = 2.5\ GeV^2$

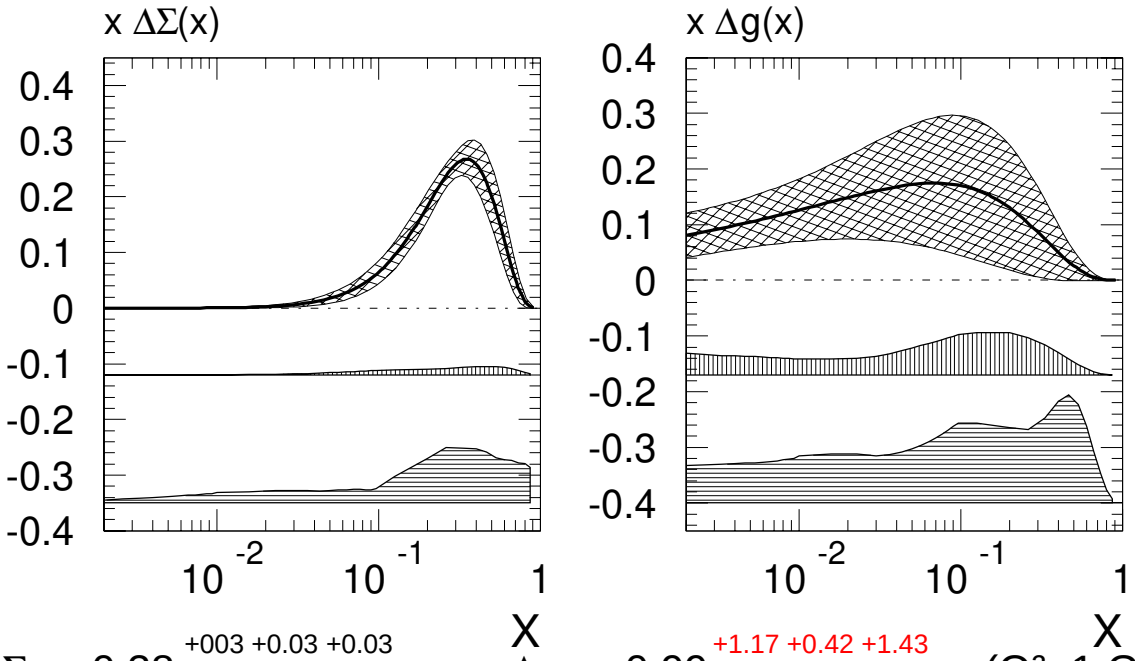
$$g_1(x,Q^2) = \sum_{f=q,\bar{q}} e_f^2 \Delta q_f(x,Q^2)$$



ΔG from QCD analysis (SMC)

$$g_1^{p(n)}(x,Q^2) = \tfrac{1}{9}(C_{NS} \otimes \Delta q_{NS} + C_S \otimes \Delta\Sigma + 2N_f C_g \otimes \Delta g)$$

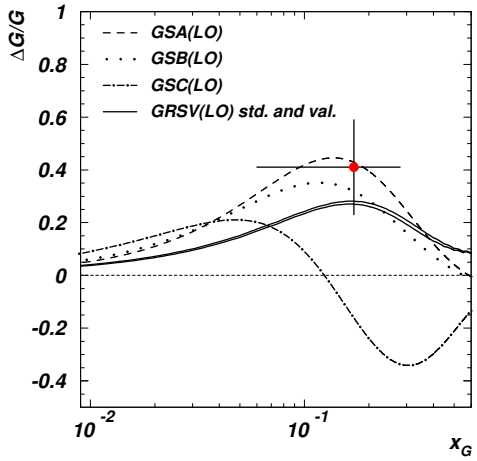
SMC, PRD58(1998)112002



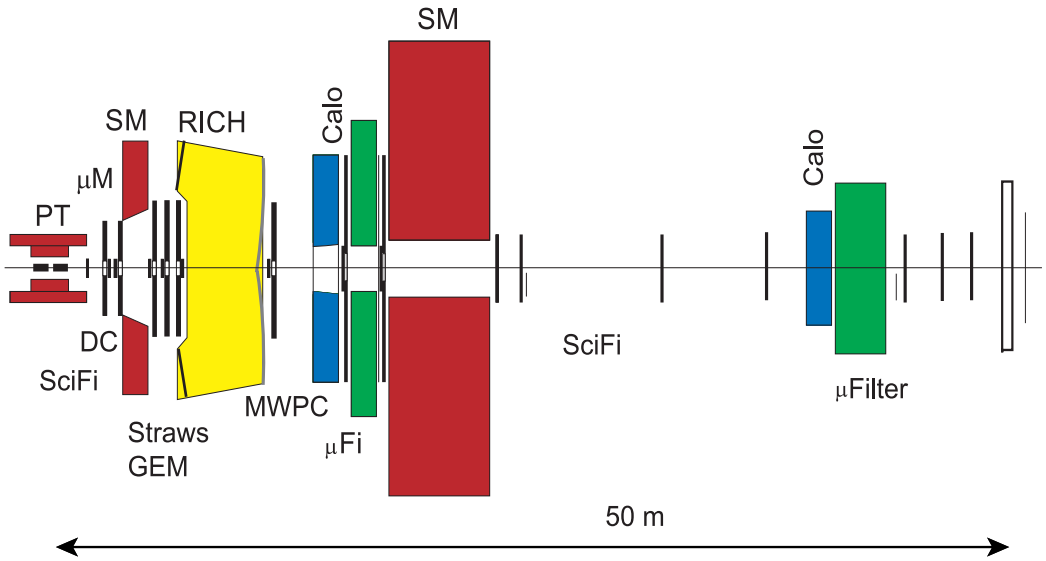
$\Delta\Sigma_{AB}=0.38\ ^{+003\ +0.03\ +0.03}_{-0.03\ -0.02\ -0.05}$ $\Delta g_{AB}=0.99\ ^{+1.17\ +0.42\ +1.43}_{-0.31\ -0.22\ -0.45}$ (Q^2=1 GeV²)

First direct exploration by HERMES

PRL 84 (2000) 2584.



III. COMPASS

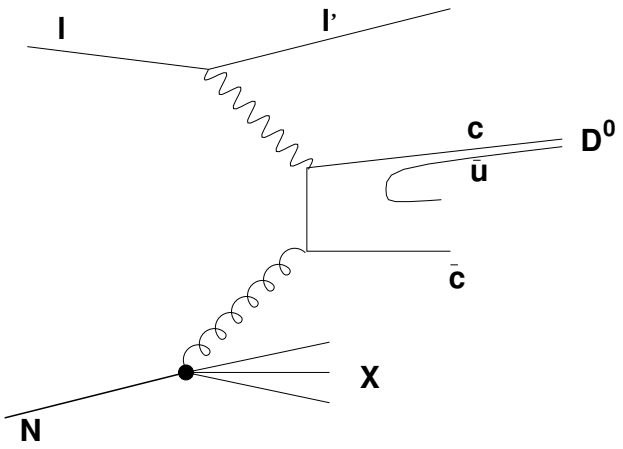


- Two-stage magnetic spectrometer
  - 100-200 GeV muon beam
  - Luminosity = 5 x SMC
  - ^{6}LiD and NH_3 target
  - 10-100 kHz trigger rate
- Primary physics goals:
  - $\Delta G/G$
  - semiinclusive DIS
    - longitudinal and transverse quark spin distribution functions (small x)
  - hadron spectroscopy with hadron beams

$\Delta G/G$

- Open Charm

  880 reconstructed D-mesons/day



$$A_{\gamma N}^{c\bar{c}} = \frac{\Delta\sigma^{\gamma N \to c\bar{c}X}}{\sigma^{\gamma N \to c\bar{c}X}} = \frac{\int d\hat{s}\, \Delta\sigma(\hat{s})\, \Delta G(x_G, \hat{s})}{\int d\hat{s}\, \sigma(\hat{s})\, G(x_G, \hat{s})}$$

$$\delta\left(\frac{\Delta G}{G}\right) = 0.11$$

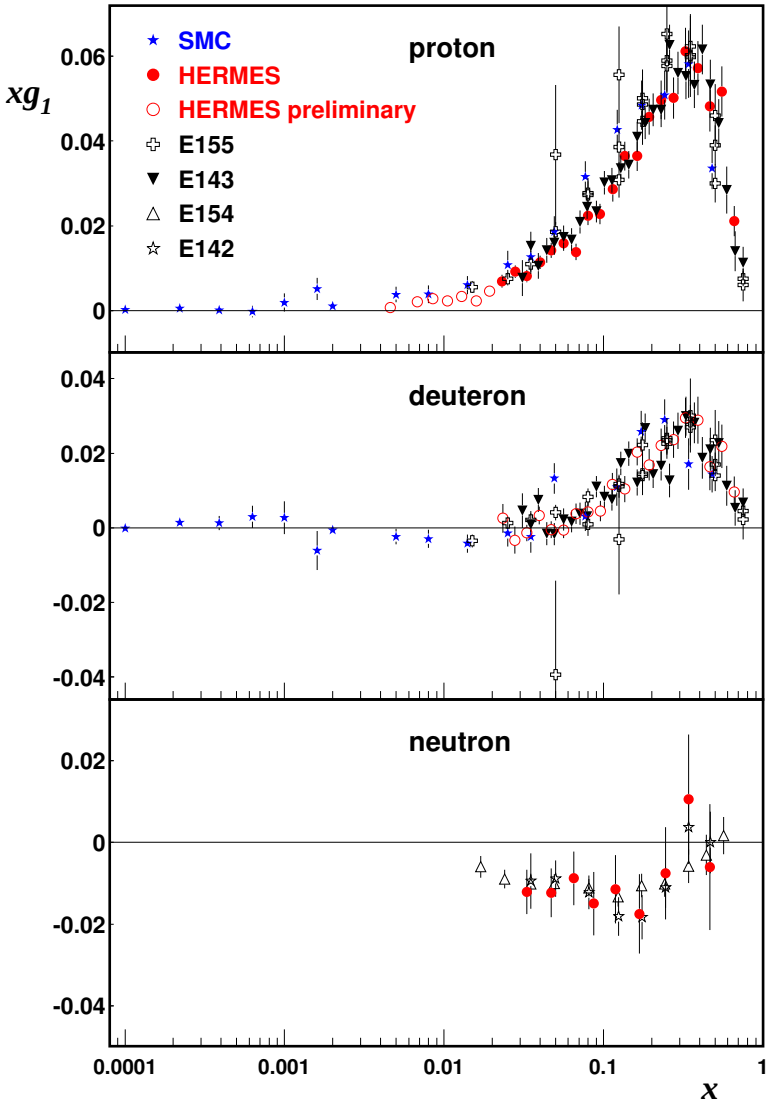
- Using two-*jet* events with high p_T

  Bravar et al, PL B421(1998)349

  - dominated by systematic error
  - several bins in x_G=0.04-0.2
  - each point $\delta\left(\frac{\Delta G}{G}\right) = 0.05$

g_1 @ low x

- Plans for COMPASS in 2001
  - Limitations in large angle tracking
  - Start with g_1 measurement on D



New HERMES data on D

IV. Future Perspectives

- HERMES run II
  - Transverse quark spin distributions $h_1(x)$
  - Strangeness polarization $\Delta s(x)$
  - Gluon polarization $\Delta G/G$
  - Exclusive scattering (recoil detector upgrade)

- COMPASS DVCS
  - Recoil detector and liquid hydrogen target to measure generalized parton distributions
  - Test measurements ongoing in 2001