Precise Results on $g_1^{\rm p}$ and $g_1^{\rm d}$ and First Measurement of the Tensor Structure Function $b_1^{\rm d}$ with the HERMES-Experiment

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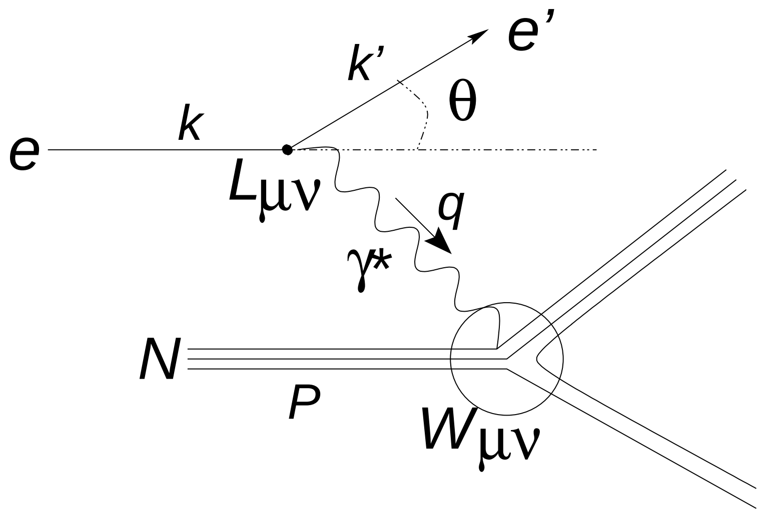
Polarized DIS



Kinematics

$$Q^2 = -q^2 \overset{\text{Lab.}}{\simeq} 2EE'(1-\cos\Theta)$$

$$x = \frac{Q^2}{2\mathbf{pq}} = \frac{Q^2}{2M\nu}$$

$$\nu = \frac{\mathbf{pq}}{M} \overset{\text{Lab.}}{\simeq} E - E'$$

$$y = \frac{\mathbf{pq}}{\mathbf{pk}} \overset{\text{Lab.}}{=} \frac{\nu}{E}$$

Cross Section

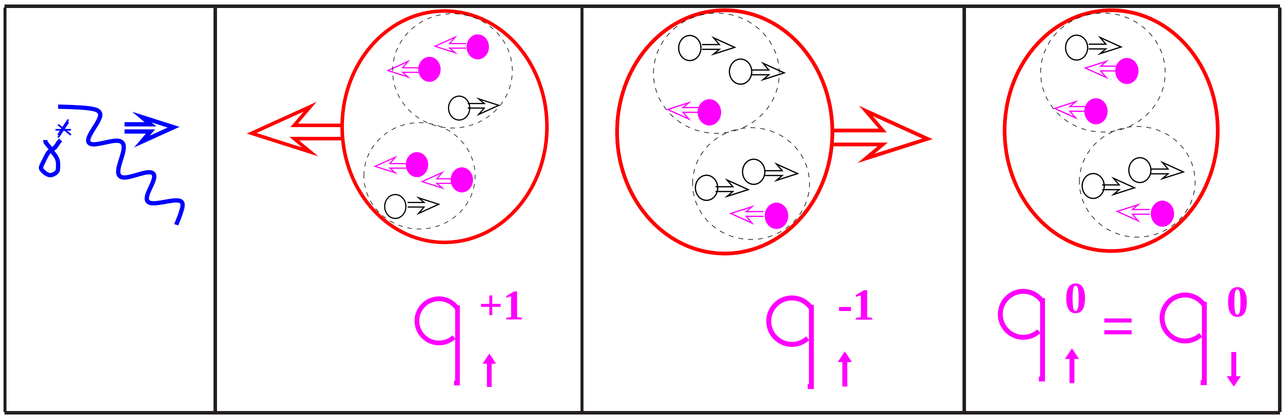
$$\left.\frac{d^2\sigma}{dE'd\Omega}\right|_{\text{Born}} = \frac{\alpha^2}{2MQ^4}\frac{E'}{E}L_{\mu\nu}W^{\mu\nu}$$

Hadronic Tensor

$$W^{\mu\nu} = W_s^{\{\mu\nu\}}(F_1, F_2, \underbrace{b_1, b_2, b_3, b_4}_{\text{target spin 1}}) + W_a^{[\mu\nu]}(g_1, g_2)$$

Structure Functions in the QPM

Quark densities $q(x, Q^2)$:



Structure functions:

Spin-$1/2$ (proton)	Spin-1 (deuteron)
$F_1 = \frac{1}{2}\sum_q e_q^2 \left(q_\uparrow^{1/2} + q_\downarrow^{1/2}\right)$	$F_1 = \frac{1}{3}\sum_q e_q^2 \left(q_\uparrow^{1} + q_\downarrow^{1} + q^0\right)$
$g_1 = \frac{1}{2}\sum_q e_q^2 \left(q_\uparrow^{1/2} - q_\downarrow^{1/2}\right)$	$g_1 = \frac{1}{2}\sum_q e_q^2 \left(q_\uparrow^{1} - q_\downarrow^{1}\right)$
	$b_1 = \frac{1}{2}\sum_q e_q^2 \left(2q^0 - (q_\uparrow^{1} + q_\downarrow^{1})\right)$

Measured Inclusive Asymmetries

- Measured DIS Yield proportional to

$$\sigma = \sigma_{\text{unpol}} \left[1 + P_{\mathrm{B}} P_z A_{\parallel} + \frac{1}{2} P_{zz} A_{zz} \right]$$

- Inclusive vector asymmetry

$$A_{\parallel} \quad := \quad \frac{\sigma^{\overrightarrow{\Leftarrow}} - \sigma^{\overrightarrow{\Rightarrow}}}{\sigma^{\overrightarrow{\Leftarrow}} + \sigma^{\overrightarrow{\Rightarrow}}} = \frac{1}{P_{\mathrm{B}} P_z} \cdot \frac{\frac{N^{\overrightarrow{\Leftarrow}}}{L^{\overrightarrow{\Leftarrow}}} - \frac{N^{\overrightarrow{\Rightarrow}}}{L^{\overrightarrow{\Rightarrow}}}}{\frac{N^{\overrightarrow{\Leftarrow}}}{L^{\overrightarrow{\Leftarrow}}} + \frac{N^{\overrightarrow{\Rightarrow}}}{L^{\overrightarrow{\Rightarrow}}}}$$

$$\frac{g_1}{F_1} \quad = \quad \frac{1}{1+\gamma^2} \cdot \left(\frac{A_{\parallel}}{D} + (\gamma - \eta) A_2 \right)$$

Kinematic variables

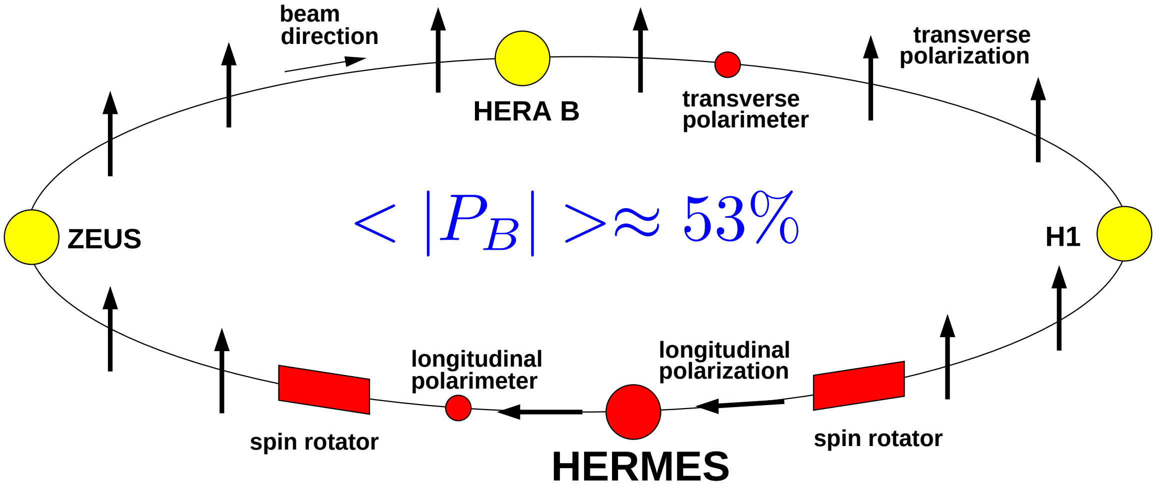
$$\gamma = \frac{\sqrt{Q^2}}{\nu}, \qquad \eta = \eta(x, Q^2), \qquad D = \frac{P_{\gamma^\star}}{P_{\mathrm{B}}}$$

- Inclusive tensor asymmetry

$$A_{zz} := \frac{(\sigma^{\overrightarrow{\Leftarrow}} + \sigma^{\overrightarrow{\Rightarrow}}) - 2\sigma^0}{\sigma^{\overrightarrow{\Leftarrow}} + \sigma^{\overrightarrow{\Rightarrow}} + \sigma^0} = -\frac{2}{3}\frac{b_1}{F_1}$$

The HERMES Experiment

Longitudinally Polarized e-Beam (27.6 GeV)



Longitudinally Polarized Internal H/D Gas Target

Single Hyperfine States
can be Injected!

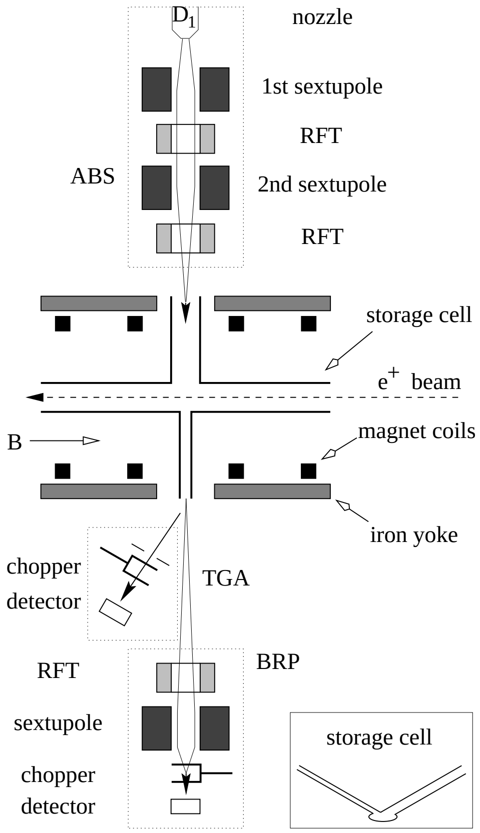
Polarizations:

vector $\boxed{V = \frac{n^+ - n^-}{n^+ + n^- + n^0}}$

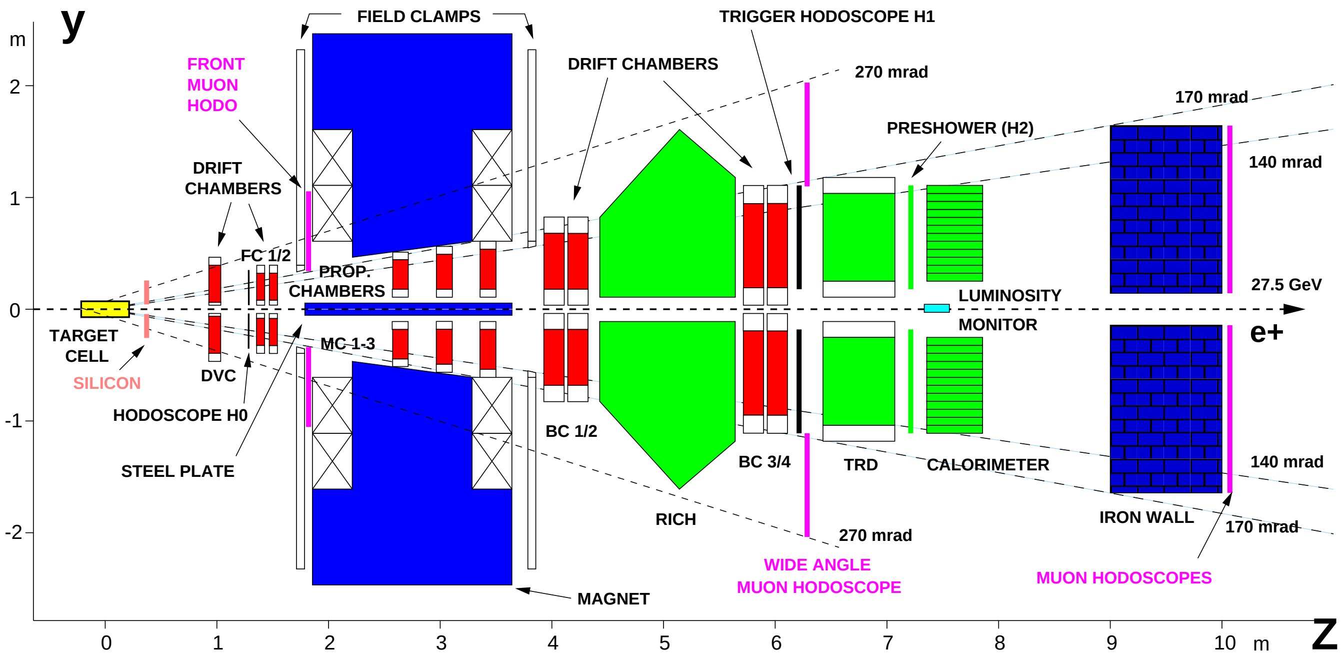
tensor $\boxed{T = \frac{(n^+ + n^-) - 2n^0}{n^+ + n^- + n^0}}$

$< |P_z| > \approx 85\%$

$< |P_{zz}| > \approx 83\% \quad < |P_z| > \approx 0$



The HERMES Spectrometer



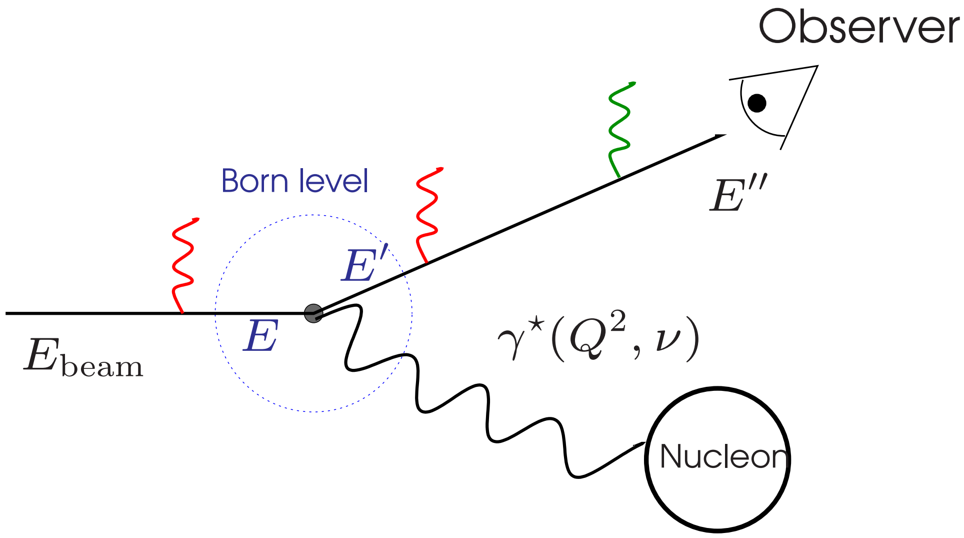
- Acceptance: $40 < \theta < 220$ mrad

- Momentum resolution: $\frac{\delta p}{p} \approx 2\%$

  Angular resolution: $0.3 - 0.6$ mrad

- PID: RICH, TRD, preshower, calo
  - Efficiency of electron ID: 98-99 $\%$
  - Hadron contamination: $< 1\%$

Radiative and Smearing Effects



- Background Tail
  - Radiation from (Quasi)-Elastic

- Intra-Bin Events Migration
  - Radiation from DIS
  - Detector Smearing

Unfolding Technique

If only (Quasi)-Elastic Background

$$A_{||}^{\rm Born} = A_{||}^{\rm Meas}\,\frac{n^{\rm X}_{\rm unpol}}{n^{\rm B}_{\rm unpol}} - \frac{bg^{\rm X}_{\rm pol}}{n^{\rm B}_{\rm unpol}}$$

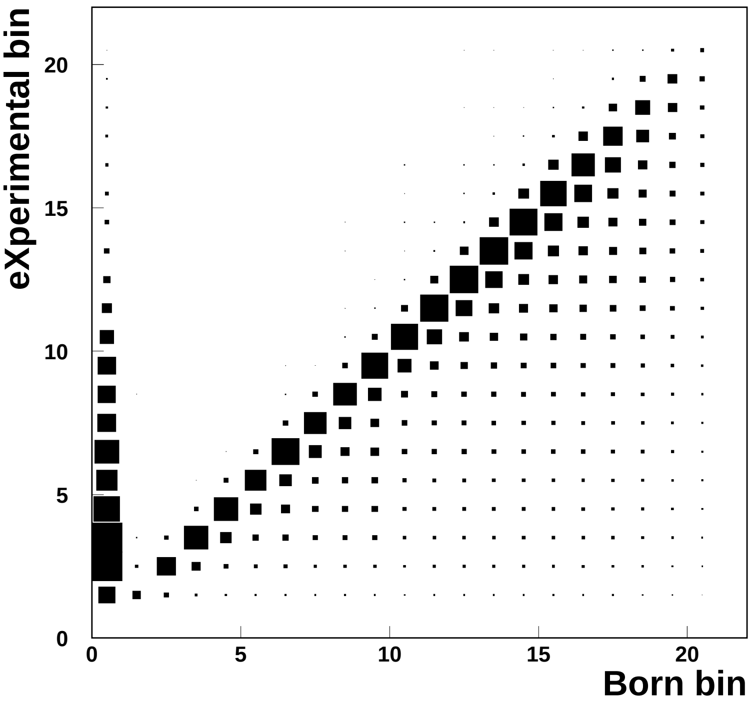
- $n^{\rm X}_{\rm unpol}$ **Unpol. experimental distribution**
- $n^{\rm B}_{\rm unpol}$ **Unpol. Born distribution**
- $bg^{\rm X}_{\rm pol}$ **Polarized radiative tail**

Intra-Bin Migration

- **Smearing Matrix**

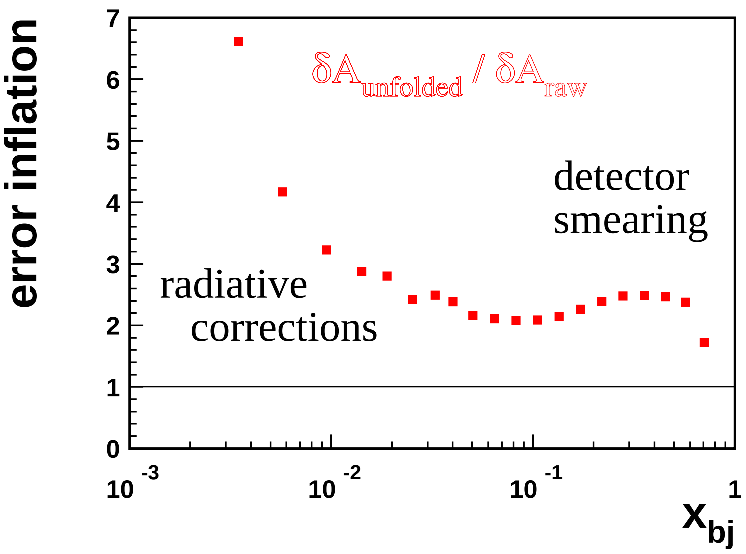
$$S_{ij} = \frac{n(i,j)}{n^B(j)}$$

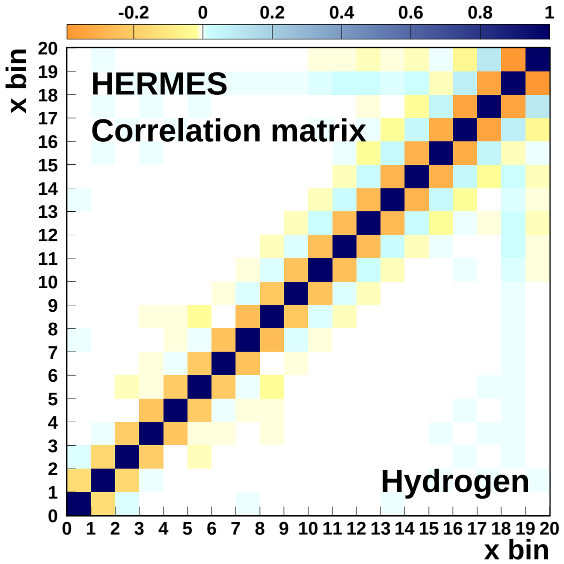
Model-Independent
Approach



Error Inflation

$$\frac{\partial A_{\parallel}^{\mathrm{Born}}(j)}{\partial A_{\parallel}^{\mathrm{Meas}}(i)} \quad = \quad D(i,j) > 1$$





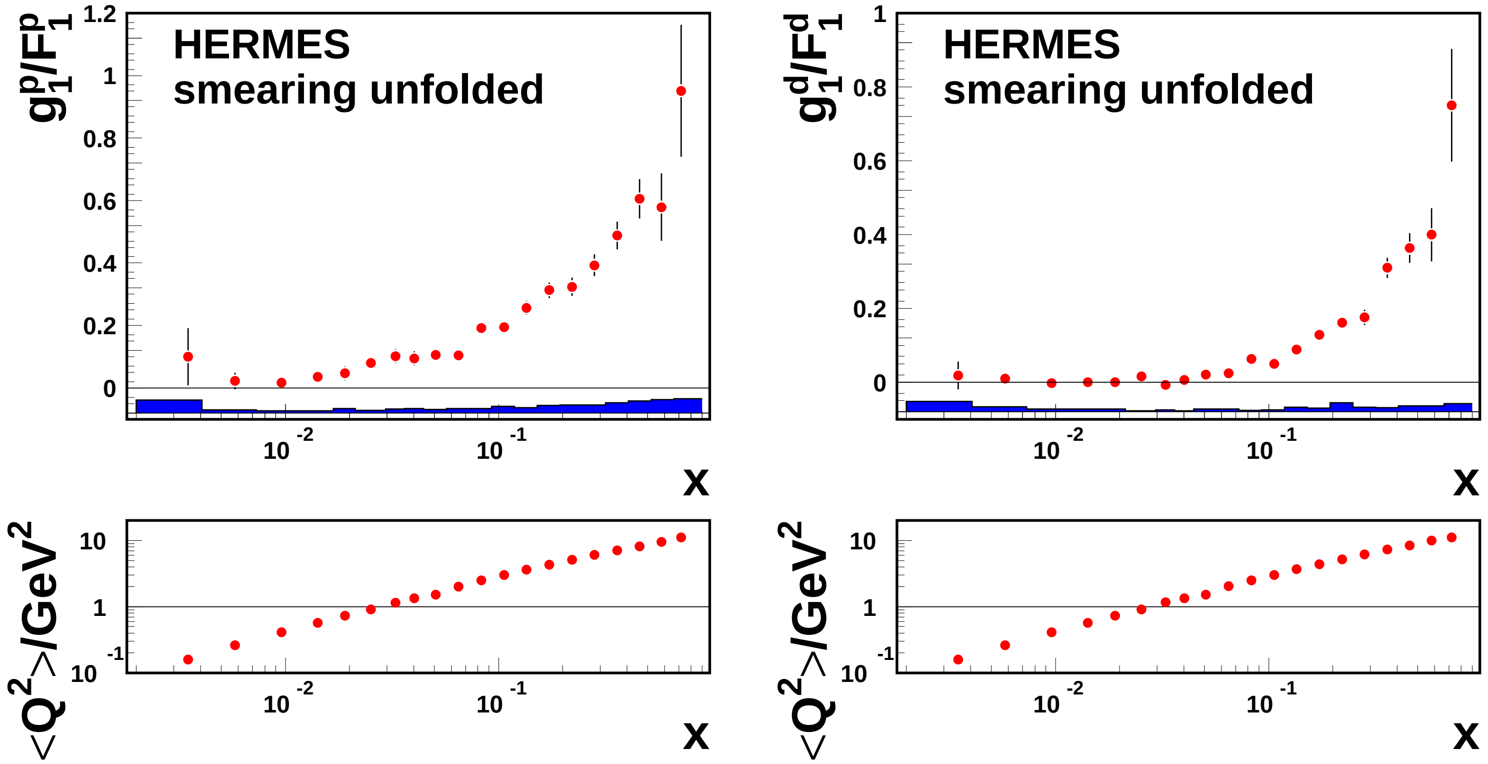
Unfolding

- **Removes Systematic Correlations** between data points
- **Indroduces Statistical Correlation**

For correct interpretation and usage of error bars:

$\Rightarrow$ **Correlation Matrix**

Results: g_1/F_1 of Proton and Deuteron



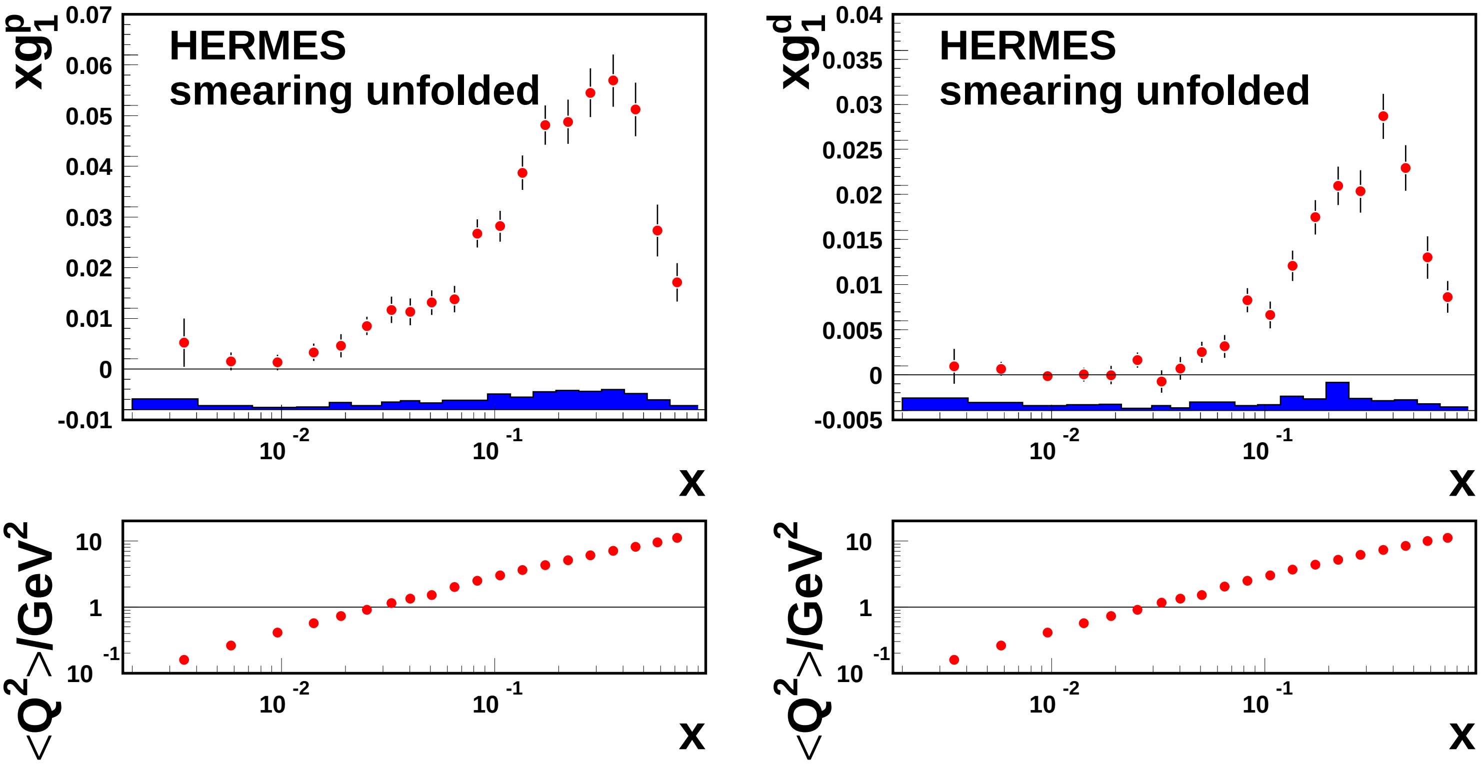
- **Statistical** Error-bars

  Diagonal Elements of Covarinace Matrix

- **Systematic** Errors

  Dominated by Target and Beam Polarization

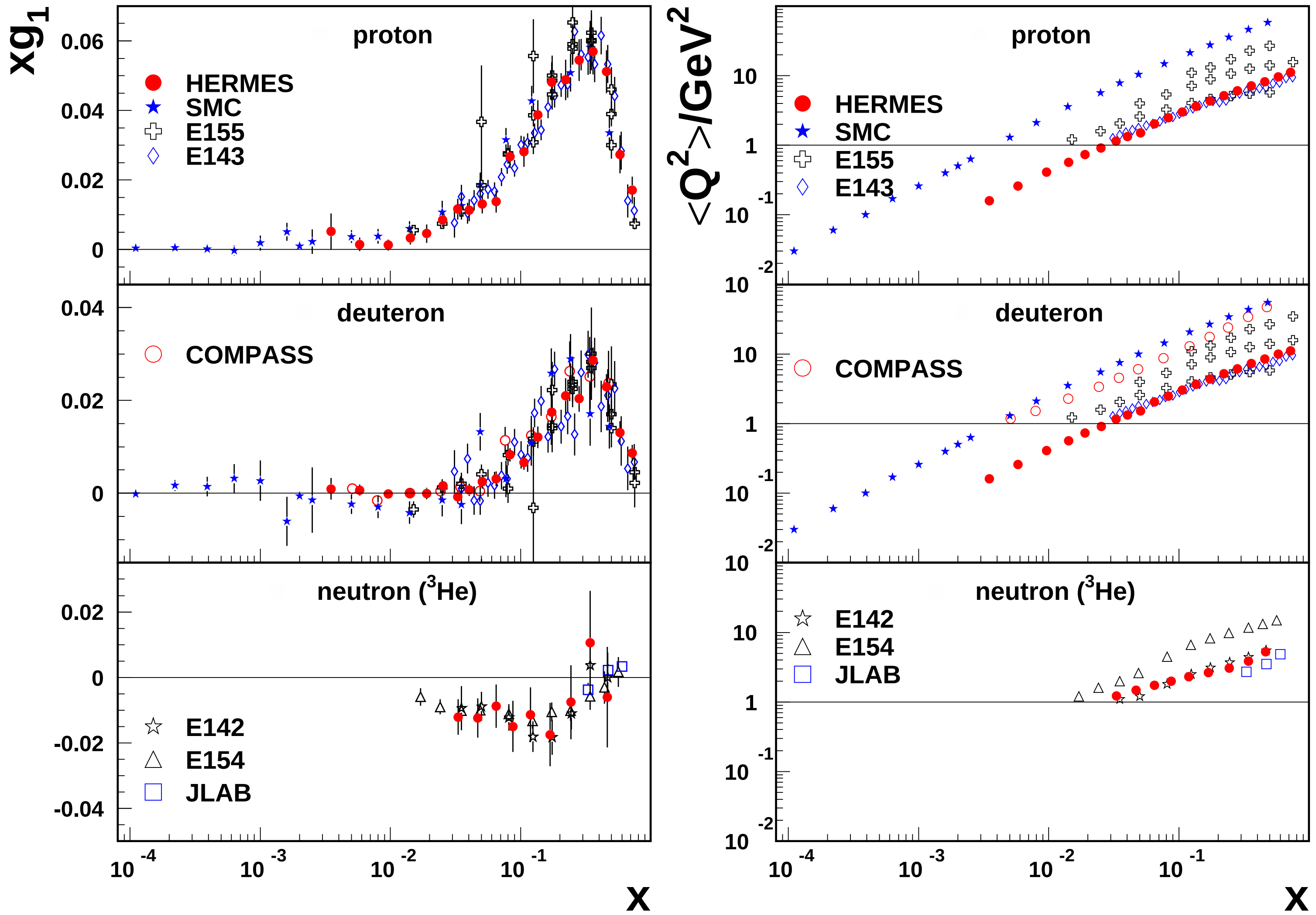
Results: xg_1 of Proton and Deuteron



- **Statistical** Error-bars
  Diagonal Elements of Covarinace Matrix

- **Systematic** Errors
  Dominated by Target and Beam Polarization

Comparison to World Data



First Moments Calculation

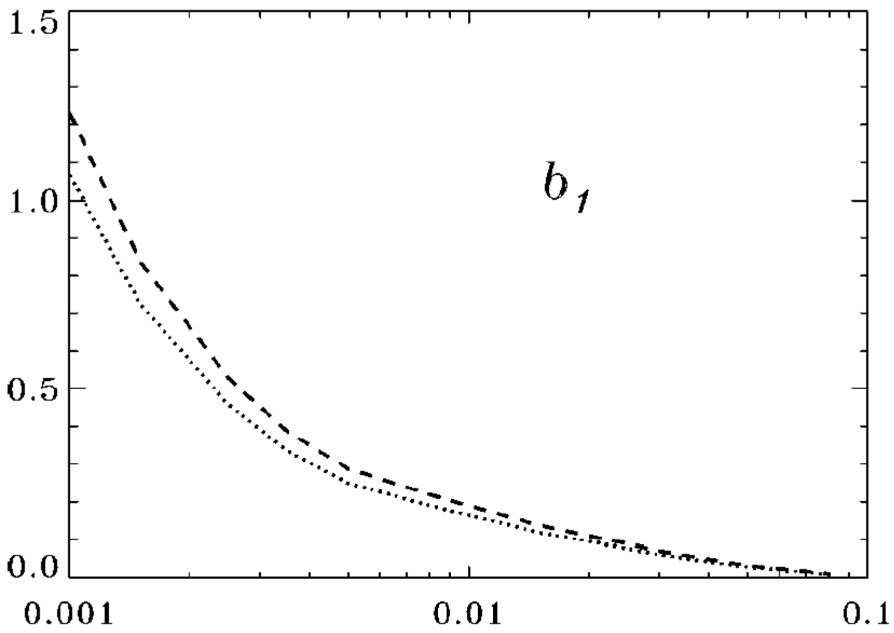
Exp.	$Q^2(\mathrm{GeV}^2)$	x range	Target	Moment	HERMES Moment
SMC	5	0.03-0.7	p	0.128 ± 0.006	**0.1141 ± 0.0026**
E143	5	0.03-0.8	p	0.117 ± 0.003	**0.1174 ± 0.0027**
SMC	5	0.03-0.7	d	0.043 ± 0.007	**0.0416 ± 0.0013**
E143	5	0.03-0.8	d	0.043 ± 0.003	**0.0433 ± 0.0013**

Full Statistical Power of the HERMES Data!

b_1^{d} Model Calculations

- Deuteron: D-state admixture
  - Elastic Scattering
    El. Quadrupole Moment $\neq 0$
  - DIS
    Shadowing Effect
    $\Rightarrow$ Double Scattering Mechanisms
    Significant contribution to b_1 at small x

Nikolaeva and Schäfer, *Phys. Lett.* B **398** (1997) 245
Edelmann, Piller and Weise, *Phys. Rev.* C **57** (1998) 3392
Bora and Jaffe, *Phys. Rev.* D **57** (1998) 6906



Results: A_{zz} and b_1^d

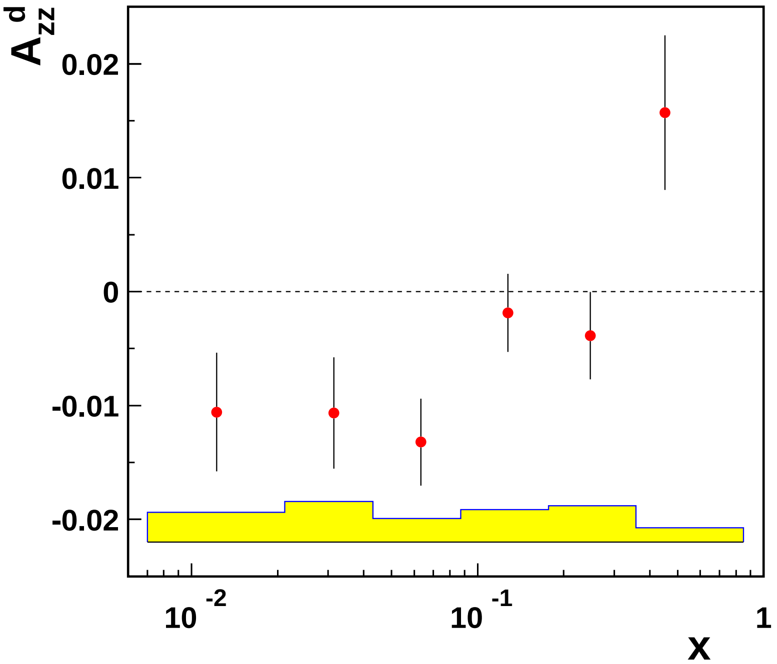
- HERMES

  First measurement ever

- $A_{zz} \neq 0$

- $A_{zz} = \mathcal{O}(1\%)$

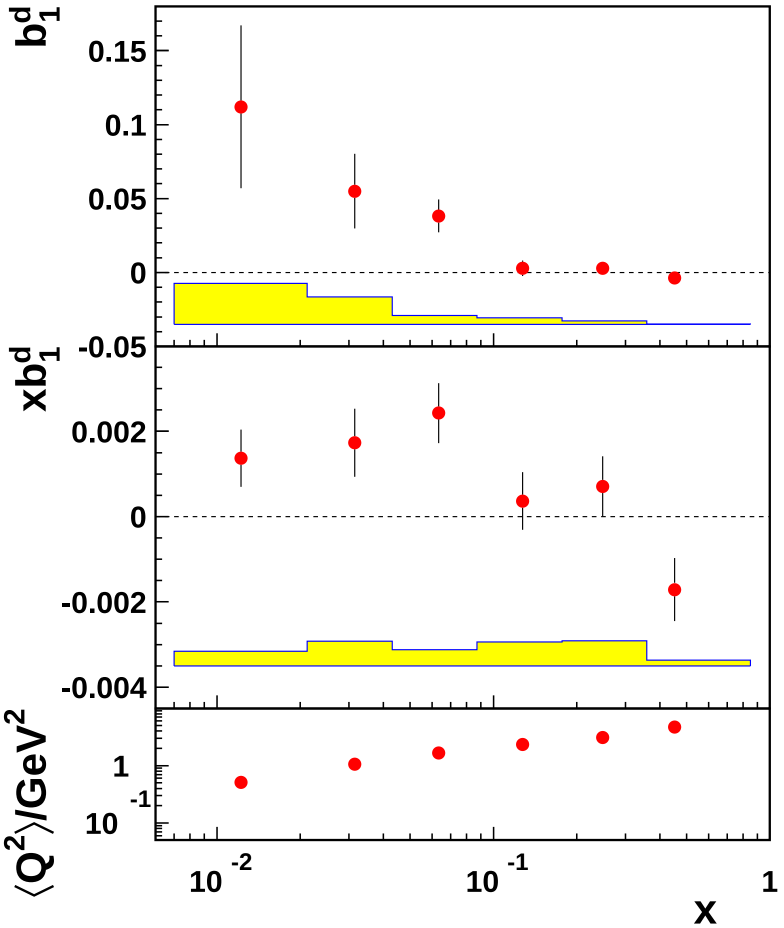
  $\Rightarrow$ Small Impact on g_1



- First Moment $\neq 0$:

  $\mathbf{1.05 \pm 0.34_{stat} \pm 0.35_{sys}}$

- Qualitative Agreement with Double Scattering Models



Summary and Outlook

- Final Results of the $g1$ structure function for proton and deuteron from the HERMES data

- Data points of spin structure function now systematically uncorrelated, but statistically correlated

  $\Rightarrow$ Correlation matrix for correct calculation of QCD fits and moments

- First measurement of tensor structure function b_1^{d} by HERMES

  $\Rightarrow$ b_1^{d} different from zero at small x

- To come: HERMES publications on spin and tensor structure functions