The measurement of the tensor structure function b_1^{d} of the deuteron with the HERMES-experiment

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for the hermes -collaboration

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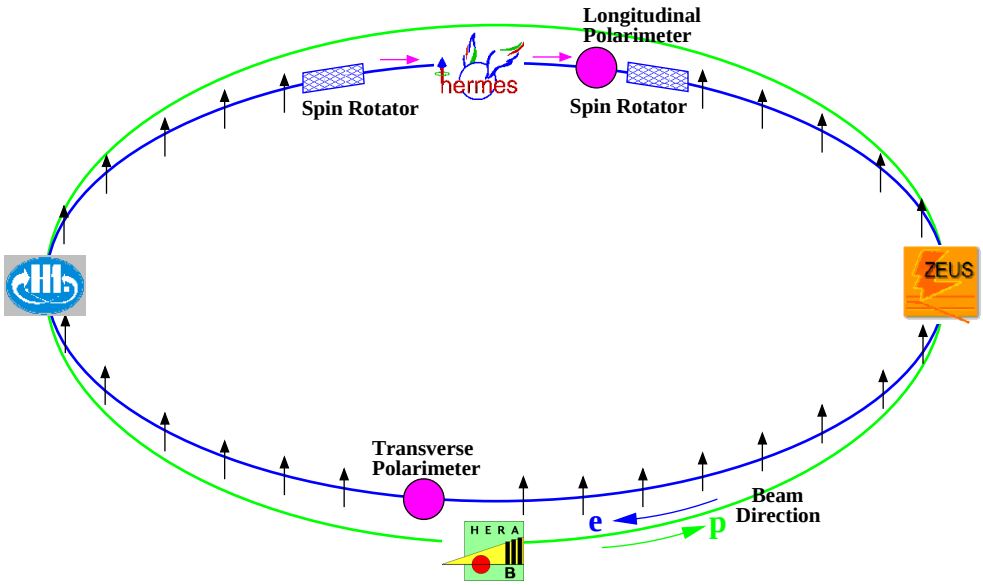
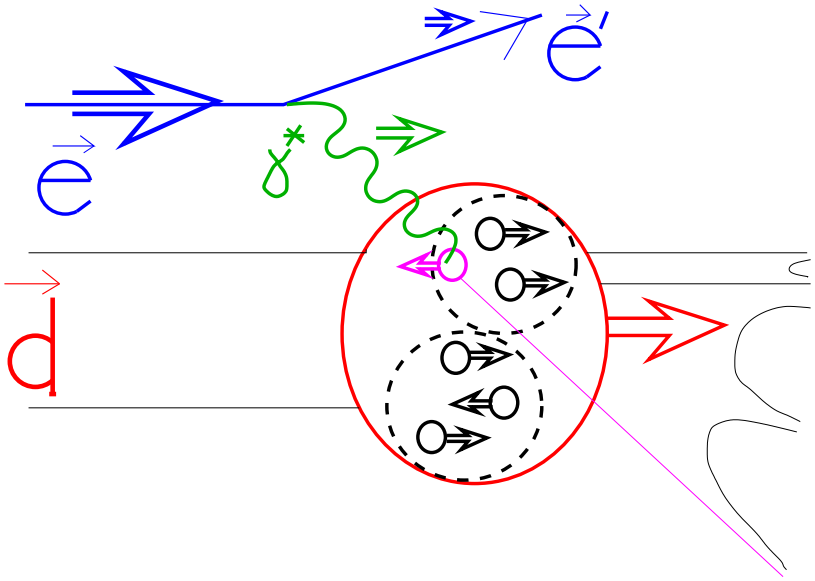
bmb+f - Förderschwerpunkt
HERMES
Großgeräte der physikalischen Grundlagenforschung

DIS on a Spin-1 target at HERMES

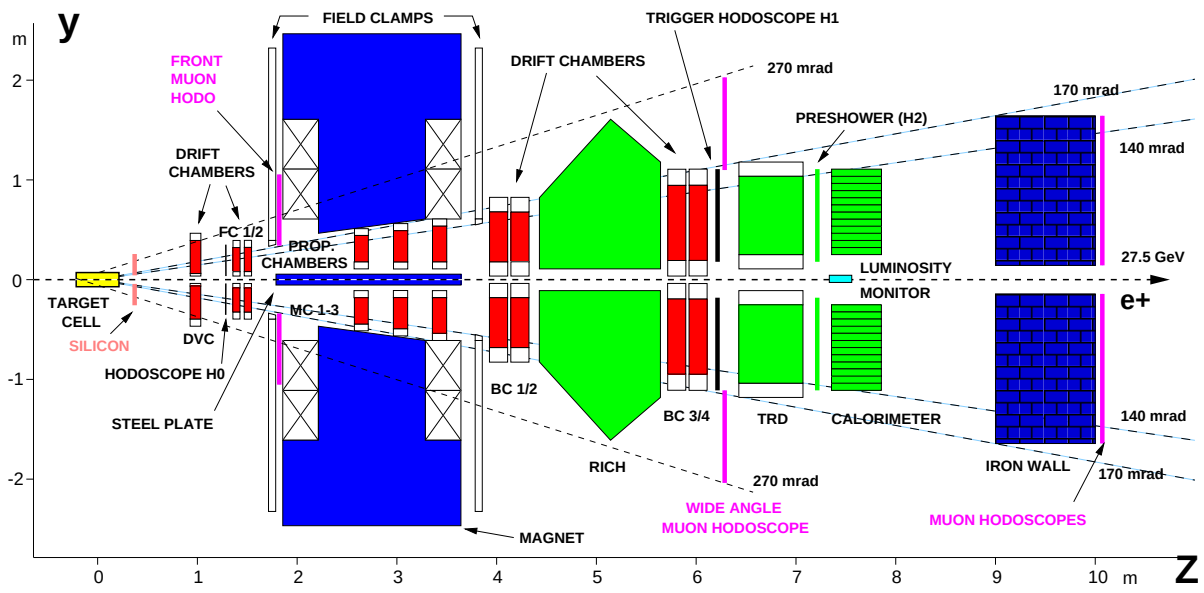


Longitudinally polarized e^+-beam (27.6 GeV) hits

polarized internal gaseous deuterium target:



The HERMES spectrometer

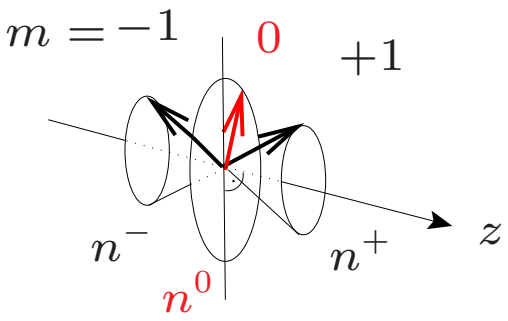


- Acceptance: $40 < \theta < 220$ mrad
- Momentum resolution: $\frac{\delta p}{p} = 2\%$;
  Angular resolution: $0.3 - 0.6$ mrad;
- Calorimeter: $\frac{\delta E}{E} = \frac{(5.1 \pm 1.1)}{\sqrt{E[\mathrm{GeV}]}}\%$

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

Polarized atomic deuterium target

Deuteron (Spin-1):



polarizations:

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

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

$|V| \leqq 1, \; -2 \leq T < 1$

HERMES target: Atomic Beam Source + gas analyzing system

Special:

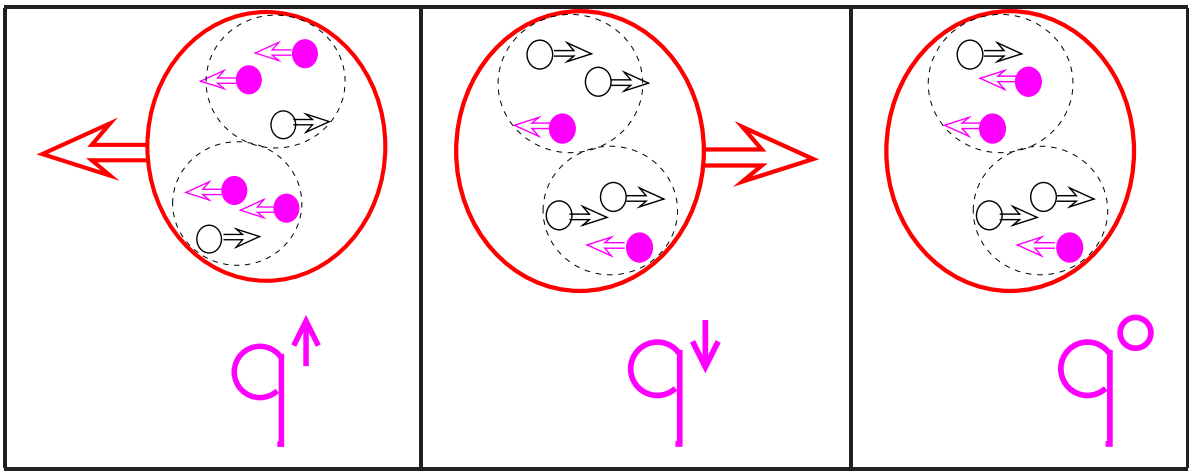
- Hyperfine states can be selected separately
- Negative T reachable!

target state	injected	V	T
vector +	n^+	$+1$	$+1$
vector −	n^-	-1	$+1$
tensor +	$n^+ + n^-$	0	$+1$
tensor −	n^0	0	-2

$\Rightarrow$ High T (at V=0) reachable

Structure functions in the Quark Parton Modell

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



Structure functions:

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

Tensor asymmetry A_T from HERMES-data

- Cyclic alternation of target injection mode

  $\Rightarrow$ measured cross sections $\sigma^{\uparrow\downarrow}$, $\sigma^{\uparrow\uparrow}$, σ^0 $\qquad$ $(\sigma^{\pm})$

  b_1 not sensitive to beam polarization P_B $\Rightarrow$ sum up!

- $$\sigma = \sigma_{\mathrm{unpol}} \left[1 + P_B V A_{\parallel} + \frac{1}{2} T A_T \right]$$
  $$(\sigma_{\mathrm{unpol}} = \tfrac{1}{3} \cdot (\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow} + \sigma^0))$$

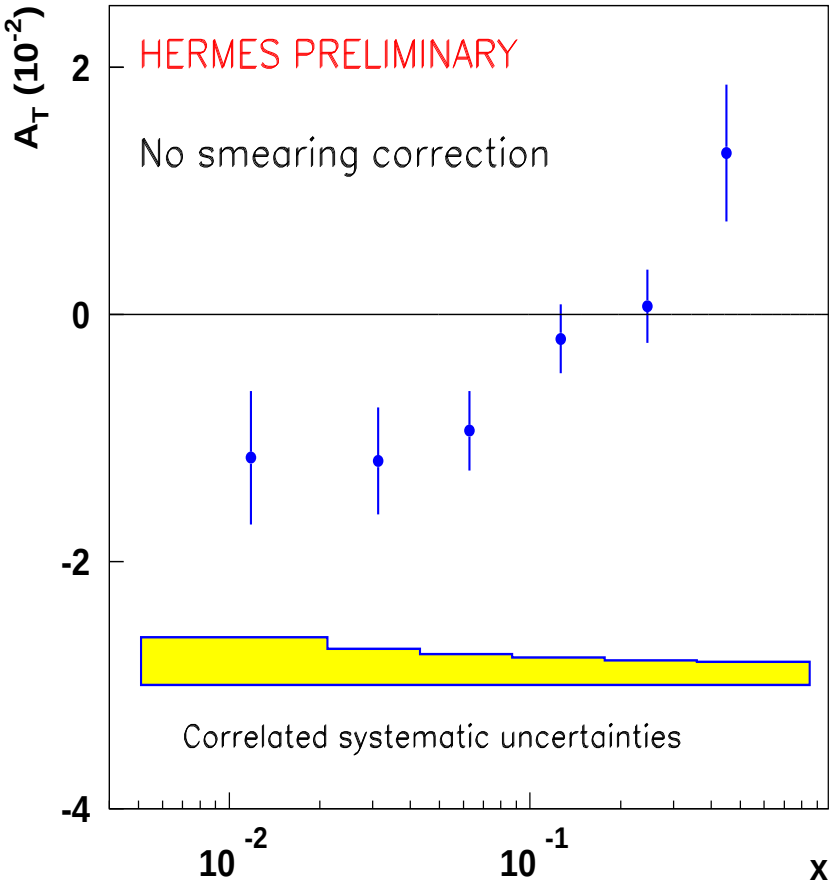
- Inclusive tensor asymmetry:

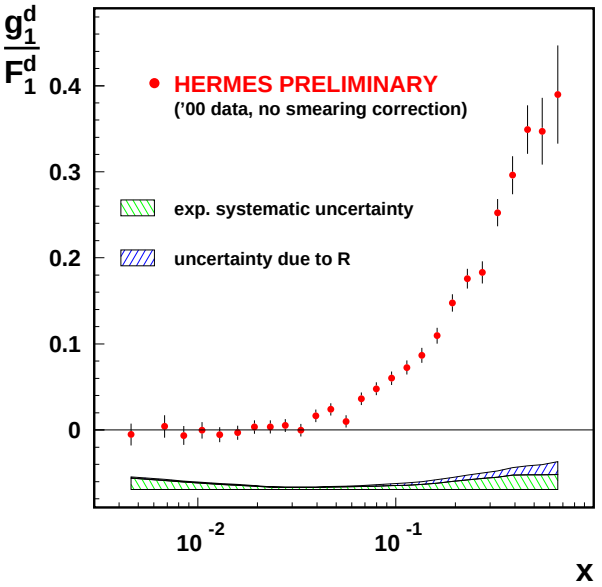
$$A_T := \frac{(\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}) - 2\sigma^0}{3\sigma_{\mathrm{unpol}}} = -\frac{2}{3}\frac{b_1}{F_1}$$

- Inclusive vector asymmetry:

$$A_{\parallel} := \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{2\sigma_{\mathrm{unpol}}} = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}} \cdot \left[1 + \frac{1}{2} T A_T \right] \sim \frac{g_1}{F_1}$$

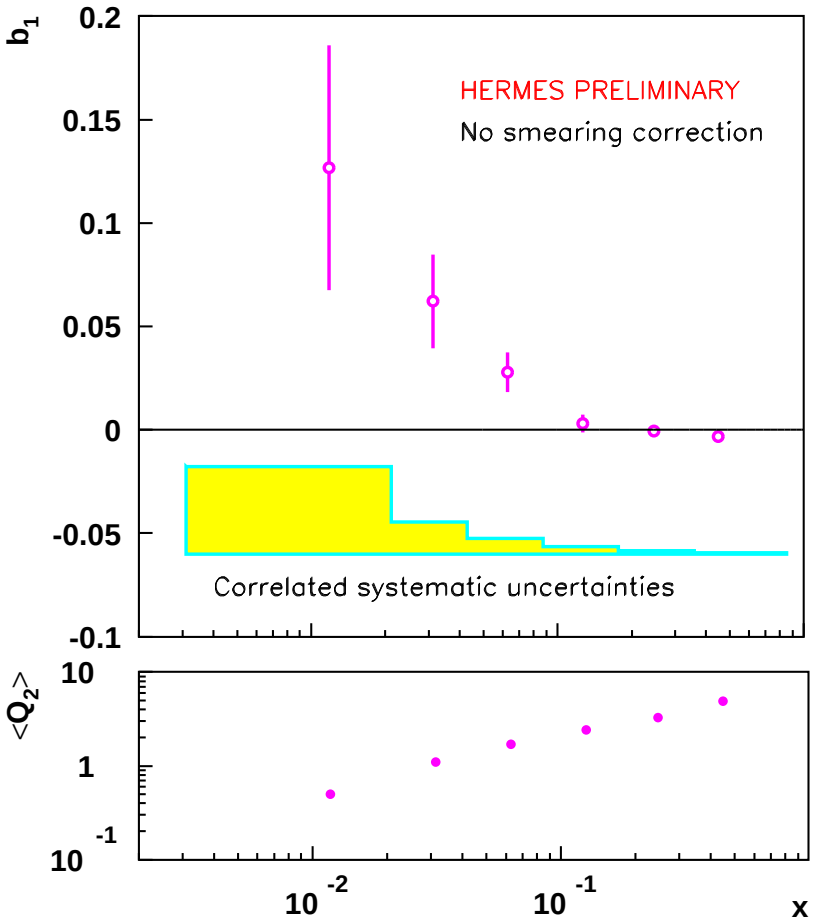
Results: tensor asymmetry A_T

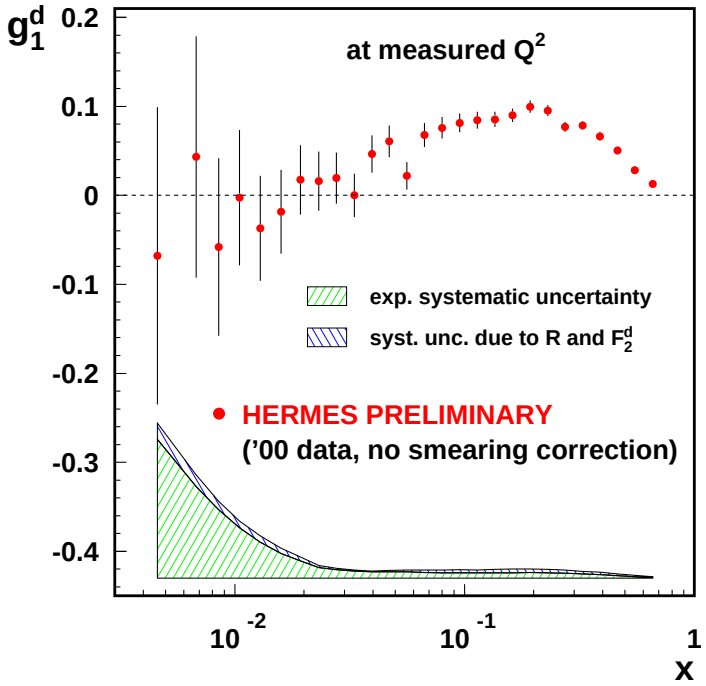




- $A_T = \mathcal{O}(1\%) \Rightarrow$ Impact on g_1 small
- $x \to 0$: $|A_T| > |A_{\|}|$

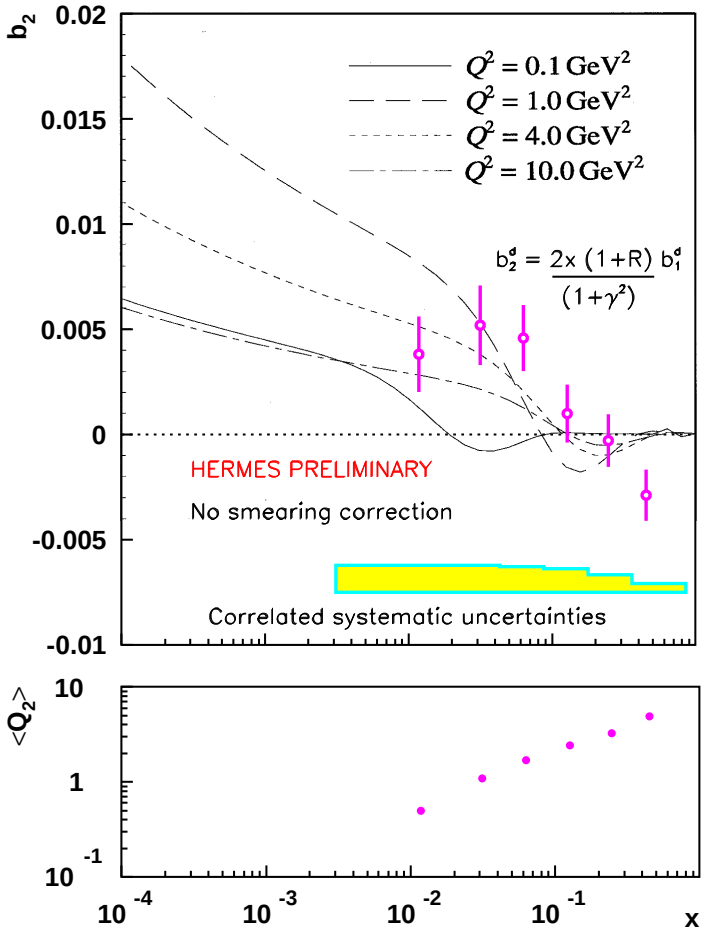
Results: tensor structure function b_1^d





- $b_1^d \gg \mathcal{O}(10^{-3}..10^{-4})$ (older models)
- $x \to 0$: $b_1^d \nearrow$, here even $b_1^d > g_1^d$!

b_1^{d}, b_2^{d} and model calculations



$\mathcal{O}(b_1^{\mathrm{d}}) \overset{\surd}{\longleftrightarrow}$ latest model calculations

- deuteron: D-state admixture
  $\Rightarrow$ el. quadrupole moment $\neq 0$

  $\hookrightarrow$ double scattering mechanisms with a significant contribution to b_1 at small x
  (e.g. Nikolaev *et al.*, *Phys. Lett.* B **398** (1997) 245)
- Callan-Gross relation $\Rightarrow$

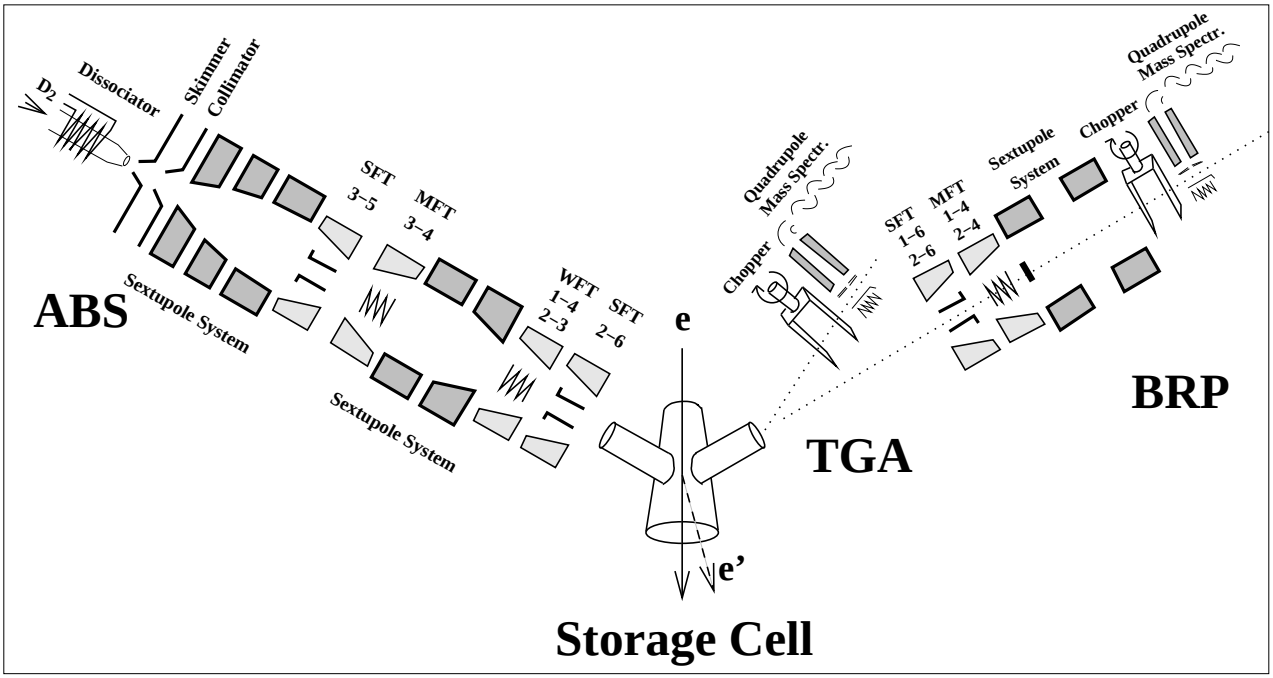
$$b_2^{\mathrm{d}} = \frac{2x(1+R)}{1+\gamma^2} b_1^{\mathrm{d}}$$

Theory curves: Bora *et al.*, *Phys. Rev.* D **57** (1998) 6906

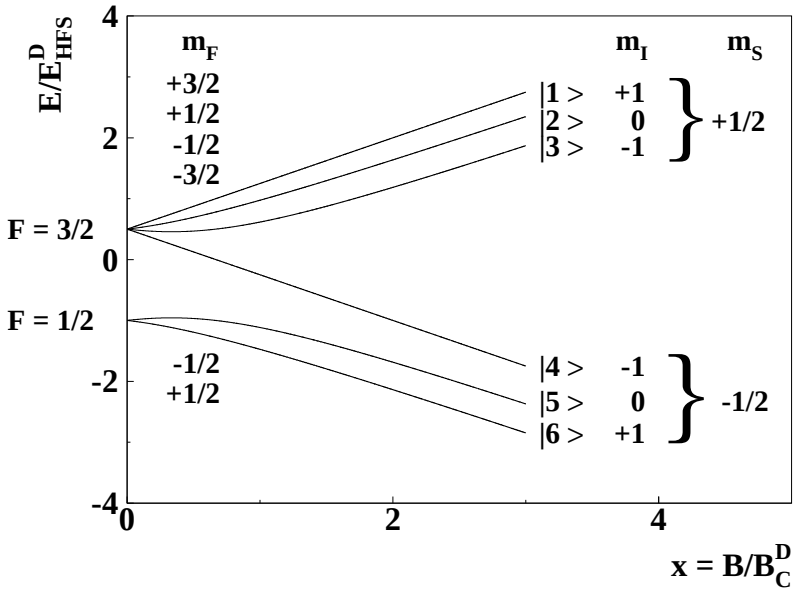
Summary

- First measurement of the tensor structure function $b_1^{\mathrm{d}}(x, Q^2)$ of the deuteron with the HERMES-experiment due to special features of the gaseous HERMES target
- Tensor asymmetry $A_T = \mathcal{O}(1\%) \Rightarrow$ small impact on g_1 measurement
- b_1^{d} large for small x!
- Measured b_1^{d} in good agreement with latest model calculations
- Interpretation of b_1:
  - Reason for $b_1 \neq 0$: double-scattering mechanisms
  - Measure for the deviation of the nucleus from a trivial bound state of p and n

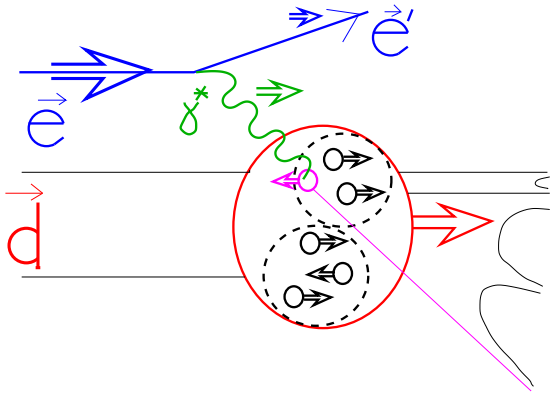
The HERMES-target



Hyperfine splitting in a magnetic field for deuterium:



Structure functions and interaction



x-section for DIS:

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

Leptonic and hadronic tensor each separable in

{symmetric}, spin *in*dependent and

[anti-symmetric], spin dependent part $\Rightarrow$

$$L_{\mu\nu}W^{\mu\nu} = \underbrace{L_{\{\mu\nu\}}W^{\{\mu\nu\}}(F_1, F_2, b_1, b_2, b_3, b_4)}_{\text{unpolarized}} + \underbrace{iL_{[\mu\nu]}W^{[\mu\nu]}(g_1, g_2)}_{\text{polarized inclusive x-section}}$$

$\Rightarrow b_1$ not sensitive to beam polarization

(but implicitly dependent on target spin)

Leptonic and hadronic tensor

$$L^{\mu\nu} = L^{\{\mu\nu\}} + iL^{[\mu\nu]}(s)$$

spin *in*dependent and {symmetric}

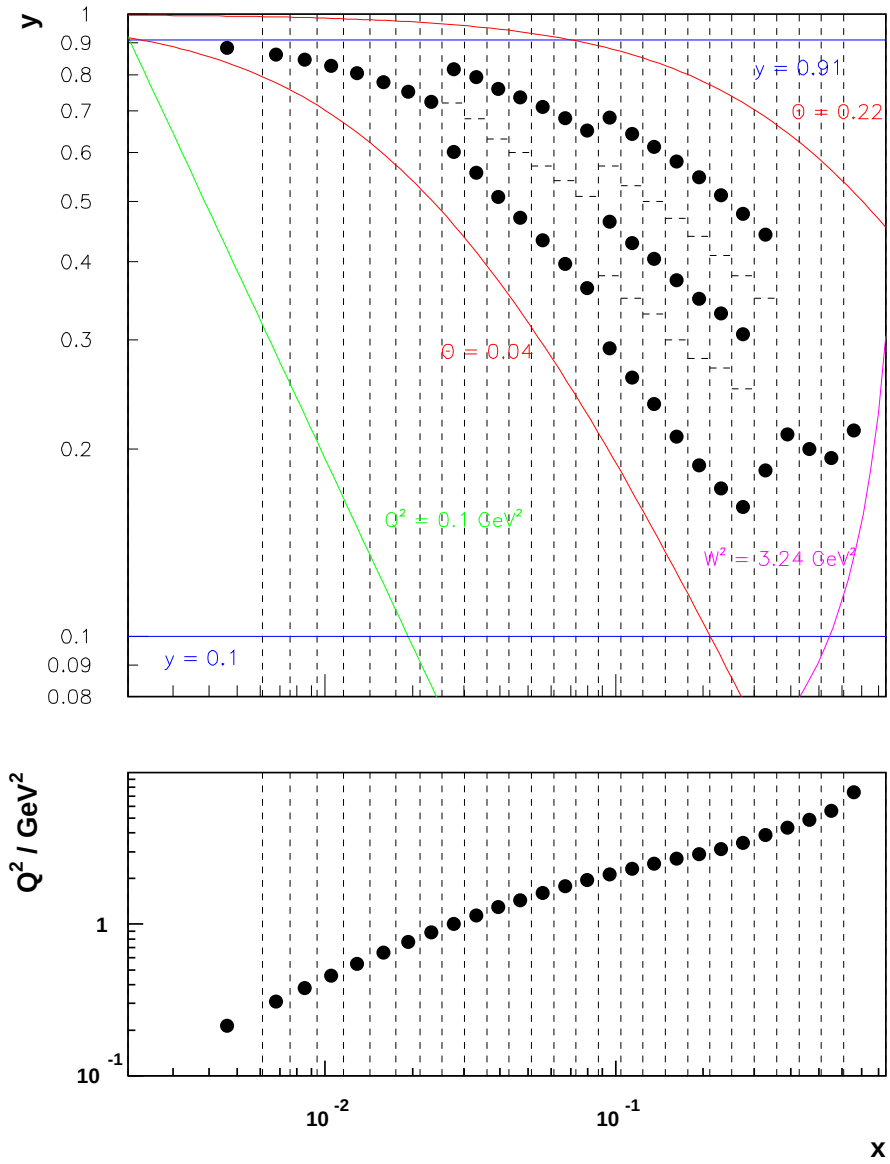
spin dependent and [anti symmetric]

$$W^{\mu\nu} = W^{\{\mu\nu\}}(F_1, F_2) + iW^{[\mu\nu]}(g_1, g_2) +$$

$$+W^{\{\mu\nu\}}(b_1, b_2, b_3, b_4)$$

implicitly dependent on target spin
(additionally and only for Spin-1)

Kinematic region at HERMES



For the inclusive g_1- und b_1 analysis:
$0.002 < x < 0.85$, $0.1\mathrm{GeV}^2 < Q^2 < 20\mathrm{GeV}^2$
b_1: 6 bins in x