HERMES Measurements of the Deuteron Spin Structure Function g_1^{d}

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on behalf of the hermes-collaboration

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- Motivation
- The HERMES experiment
- Formalism of g_1 determination
- Results
- Summary and outlook

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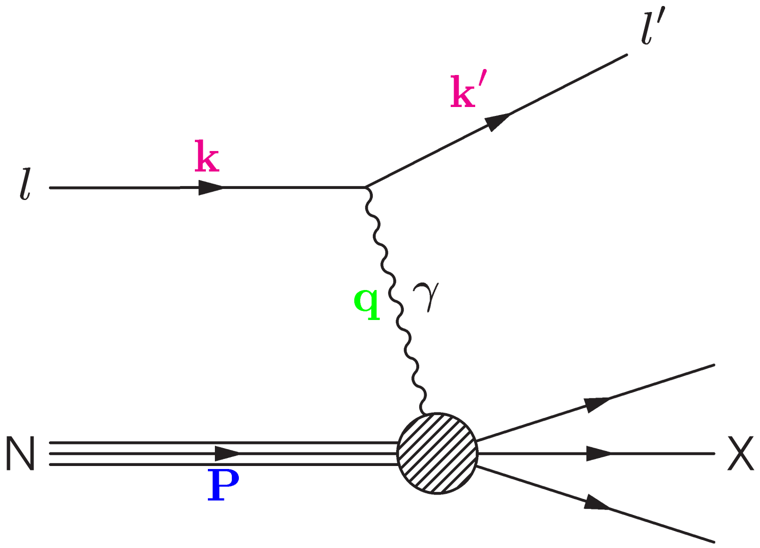
Deep Inelastic Scattering



$$Q^2 = -\mathbf{q}^2 \overset{\text{lab}}{\approx} 4EE'\sin^2\frac{\theta}{2}$$

$$\nu = \frac{\mathbf{Pq}}{M} \overset{\text{lab}}{=} E - E'$$

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

$$y = \frac{\mathbf{Pq}}{\mathbf{Pk}} \overset{\text{lab}}{=} \frac{\nu}{E}$$

- cross section:

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}\Omega\,\mathrm{d}E'} = \frac{\alpha^2}{Q^4}\frac{E'}{E}L^{\mu\nu}W_{\mu\nu}$$

- hadronic tensor:

$$W_{\mu\nu} = -F_1 g_{\mu\nu} + F_2\frac{p_\mu p_\nu}{\nu}$$
$$+\mathrm{i}\,\epsilon_{\mu\nu\lambda\sigma}\frac{q^\lambda}{\nu}\left(g_1 s^\sigma + \frac{g_2}{\nu}((\mathbf{pq})s^\sigma - (\mathbf{sq})p^\sigma)\right)$$
$$+\text{quadrupole terms}(b_1, b_2, b_3, b_4)$$ (for spin 1)

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Structure Functions in the Quark-parton Model

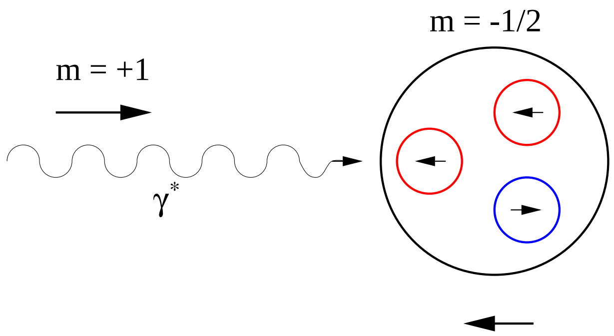
- quark densities $q^m_{\uparrow/\downarrow}$ for quark spin $\uparrow/\downarrow$ and hadron spin m (w.r.t. quantization axis)
- symmetry: $q^1_{\uparrow/\downarrow} = q^{-1}_{\downarrow/\uparrow}\,, \quad q^0_\uparrow = q^0_\downarrow$

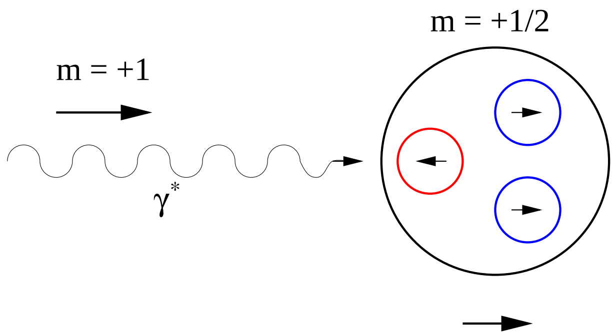
  $\leadsto$ choose 3 independent ones: $q^1_\uparrow$, $q^1_\downarrow$, $q^0_\uparrow$
- twist-2 structure functions:

$$
\begin{aligned}
F_1 &= \frac{F_2(x,Q^2)}{2x(1+R(x,Q^2))} \\
F_2 &= \frac{2}{3}x\sum_f e_f^2(q^1_\uparrow + q^1_\downarrow + q^0_\uparrow) \\
g_1 &= \frac{1}{2}\sum_f e_f^2(q^1_\uparrow - q^1_\downarrow) \\
b_1 &\approx \frac{b_1}{2x} \\
b_2 &= x\sum_f e_f^2(2q^0_\uparrow - q^1_\uparrow - q^1_\downarrow)
\end{aligned}
$$

Measurement of g_1: Simple Sketch

Photon-nucleon interaction:



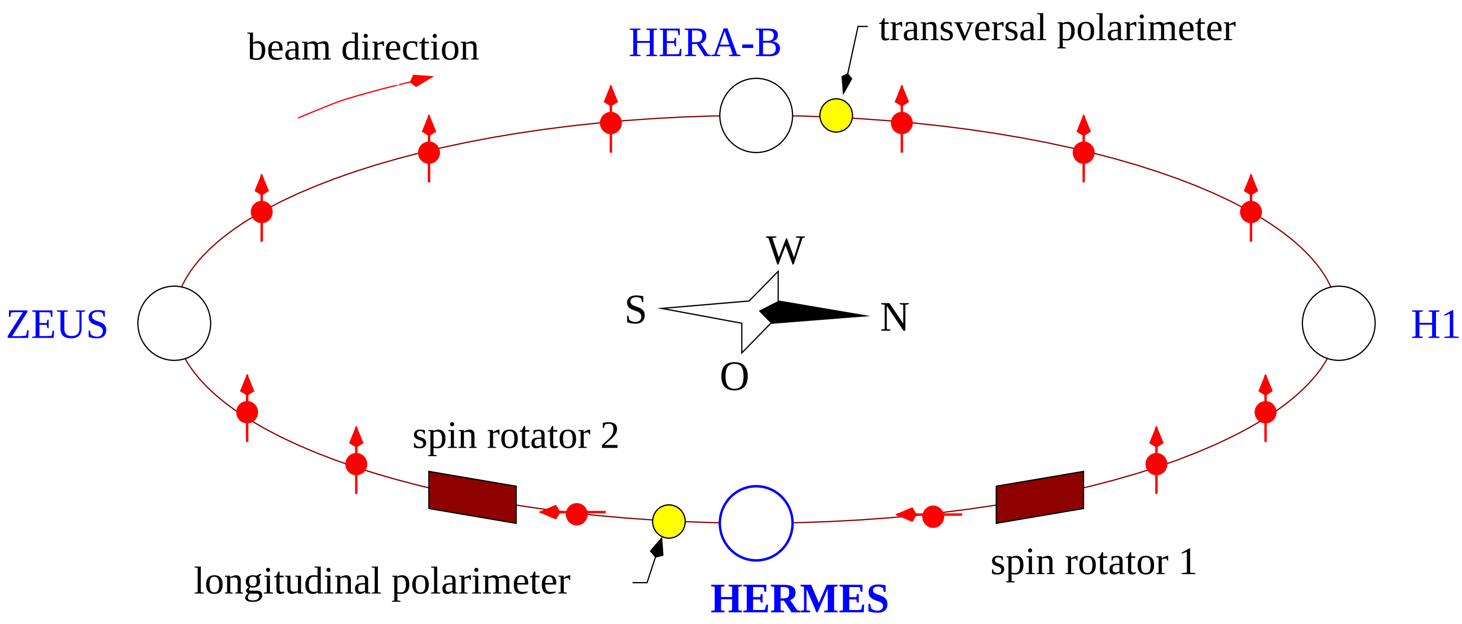


$$\sigma_{1/2} \sim \sum_f e_f^2 q_f^\uparrow \qquad \sigma_{3/2} \sim \sum_f e_f^2 q_f^\downarrow$$

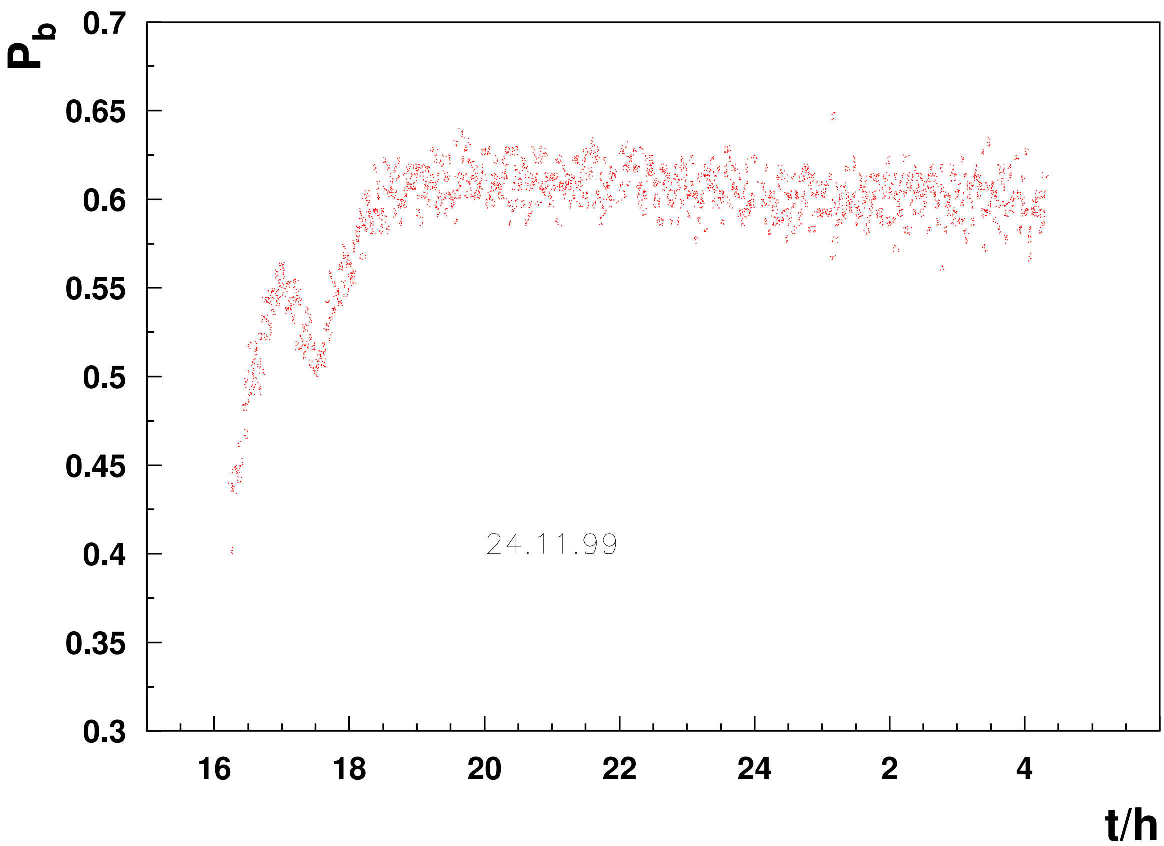
$\rightsquigarrow$ **approximatively**

$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{\sum_f e_f^2 \Delta q_f}{\sum_{f'} e_{f'}^2 q_{f'}} = \frac{g_1}{F_1}$$

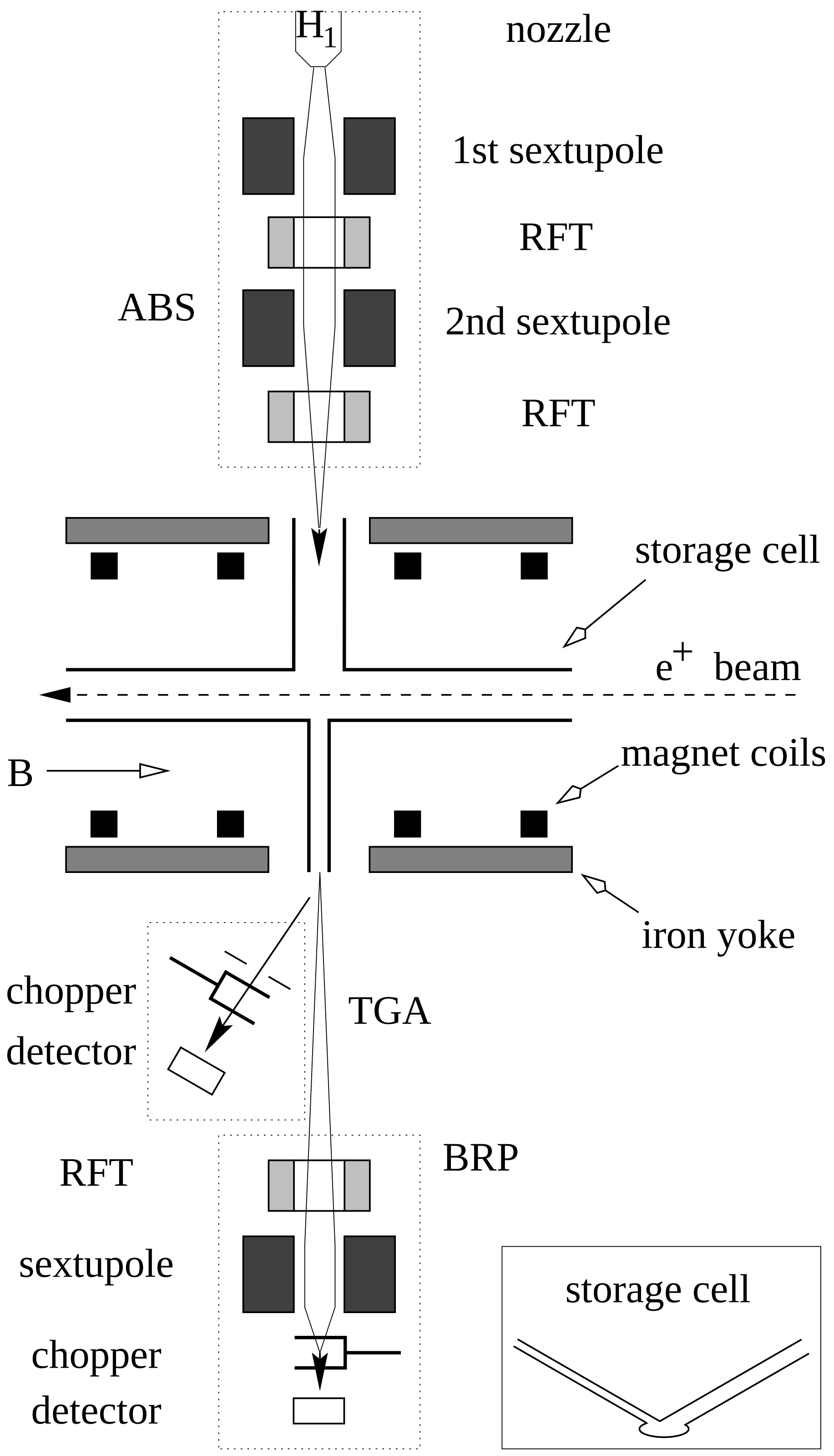
The Polarized Electron Beam at HERA (DESY)



typical electron beam currents: $I_e \approx 30 \text{ mA}$



The Polarized Internal Gas Target



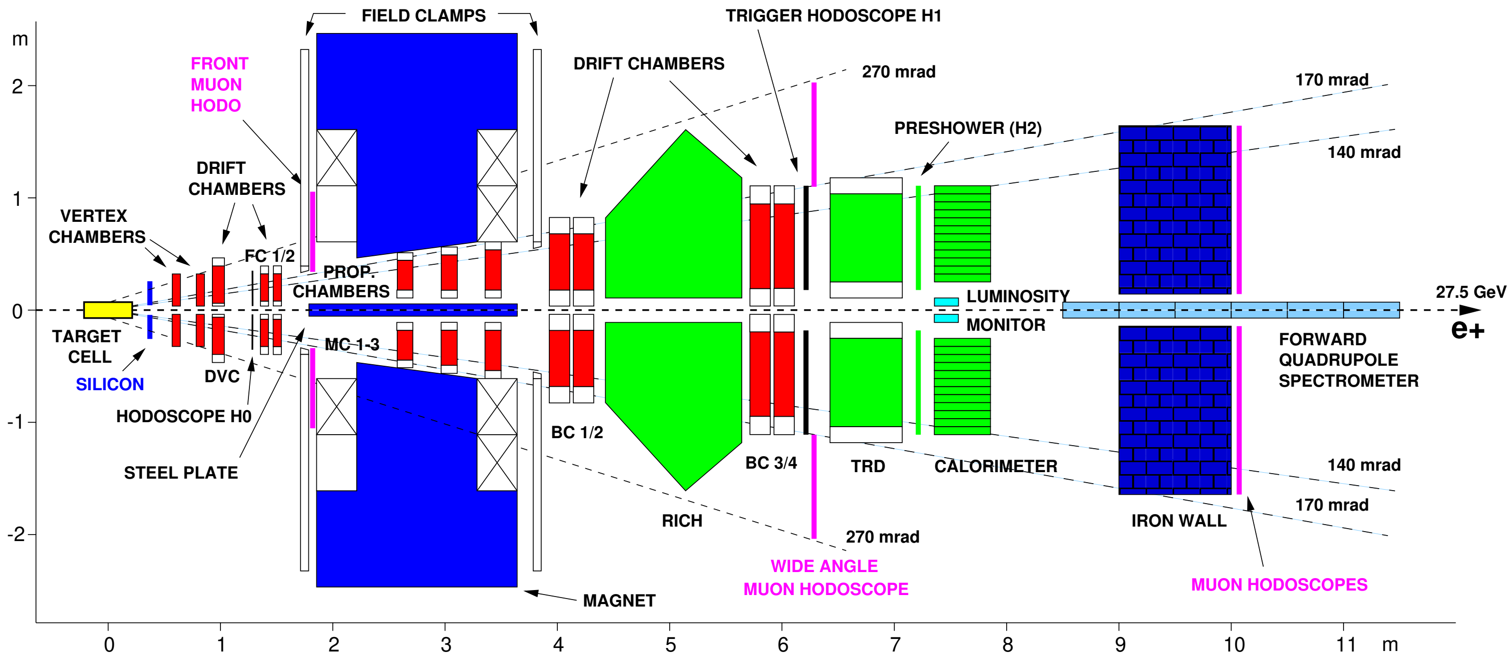
Target Performance

$$P_{\rm t} = \alpha_0(\alpha_{\rm r} + (1 - \alpha_{\rm r})\beta)P_{\rm a}$$

- $P_{\rm t}$ Target Polarization (averaged)
- α_0 Initial degree of dissociation
- $\alpha_{\rm r}$ Recombination inside cell
- β Polarization of molecules, $\beta = P_a/P_m$
- $P_{\rm a}$ Polarization of atoms

	1996/1997 Hydrogen	1998/1999 Deuterium	2000 Deuterium
$\langle \rho^{\rm t} \rangle$ $({\rm cm}^{-2})$	$7.5 * 10^{13}$	$7.5 * 10^{13}$	$14 * 10^{13}$
$T_{\rm c}$ (K)	100	90	65
$B^{\rm t}$ (mT)	335	335	335
α_0	0.99 ± 0.02	0.94 ± 0.03	0.953 ± 0.014
$\alpha_{\rm r}$	0.93 ± 0.04	1.00 ± 0.03	0.997 ± 0.013
$P_{\rm a}$	0.92 ± 0.03	0.99 ± 0.01	0.99 ± 0.01
β	0.60 ± 0.40	0.60 ± 0.40	0.60 ± 0.40
$\langle P_{\rm t} \rangle$	0.88 ± 0.04	0.84 ± 0.03	0.85 ± 0.02

The HERMES Spectrometer



- **geometric acceptance:** $0.04 < \theta < 0.22$

- **DIS trigger:** hodoscopes * calorimeter (> 1.4 GeV)

- **resolution:**

  $\delta p/p \leq 1.25$ %

  $\delta\theta \leq 0.6$ mrad

- **particle identification:**

  $\langle\epsilon\rangle = 98$ %

  $h \leq 0.25$ %

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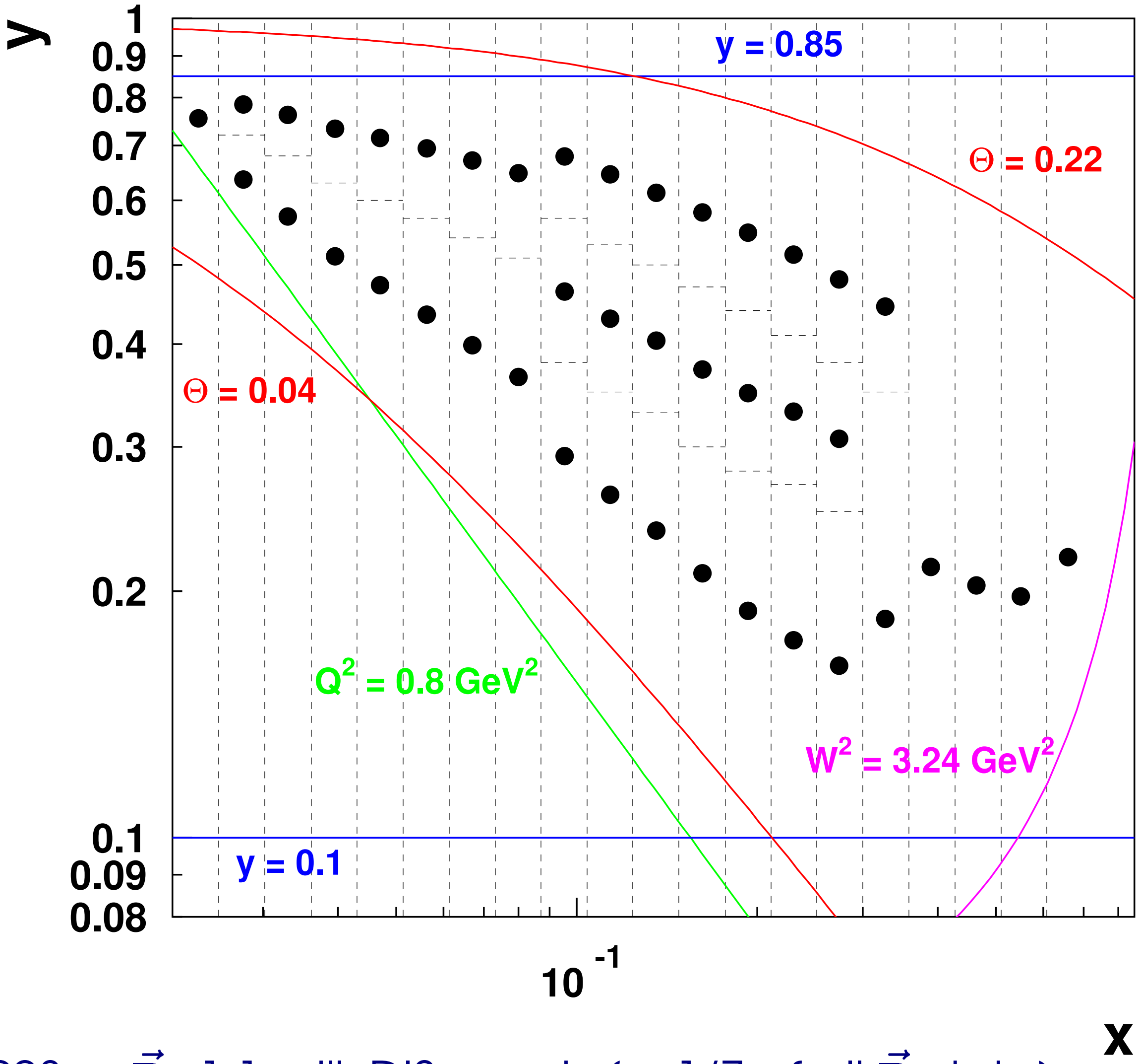
Kinematic Range of g_1^{d} Analysis

$$0.0212 < x < 0.85$$
$$0.85 > y > 0.1$$
$$0.8\ \mathrm{GeV}^2 < Q^2$$



- 1998 $e^-\vec{\mathrm{D}}$: 1.1 mill. DIS events ($\sim$ 1/7 of all $\vec{\mathrm{D}}$ data)
- further data being analyzed: $y_{\max} \to 0.91$

$$\leadsto x_{\min} \to 0.0021, \quad Q^2_{\min} \to 0.1\ \mathrm{GeV}^2$$

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Asymmetry Formalism

- **longitudinal cross-section asymmetry**

$$A_{||} = \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}} = \frac{1}{P_{\mathrm{b}} P_{\mathrm{t}}} \frac{(N/L)^{\rightleftarrows} - (N/L)^{\rightrightarrows}}{(N/L)^{\rightleftarrows} + (N/L)^{\rightrightarrows}}$$

$P_{\mathrm{t}}, P_{\mathrm{b}}$: target and beam polarization

$N^{\rightleftarrows/\rightrightarrows}$: number of DIS events

$L^{\rightleftarrows/\rightrightarrows}$: deadtime corrected luminosity

- **spin asymmetries in absorption of virtual photons**:

$$A_1 = \frac{g_1 - \gamma^2 g_2}{F_1}, \qquad A_2 = \gamma \frac{g_1 + g_2}{F_1}$$

with $A_{||} = D(A_1 + \eta A_2)$

- **structure function ratio**:

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

$D = P_{\gamma *}/P_{\mathrm{b}}$: depolarization factor $(D \approx y)$

η, γ: kinematic factors

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Extraction of the Spin Structure Function g_1^{d}

- assumption about g_2^{d} (preliminary!):

$$g_2^{\mathrm{d}} = 0 \quad \Longrightarrow \quad A_2^{\mathrm{d}} = \gamma \frac{g_1^{\mathrm{d}}}{F_1^{\mathrm{d}}}$$

$\leadsto$ use fit to $g_1^{\mathrm{d}}/F_1^{\mathrm{d}}$ world data

- final extraction:

$$g_1 = \left(\frac{g_1}{F_1}\right)_{\mathrm{meas}} \cdot F_1^{\mathrm{param}} = \left(\frac{g_1}{F_1}\right)_{\mathrm{meas}} \cdot \frac{(1+\gamma^2)F_2}{2x(1+R)}$$

F_2^{d}:	Nucl. Phys. **B371** (1992) 3
$R = \sigma_{\mathrm{L}}/\sigma_{\mathrm{T}}$:	Phys. Lett. **B250** (1990) 193
$b_1^{\mathrm{d}} = 0$	(assumption; data not analyzed yet !)

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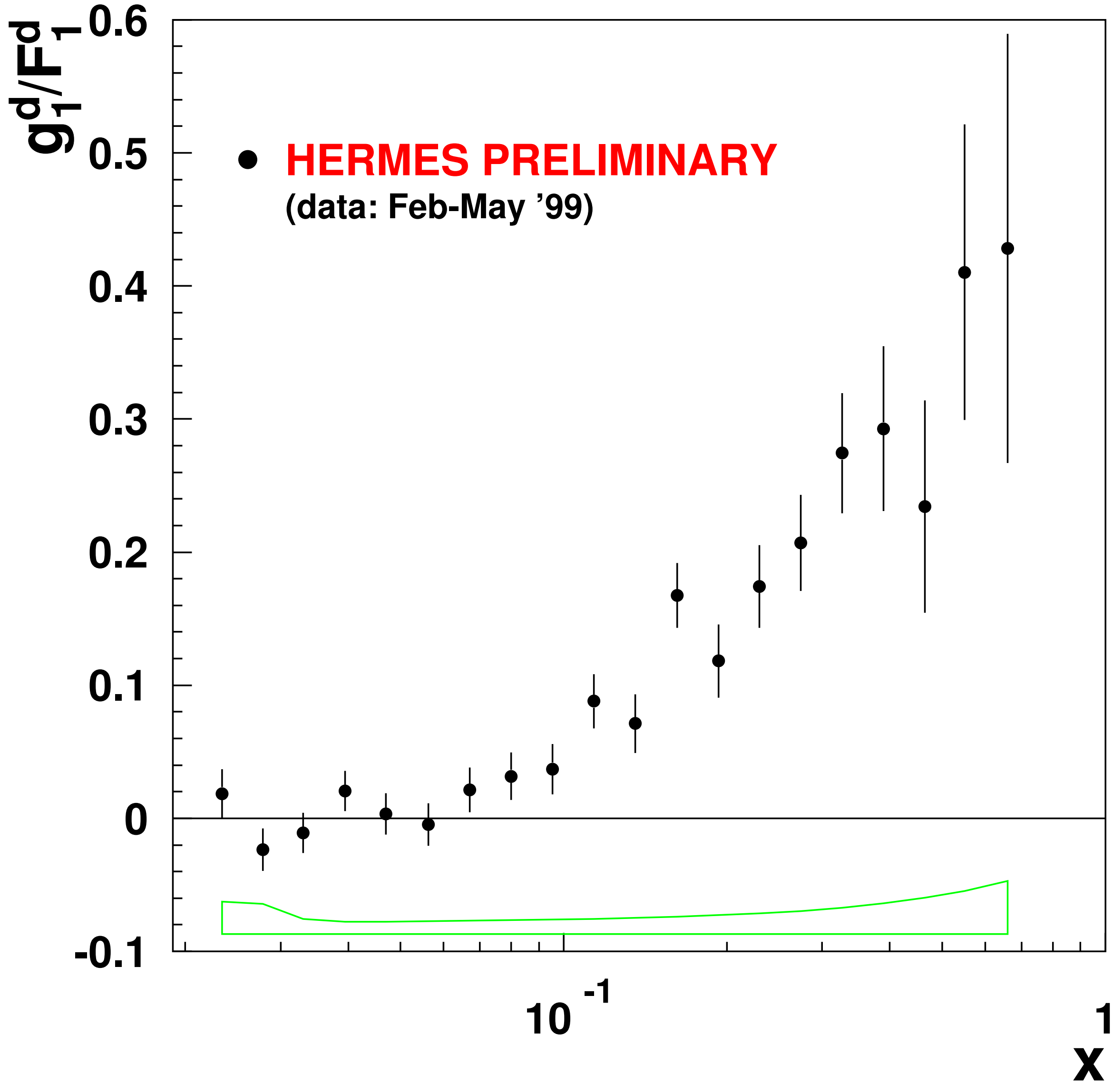
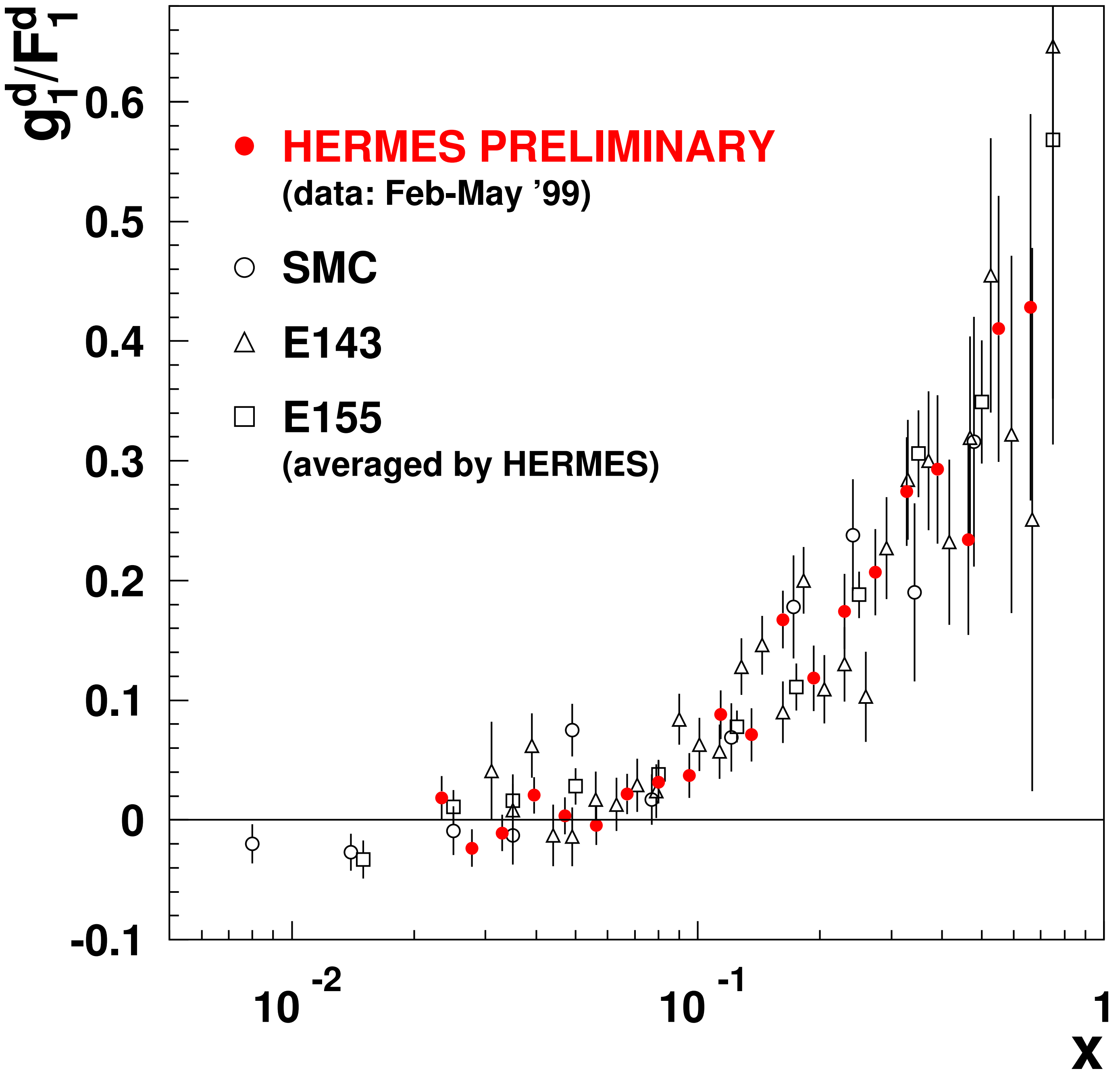
Measurement of $g_1^{\mathrm{d}}/F_1^{\mathrm{d}}$



dominant contributions to systematic uncertainty:

- radiative corrections: $\leq \mathbf{0.024}$ (abs.)
- A_2^{d} assumption: $\leq \mathbf{3.0\ \%}$
- Beam Polarization: **3.4 %**
- Target Polarization: **8.0 %** (preliminary!)

$g_1^{\rm d}/F_1^{\rm d}$: Comparison with World Data

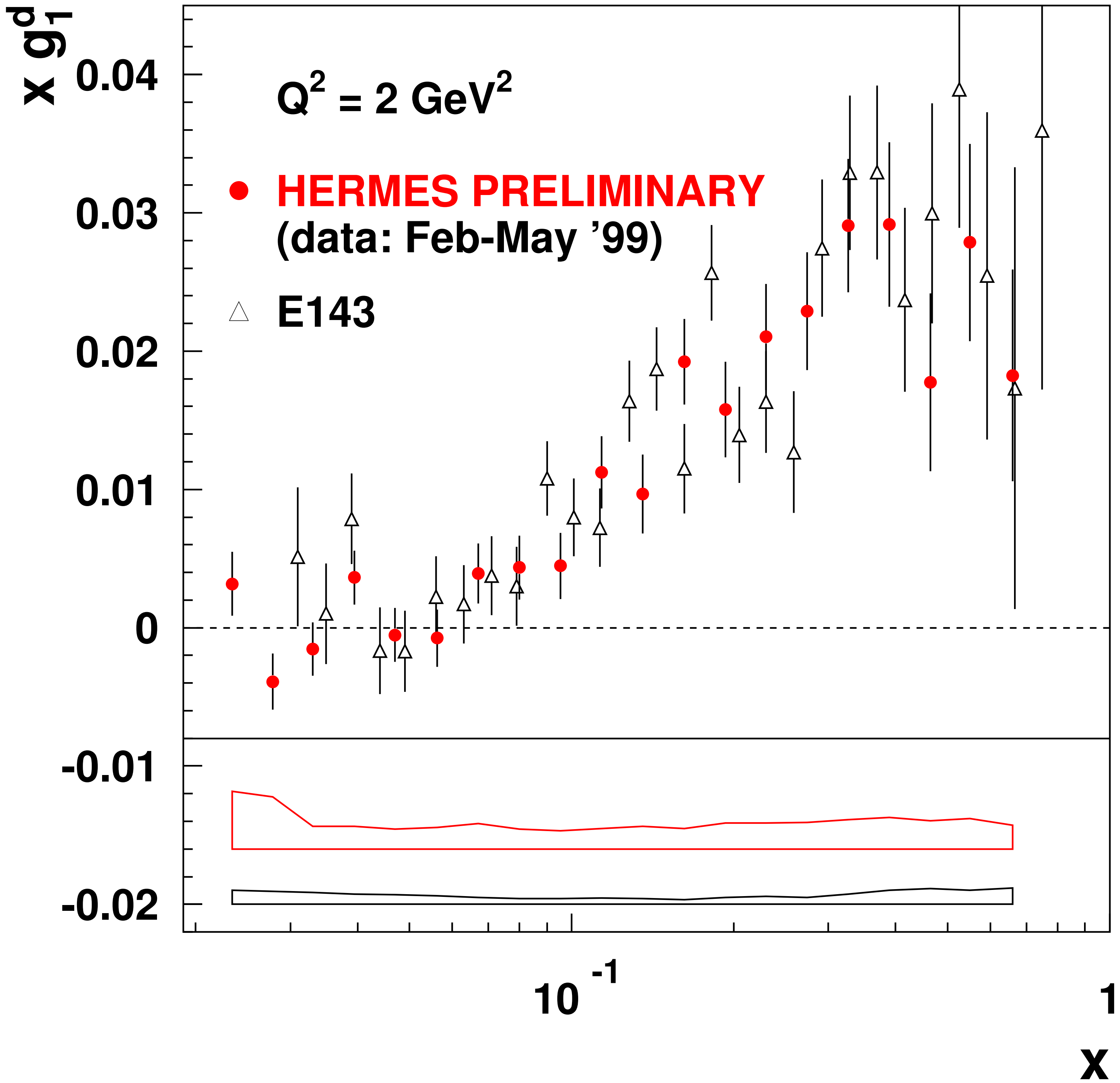


- no significant Q^2-dependence in $g_1^{\rm d}/F_1^{\rm d}$

  $\rightsquigarrow$ $g_1^{\rm d}$ scales like $F_1^{\rm d}$

- 6 times more data on tape are being analyzed

Resulting Structure Function g_1^{d}



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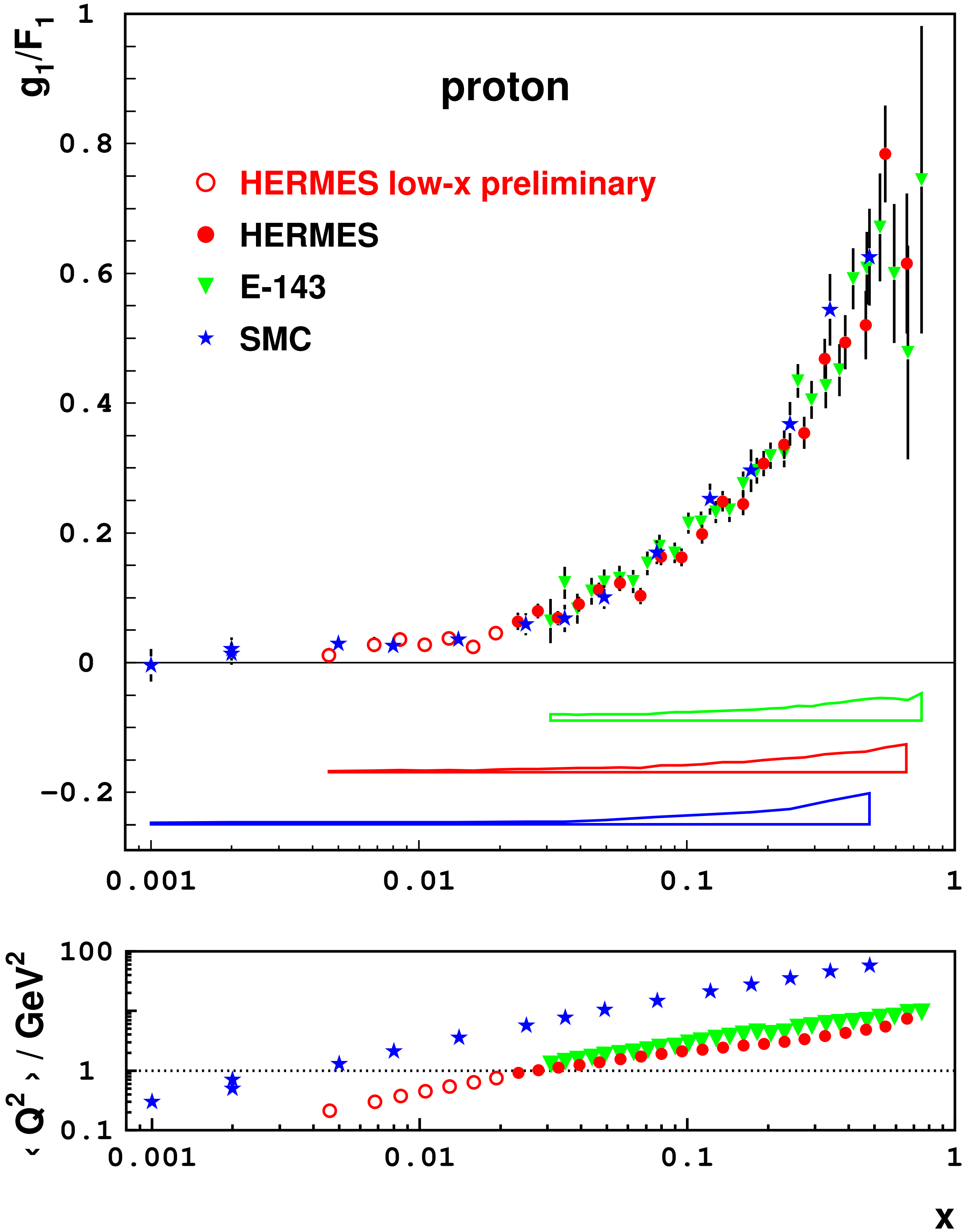
$g_1^{\mathrm{p}}/F_1^{\mathrm{p}}$ from '97 Hydrogen Data



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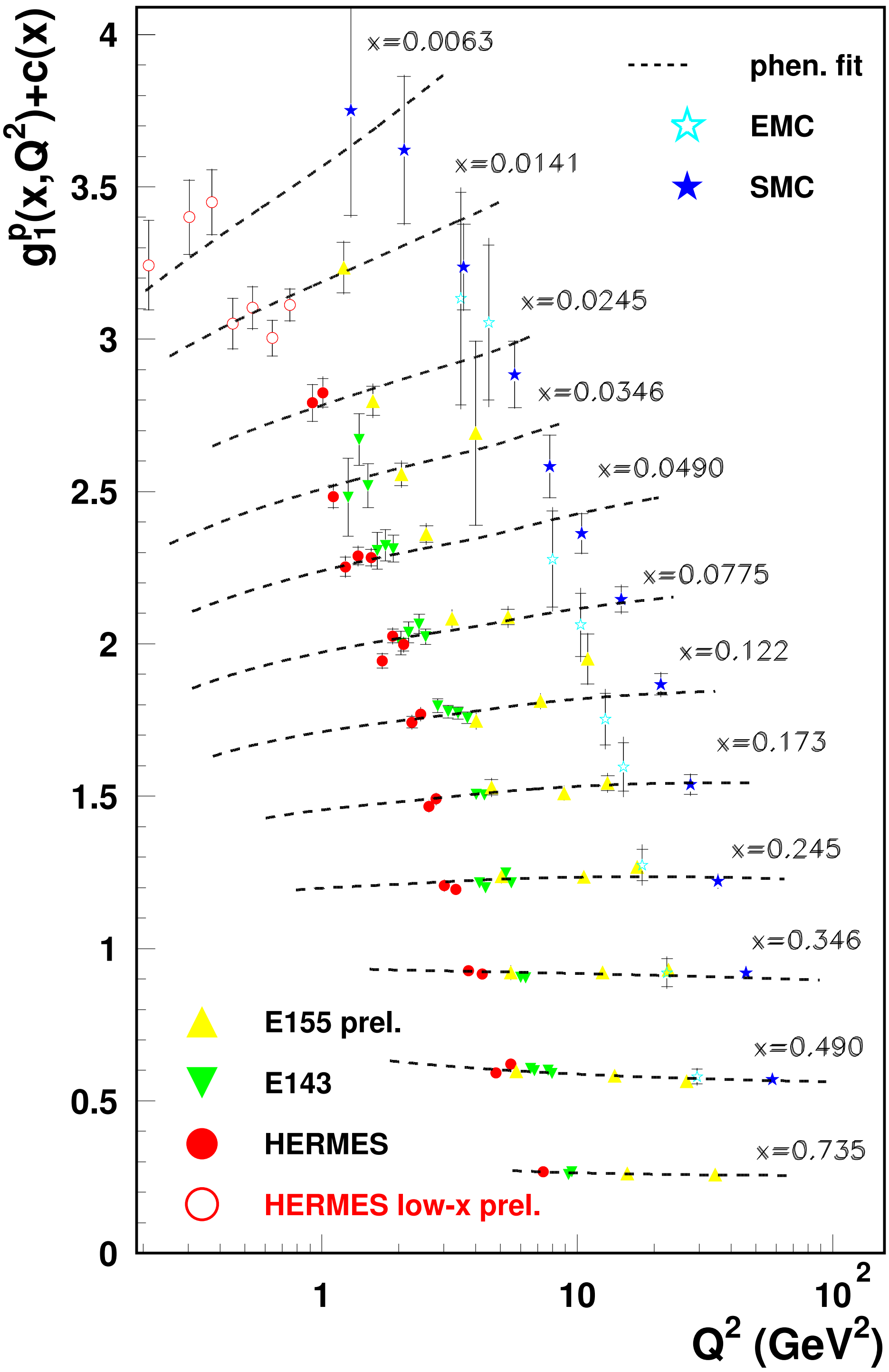
g_1^p from '97 Hydrogen Data



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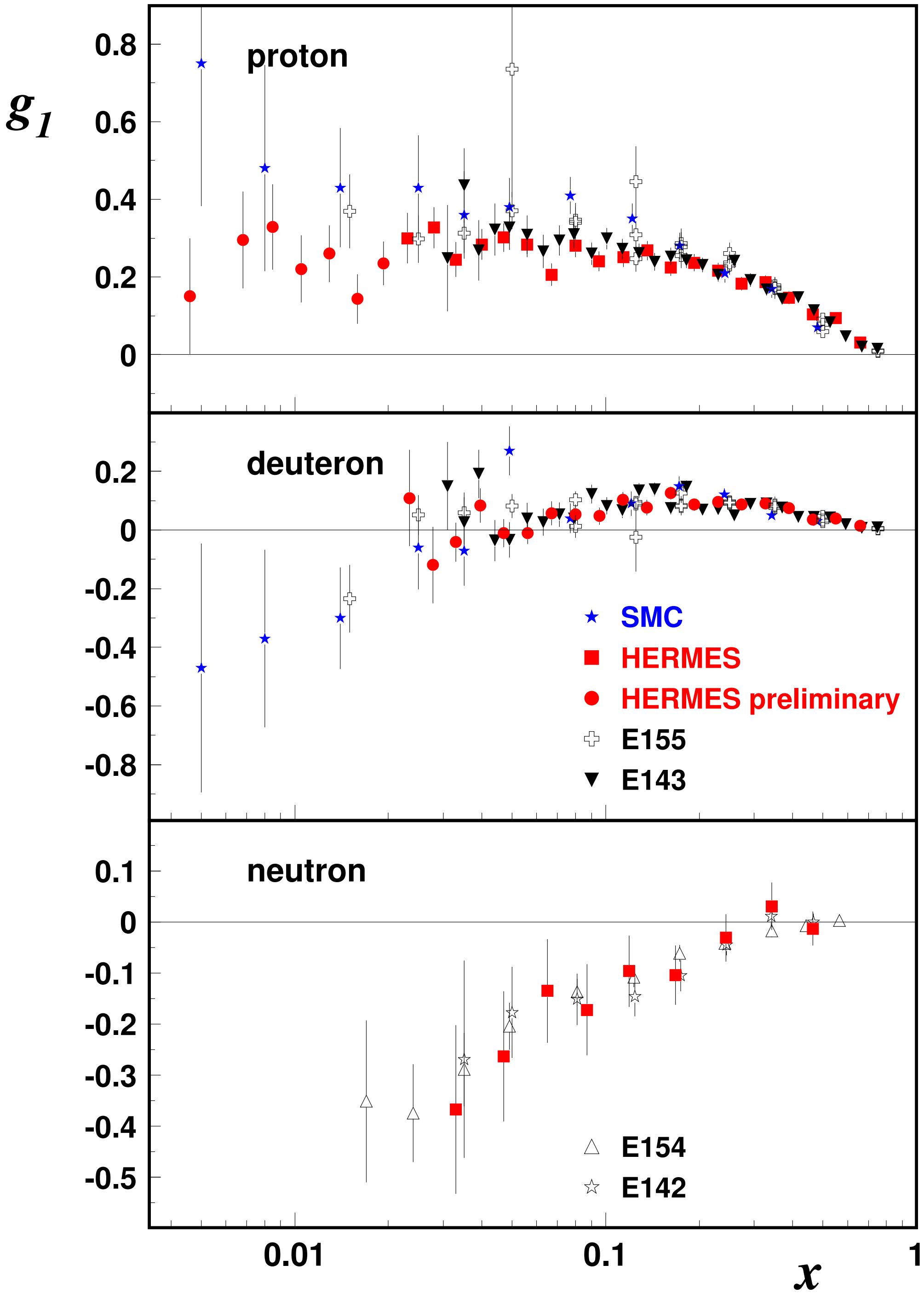
World Data for g_1



- data shown at **measured** Q^2 !
- SMC results for $Q^2 > 1\ \mathrm{GeV}^2$ only
- HERMES low-x data on the deuteron are being analyzed

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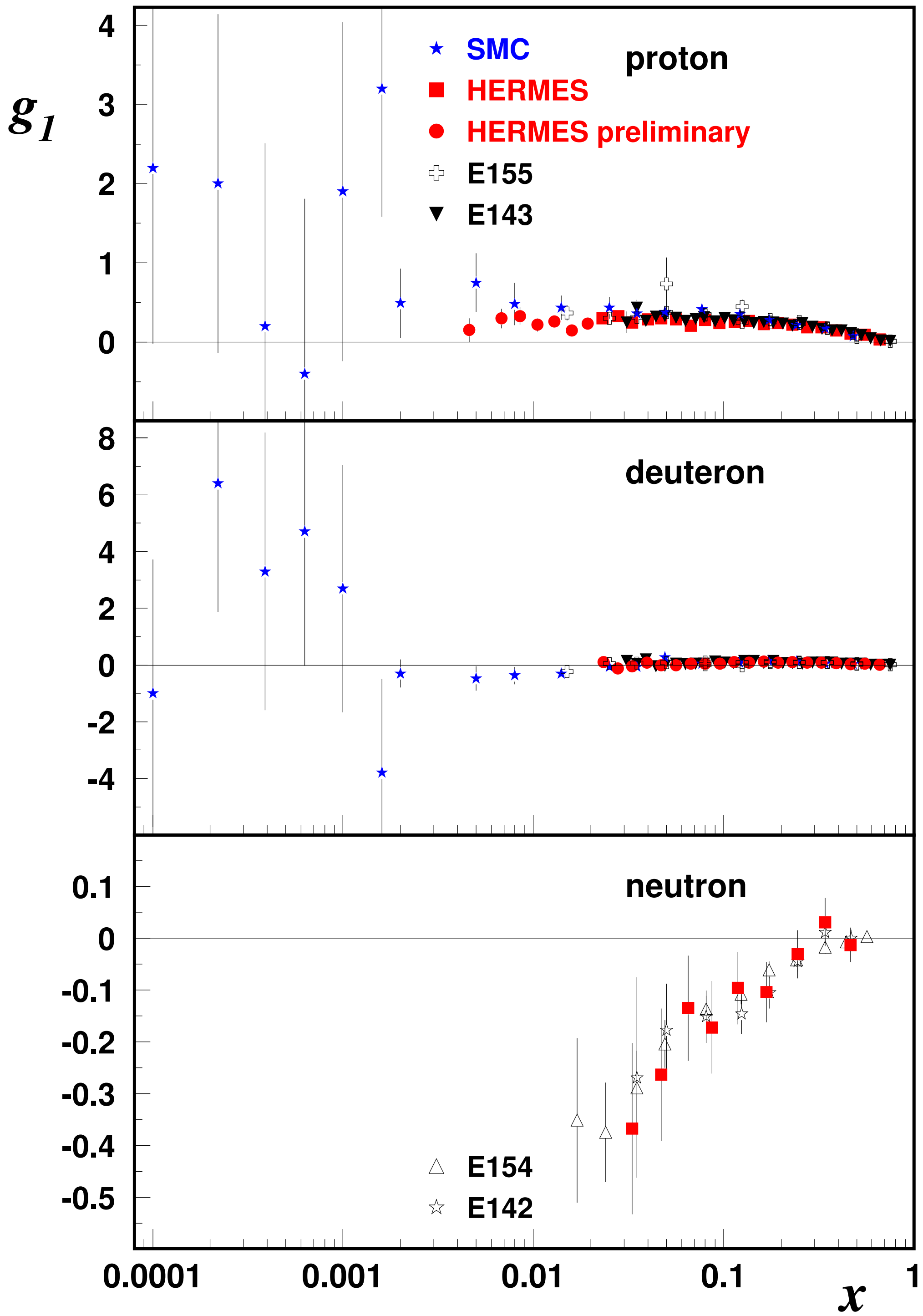
World Data for g_1



- data shown at **measured** Q^2 !
- all SMC results shown

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Summary

- new preliminary HERMES results for the polarized deuteron structure function g_1^{d} in the kinematic range

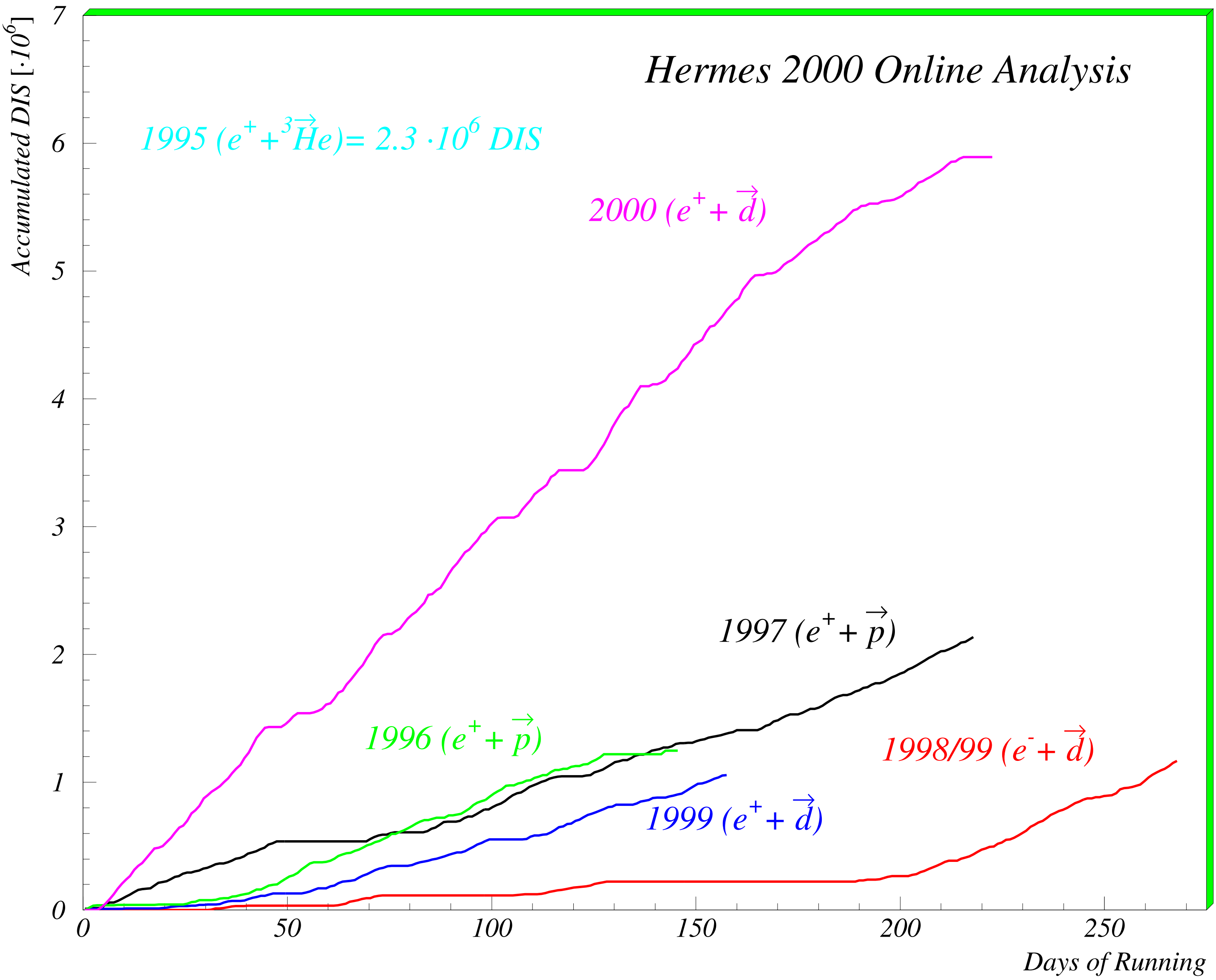
  $0.0212 < x < 0.85, \quad Q^2 > 0.8\ \mathrm{GeV}^2$

- good agreement with world data with improved accuracy

  $\leadsto$ no significant Q^2 dependence of $g_1^{\mathrm{d}}/F_1^{\mathrm{d}}$

- 6 times more data on tape

Further HERMES Data...



- 2000 $e^+\vec{\mathrm{D}}$: 10 mill. DIS events including low-x region
- 1 mill. with tensor-polarized D $\rightsquigarrow$ first measurement of b_1^{d}
- + 30 mill. with unpolarized targets

$({}^1\mathrm{H}, {}^2\mathrm{D}, {}^3\mathrm{He}\,, {}^4\mathrm{He}, {}^{14}\mathrm{N}, {}^{20}\mathrm{Ne}, {}^{84}\mathrm{Kr})$