The Polarized Structure Function g_1^p at Low x_{Bj} and Low Q^2 measured with HERMES

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on behalf of the HERMES Collaboration

Outline:

- Introduction
- The Hermes Experiment
- Measurement of g_1^p at low x_{Bj} and low Q^2
- Summary

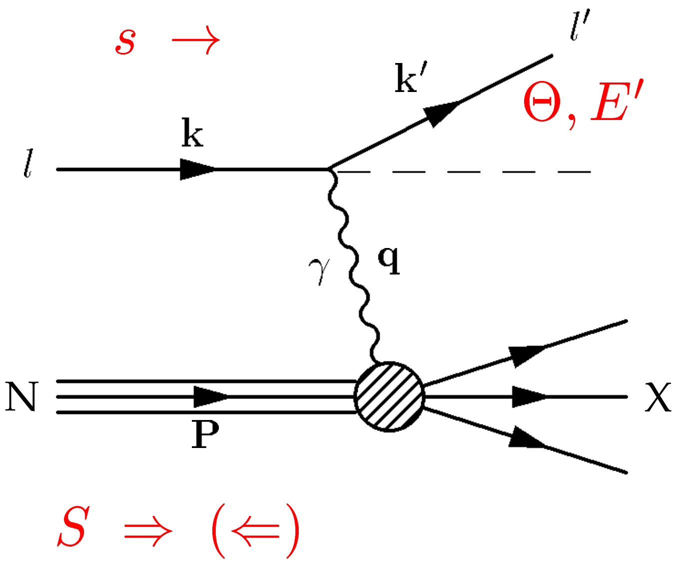
Goal for g_1^p: extension of kinematic range

$$x > 0.002, \ y < 0.91, \ Q^2 > 0.1 \ GeV^2$$

DIS 2000, Liverpool, April 27 2000

Deep Inelastic Scattering

- DIS KINEMATICS:



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

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

$$x = \frac{Q^2}{2Pq}, \quad \gamma^2 = \frac{Q^2}{\nu^2}$$

$$W^2 = (q + P)^2$$

- LONGITUDINAL CROSS SECTION ASYMMETRY :

$$A_{\|} = \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}} = D(A_1 + \eta A_2)$$

A_1 , A_2 :	VIRTUAL PHOTON ASYMMETRIES
D :	PHOTON DEPOLARIZATION FACTOR
η :	KINEMATIC FACTOR

$$A_{\|} = \frac{1}{< P_T P_B >} \frac{(N/L)^{\rightleftarrows} - (N/L)^{\rightrightarrows}}{(N/L)^{\rightleftarrows} + (N/L)^{\rightrightarrows}}$$

P_T, P_B :	TARGET AND BEAM POLARISATION
N :	NUMBER OF INCLUSIVE DIS EVENTS
L :	DEADTIME CORRECTED LUMINOSITY

Formalism

- FROM $A_{\|}$ TO g_1/F_1 :

$$A_{\|} = \frac{\sigma^{\overset{\rightarrow}{\Leftarrow}} - \sigma^{\overset{\rightarrow}{\Rightarrow}}}{\sigma^{\overset{\rightarrow}{\Leftarrow}} + \sigma^{\overset{\rightarrow}{\Rightarrow}}} = D(A_1 + \eta A_2)$$

A_1 , A_2 :	VIRTUAL PHOTON ASYMMETRIES
D :	PHOTON DEPOLARIZATION FACTOR
η :	KINEMATIC FACTOR

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

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

WITH

$$D = \frac{y(2-y)(1+\gamma^2 y/2)}{y^2(1+\gamma^2) + 2(1-y-\gamma^2 y^2/4)(1+R)}$$

$$\eta = \frac{\gamma(1-y-\gamma^2 y^2/4)}{(1-y/2)(1+\gamma^2 y/2)}$$

$$\gamma^2 = Q^2/\nu^2$$

Motivation

Why g_1 at low x_{Bj}?

- Low$-x$ region is important for determining $\Delta\Sigma$ and ΔG, the quark and gluon contributions to the nucleon spin (extrapolation into the unmeasured region).

Why g_1 at low Q^2?

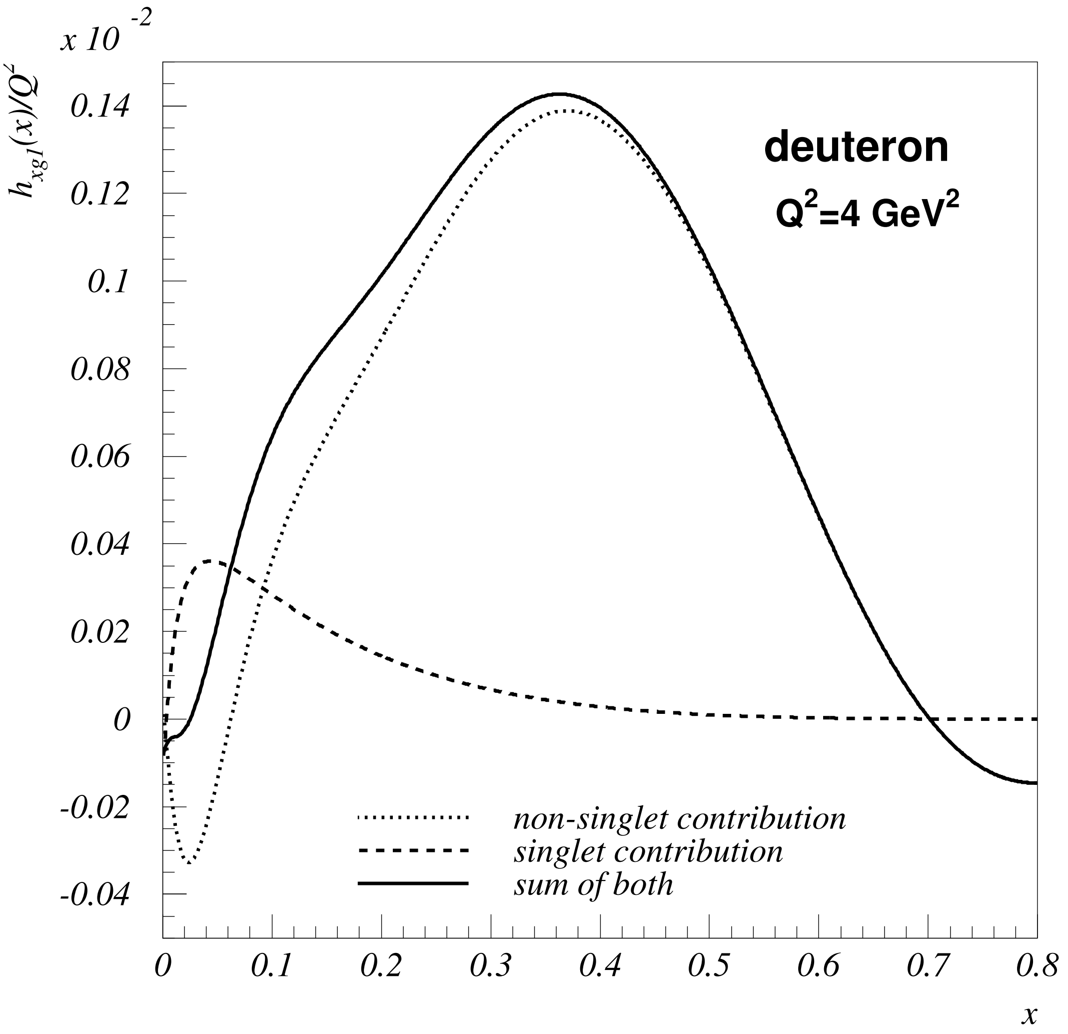
- Provide new data for the study of scaling violations.
- Allow further tests of the pQCD concept: down to which Q^2 is the concept valid?

$$
\begin{aligned}
xg_1(x,Q^2) \quad = \quad & xg_1^{tw-2}(x,Q^2) \\
& + \frac{1}{Q^2} h^{tw-4}(x,Q^2) \\
& + \frac{1}{Q^2}\left(h_{TMC}^{tw-2}(x,Q^2) + h_{TMC}^{tw-3}(x,Q^2) \right) \\
& + \mathcal{O}\left(\frac{1}{Q^4}\right)
\end{aligned}
$$

$\Longrightarrow$ field in progress

Twist-4 Contribution

- LO calculation for deuteron at $Q^2 = 4\ \mathrm{GeV}^2$

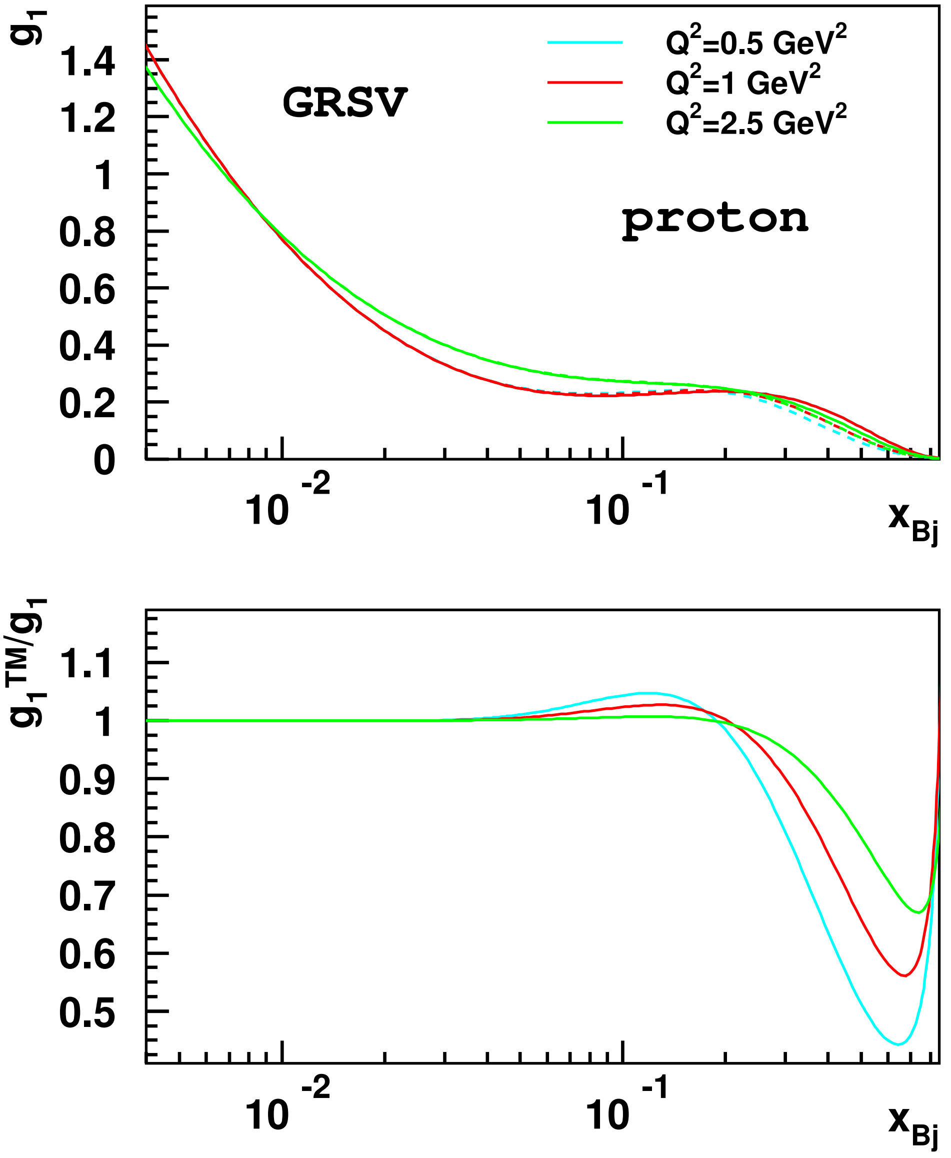


[DIS '99: E.Stein, NP B (proc. Suppl.)79 (1999) 567]

- first step towards twist-4 calculations
- status: successfully applied to unpolarized structure functions for $x > 0.1$ (NS)
- twist-4 corrections to $g_1^d(x, Q^2)$ at $Q^2 = 4\,GeV^2$ are of the order of $6\,\%$

Target Mass Correction

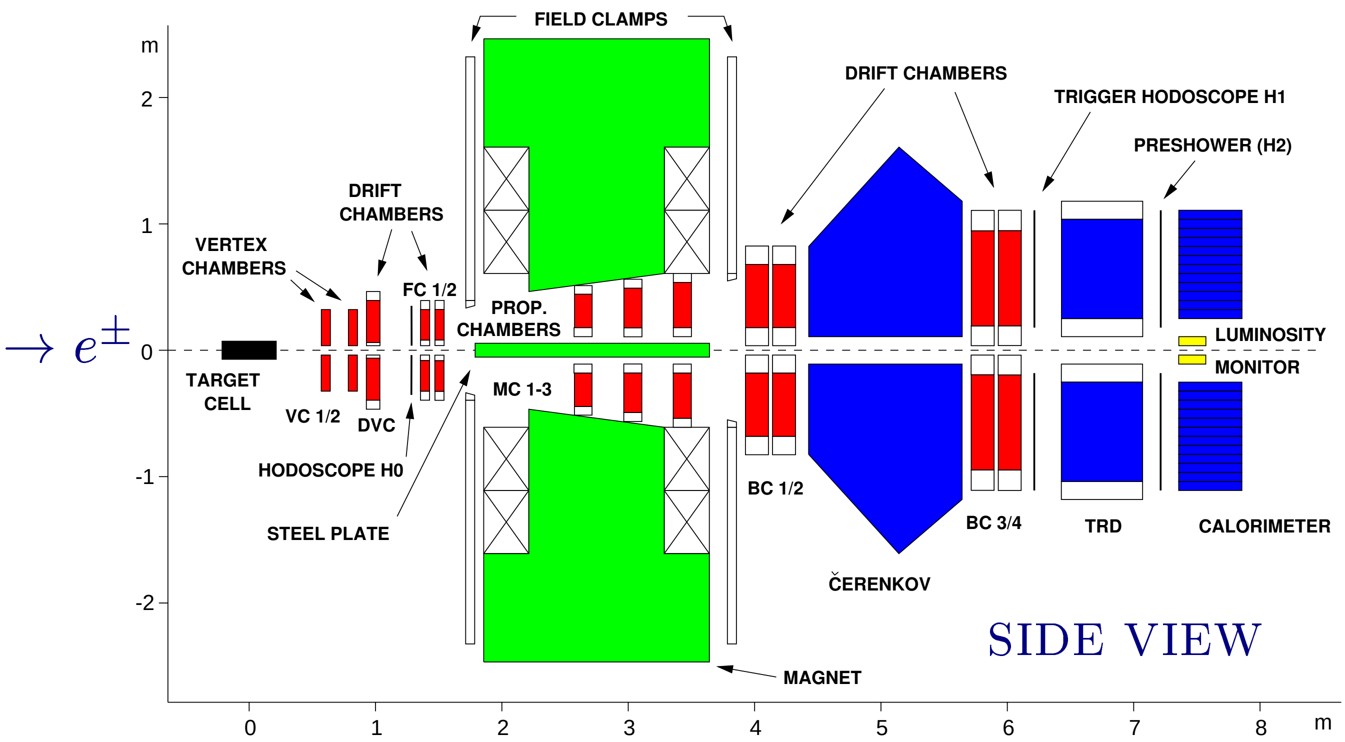
- LO target mass contribution to g_1^p at twist-2 level



[J.Blümlein, A.Tkabladze, hep-ph/9812478]

$\Longrightarrow$ no correction in the low x_{Bj} and Q^2 range:
$0.0021 < x < 0.0212, \quad 0.1 < Q^2 < 0.8$

The HERMES Experiment at DESY



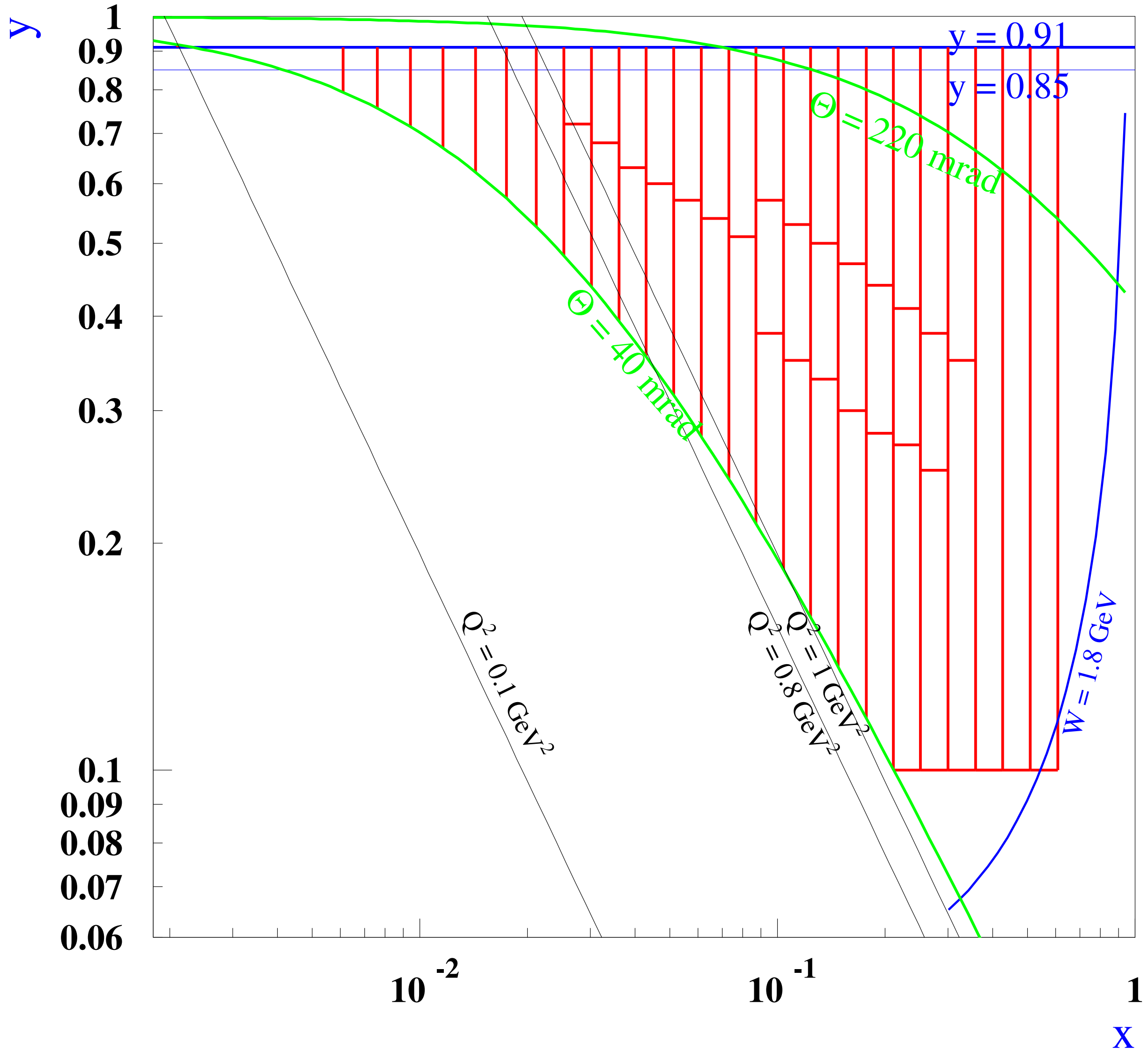
- Beam: transversely self-polarized 27.6 GeV $e^{\pm}$-beam of HERA, rotated to longitudinal spin orientation at the HERMES IP; $P_{\mathrm{beam}} \approx 0.55 \pm 0.02$
- Target: cooled open-ended storage cell inside the beam pipe, longitudinally polarized pure (^{1}H, D, ^{3}He) gas atoms of $(7-33) \times 10^{13}$ nucleons/cm^2; $P_{\mathrm{H}} = 0.88 \pm 0.04$, $P_{\mathrm{D}} \approx P_{\mathrm{H}}$, $P_{\mathrm{He}} = 0.46 \pm 0.02$
- Tracking: forward dipole magnet spectrometer with 57 chamber planes ($40\,\mathrm{mrad} < \theta < 220\,\mathrm{mrad}$); resolution: $\delta\theta < 0.6$ mrad, $\delta p/p < 1.5\%$
- Particle ID: threshold Cerenkov detector, TRD, preshower, lead-glass calorimeter; e/h misidentification $< 0.4\%$
- Fast Trigger: scintillator hodoscopes H0, H1, H2; calorimeter; energy threshold 1.4 (3.5) GeV
- Luminosity Monitor

Inclusive DIS Data at Low x and Q^2

- Extension of the Kinematic Range:

$$\begin{array}{rcccl} 0.85 & > & x & > & 0.0021\ (0.0212) \\ 0.1 & < & y & < & 0.91\ (0.85) \\ & & Q^2 & > & 0.1\ (0.8)\ \mathrm{GeV}^2 \end{array}$$

- The kinematic plane:



1997 H Data : $2.5*10^6$ Events after quality cuts

Syst. Uncertainties at Low x and Q^2

- EXPERIMENTAL SYSTEMATIC UNCERTAINTIES:

$\rightarrow$ BEAM POLAR.: $\Delta_{P_B} = 3.4\,\%$

$\rightarrow$ TARGET POLAR.: $\Delta_{P_T} = 4.7\,\%$

$\rightarrow$ OTHER SOURCES: $\Delta_{\rm misc} = 5.5\,\%$

(NORMALIZATION, HADRON CONTAMINATION, CUT STABILITY, Θ–SYSTEMATICS)

- SYSTEMATIC UNCERTAINTIES IN THE ITERATIVE EXTRACTION OF THE BORN ASYMMETRY:

$\rightarrow$ RAD. CORR. [POLRAD: J. PHYS. G20(1994)513] + SMEARING CORR.:

$\Delta_{\rm corr} \approx 5.0\,\%$ ($11\,\%$ LOWEST x)

$\rightarrow$ A_2–PARAMETRIZATION: $A_2 = 0.5 \cdot x/\sqrt{Q^2}$

[BASED ON E-143 DATA: PHYS. REV. D58(1998)112003]

$\Delta_{A_2} \leq 0.5\,\%$

FIXED: F2: ALLM97 [HEP-PH/9712415] WITH LOW-W MOD. (FOR W < 2.2 GeV AND $Q^2 < 0.5$ GeV^2) AND R1990 [PHYS. LETT. B250(1990)193]

$\Rightarrow$ TOTAL FOR LOW–x REGION: $9.4\,\%$

($13.6\,\%$ LOWEST x BIN)

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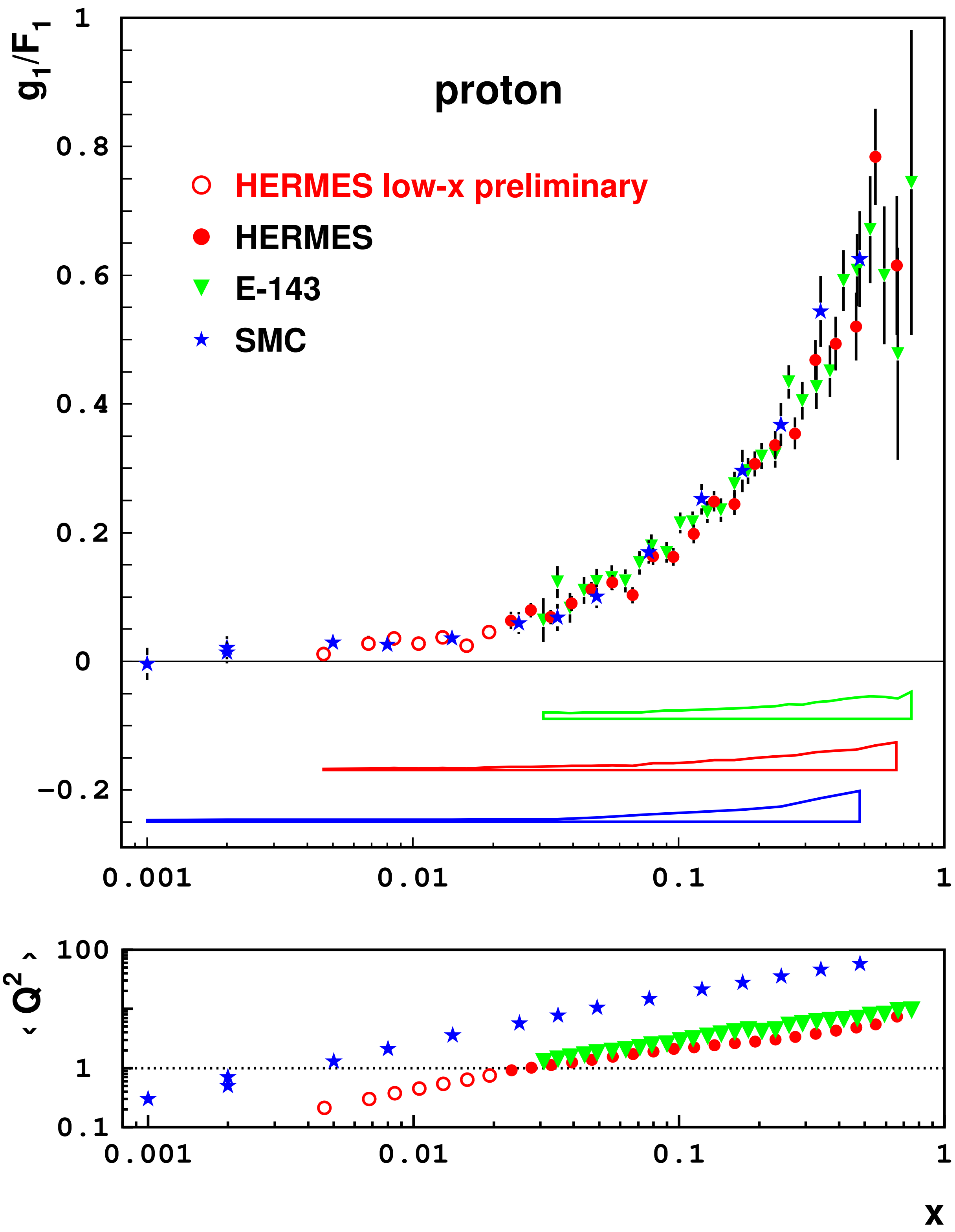
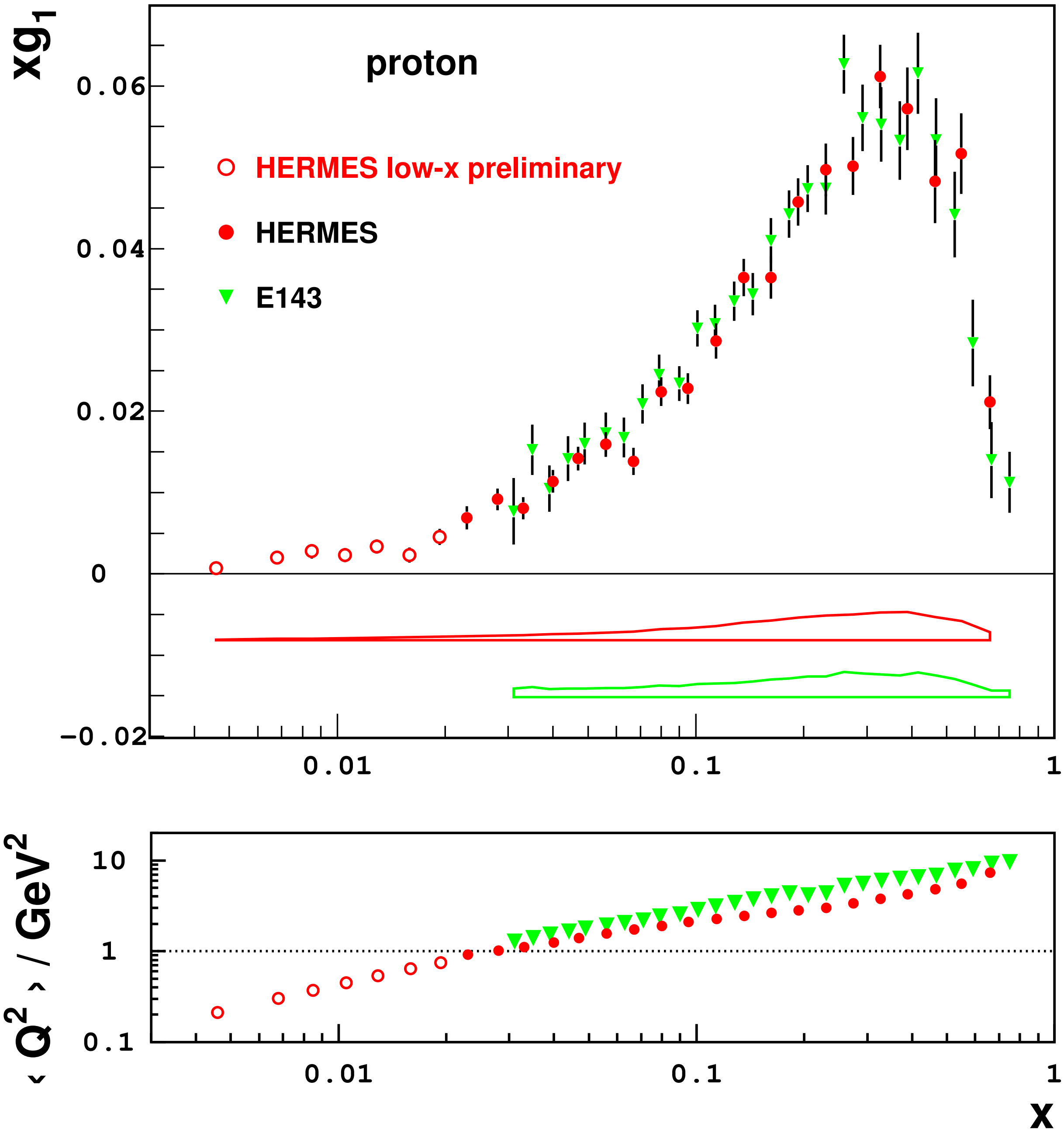
g_1^p/F_1^p : Comparison to E143 & SMC

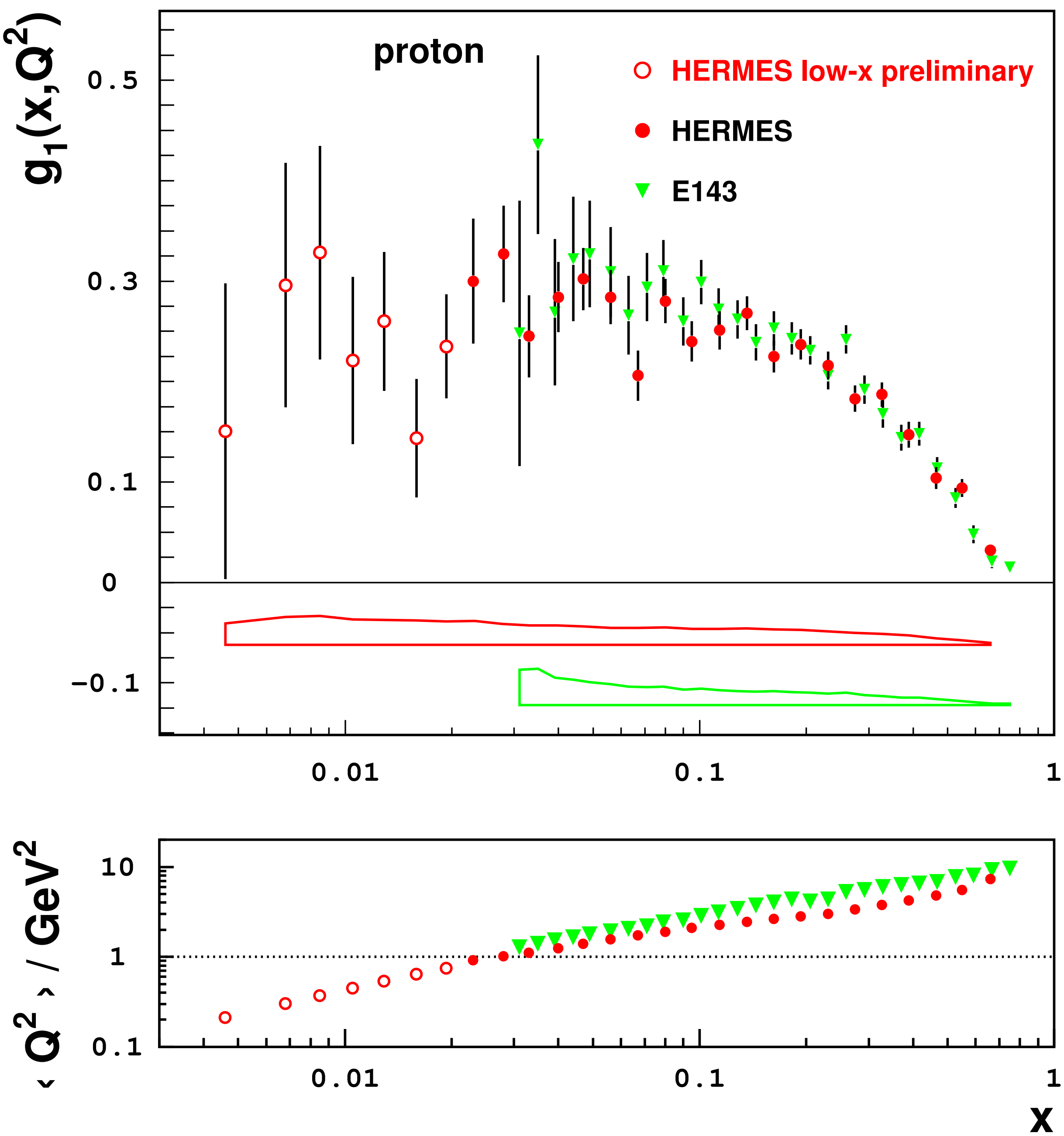


$\Rightarrow$ NO STATISTICALLY SIGNIFICANT Q^2 DEPENDENCE

xg_1^p: Comparison to E143

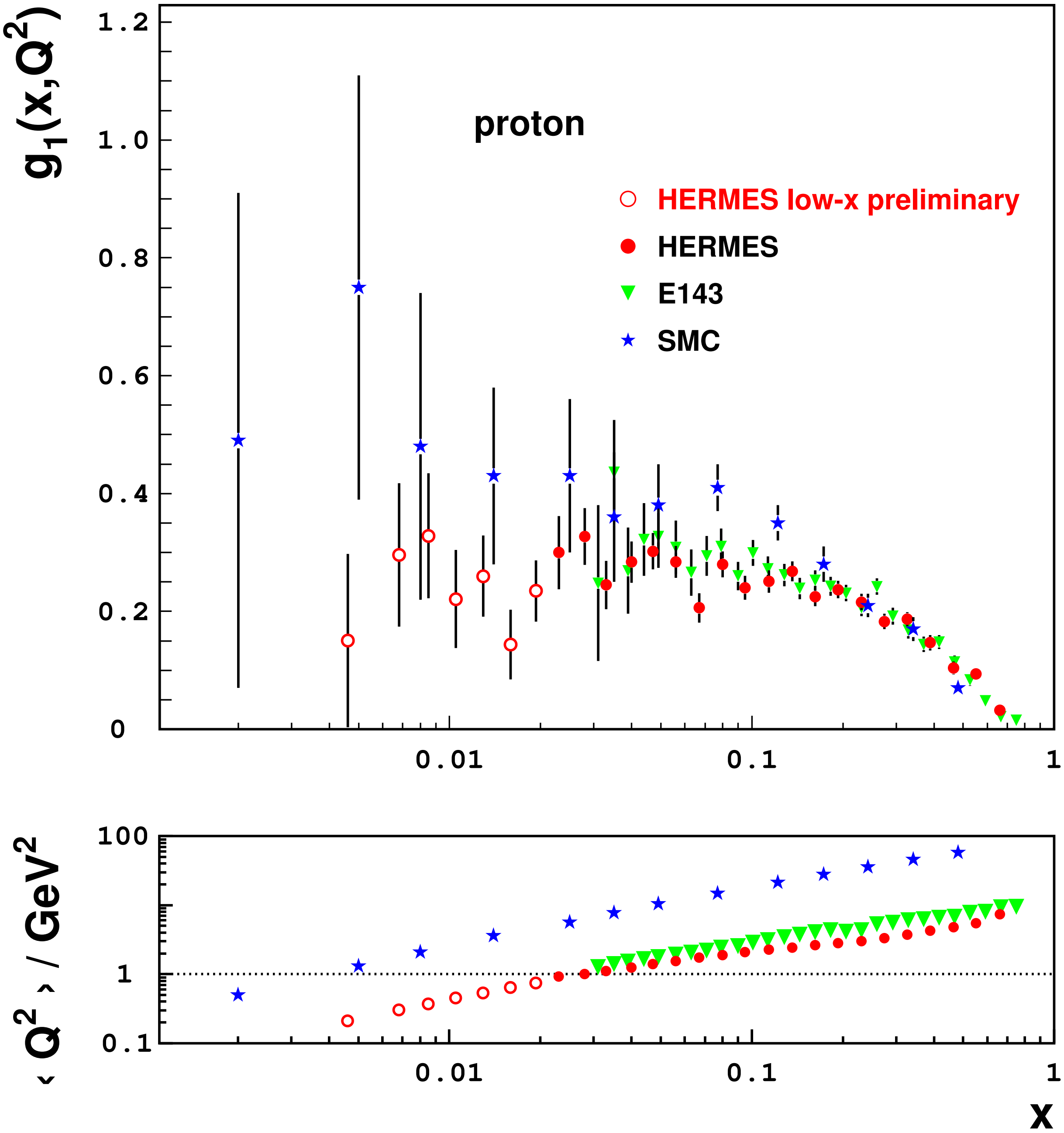


g_1^p: Comparison to E143



$\Rightarrow$ Very good agreement with E143

g_1^p: Comparison to E143 & SMC



⇒ More precise data needed for $x < 0.05$ at both

– low Q^2 (HERMES data > 1998)
– higher Q^2 (COMPASS)

Scaling Violation in g_1^p ?

- LOW–x REGION $(x < 0.05)$:

  LARGE STATISTICAL UNCERTAINTIES
  (ALL DATA SETS ARE STATISTICS DOMINATED)

  ONLY LIMITED CONCLUSIONS ON SCALING VIOLATIONS AND ΔG POSSIBLE

- MEDIUM–x REGION $(0.05 \leq x \leq 0.2)$:

  SIGNIFICANT SCALING VIOLATIONS OBSERVED

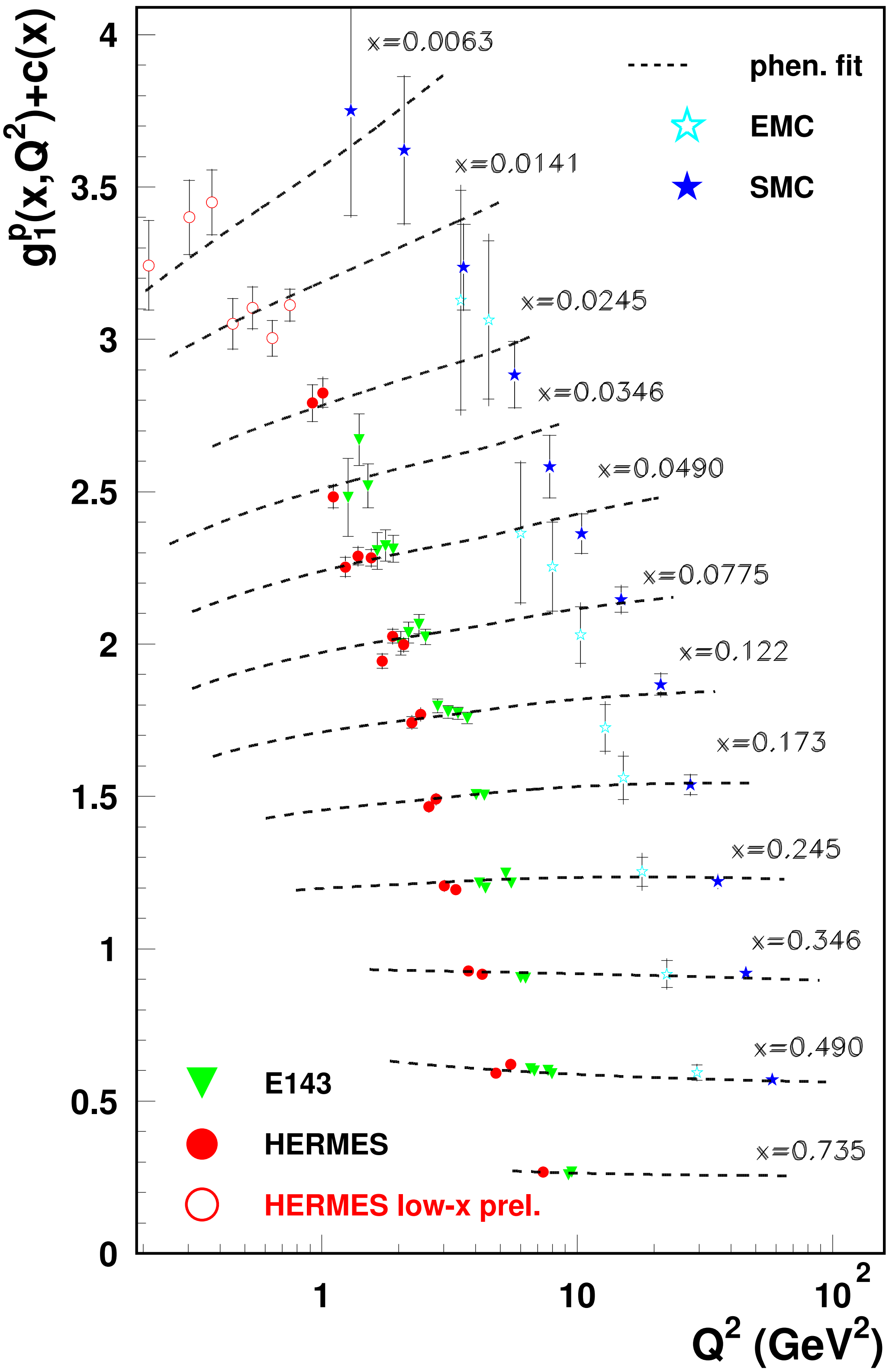
- LARGE–x REGION $(0.2 \leq x \leq 0.8)$:

  DATA CONSISTENT WITH NO SCALING VIOLATIONS

⇒ MORE PRECISE DATA NEEDED FOR $x < 0.05$ AT BOTH

  – LOW Q^2 (HERMES DATA > 1998)
  – HIGHER Q^2 (COMPASS)

g_1^p versus Q^2



Summary

- additional kinematic range explored for g_1^p at HERMES:

$$0.0021 < x < 0.0212$$

$$0.1 < Q^2 < 0.8 \text{ GeV}^2$$

$$0.85 < y < 0.91$$

$\Rightarrow$ 7 new low-x data points

statistical uncertainties about $30.0\,\%$

systematic uncertainties $\leq 14.0\,\%$

- very good agreement for g_1/F_1 with SMC low-x data

$\Rightarrow$ No statistically significant Q^2 dependence observed

- Indication for even a lower Q^2 limit of the validity range of pQCD ?

$\Rightarrow$ More precise data needed for $x < 0.05$ at both

  - low Q^2 (HERMES data > 1998)
  - higher Q^2 (COMPASS)