NEXT-TO-LEADING ORDER ANALYSIS OF POLARIZED DEEP-INELASTIC SCATTERING

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(WITH G. ALTARELLI, R. BALL, S. FORTE)

POLARIZED SPLITTING FUNCTIONS RECENTLY COMPUTED UP TO ORDER α^2 (HERTIG, VAN NEERVEN; VOGELSANG).

COEFFICIENT FUNCTIONS AT ORDER α COMPUTED LONG TIME AGO (BODWIN-QIU, KODAIRA)

→ FULL NEXT-TO-LEADING ORDER ANALYSIS NOW POSSIBLE, AS IN THE UNPOLARIZED CASE.

- ASSIGN PARTON DISTRIBUTIONS AT AN INITIAL SCALE Q_0 IN TERMS OF SOME PARAMETERS
- EVOLVE TO MEASURED (x, Q^2) AND COMPUTE g_1
- FIT PARAMETERS

PERFORMED BY MANY AUTHORS:

GEHRMANN, STIRLING

BALL, FORTE, G.R.

GLÜCK, REYA, VOGELSANG

ALTARELLI, BALL, FORTE, G.R.

(ALSO: P. 2YLA. SLAC)

PURPOSE :

ESTABLISH A RELIABLE PROCEDURE TO EXTRACT PHYSICALLY INTERESTING QUANTITIES (AND ASSESS UNCERTAINTIES):

- SINGLET AND GLUON FIRST MOMENTS
- g_1 FIRST MOMENTS
- AXIAL COUPLING
- STRONG COUPLING

NOT PRIMARILY INTERESTED IN OBTAINING POLARIZED PARTON DENSITY PARAMETRIZATIONS.

AN IMPORTANT SOURCE OF UNCERTAINTY IS THE ASSUMED FUNCTIONAL FORM OF THE INPUT PARTON DISTRIBUTIONS.

WE FIRST USE

$$\Delta f(x, Q_0^2) = N_f \eta_f x^{\alpha_f} (1-x)^{\beta_f} (1 + \gamma_f x^{\delta_f})$$

$\Delta f = \Delta q, \Delta \Sigma, \Delta q_{NS}$

N_f such that $\eta_f = \int_0^1 \Delta f \, dx$

$Q_0^2 = 1 \text{ GeV}^2$

FIT A: $\delta_\Sigma = \delta_g = 1$, $\delta_{NS} = \frac{3}{4}$

$\gamma_\Sigma = \gamma_g$

δ_{NS}	α_{NS}
1	-0.8
0.75	-0.5
0.5	-0.3

STRONGLY CORRELATED

→ SMALL-x BEHAVIOR NOT WELL CONSTRAINED BY DATA

$\delta_{NS} = \frac{3}{4}$ ALLOWS TO KEEP $|\alpha_{NS}|$ LESS THAN THE CORRESPONDING UNPOLARIZED QUANTITY.

A LESS SINGULAR INPUT:

FIT B: $\Delta\Sigma = N_\Sigma \eta_\Sigma x^{\alpha_\Sigma} \left(\log \frac{1}{x}\right)^{\beta_\Sigma}$

$$\Delta q_{NS} = N_{NS} \eta_{NS} \left[\left(\log \frac{1}{x}\right)^{\alpha_{NS}} + \gamma_{NS}\, x \left(\log \frac{1}{x}\right)^{\beta_{NS}}\right]$$

$$\Delta g = N_g \eta_g \left[\left(\log \frac{1}{x}\right)^{\alpha_g} + \gamma_g\, x \left(\log \frac{1}{x}\right)^{\beta_g}\right]$$

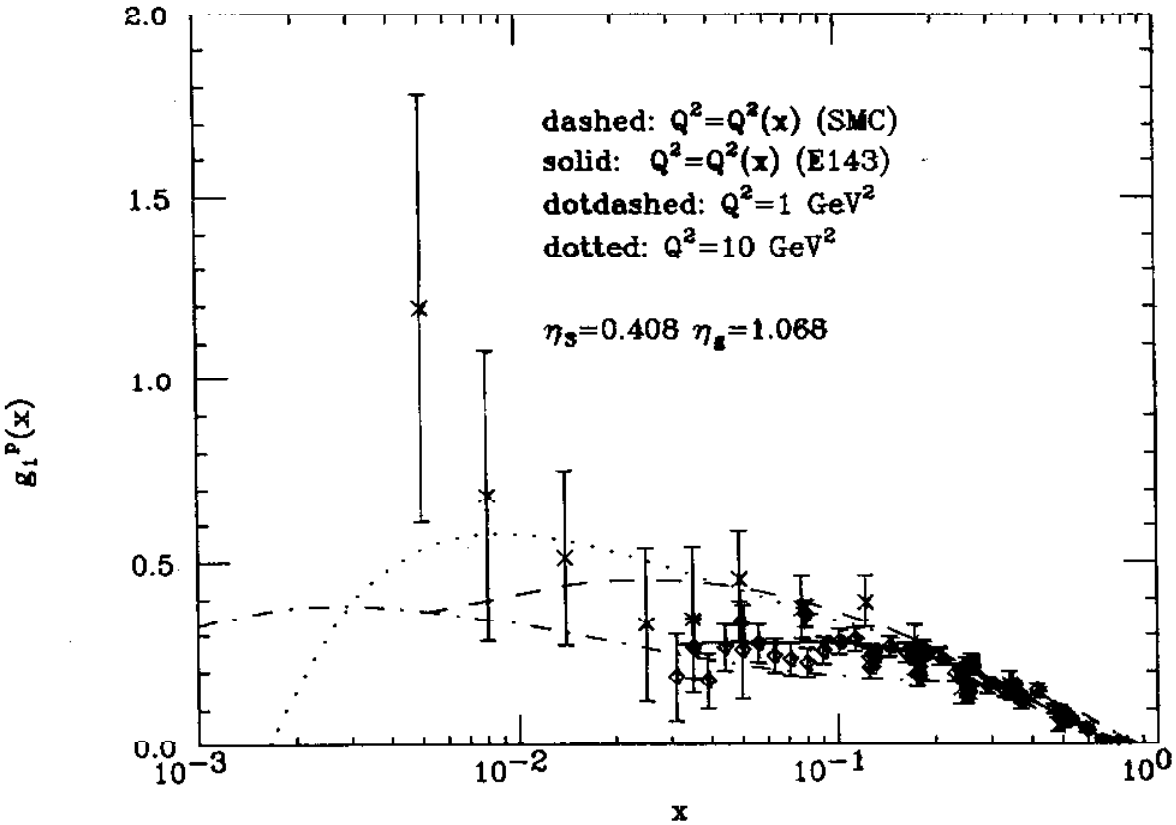
FITS OF COMPARABLE QUALITY: A POWER-LIKE SINGULAR BEHAVIOR OF NS IS NOT MANDATORY

QUITE DIFFERENT BEHAVIOR IN THE SMALL-x REGION.

$\longrightarrow$ FIGURES

FIT "A"

g_1 (PROTON)



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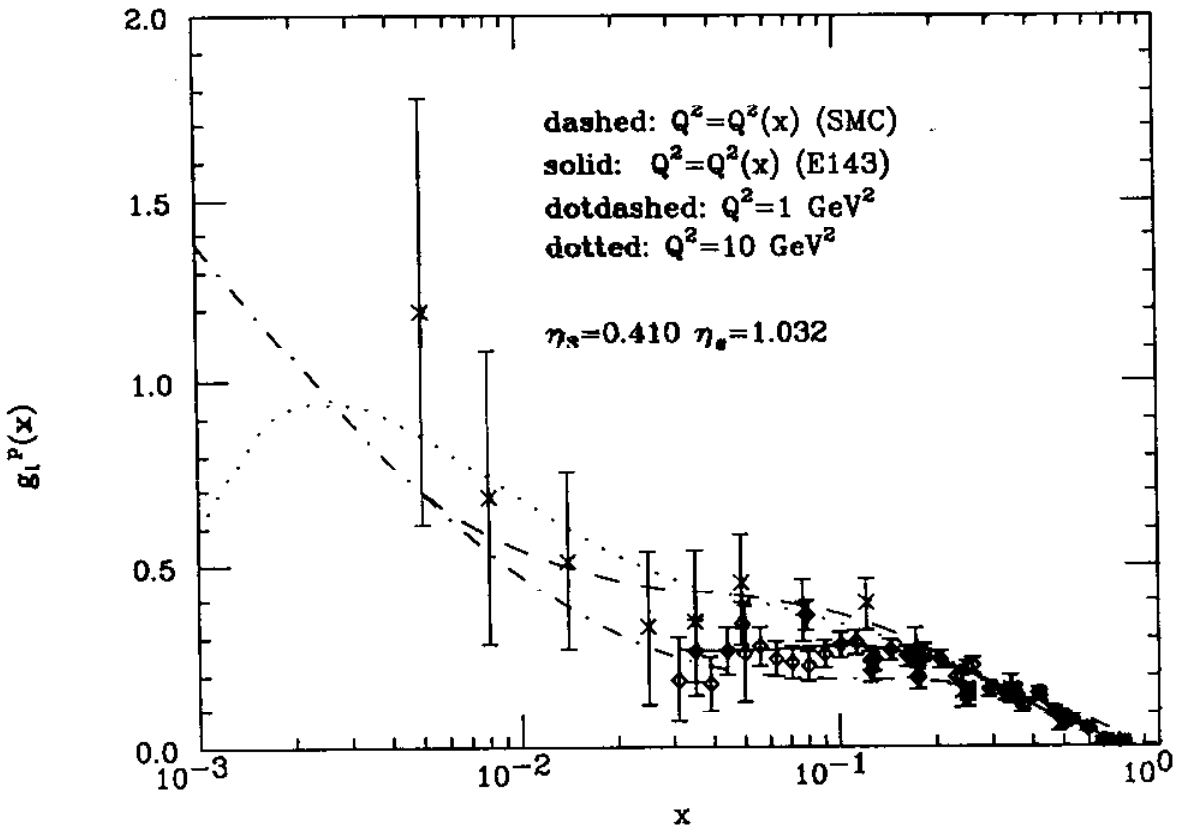
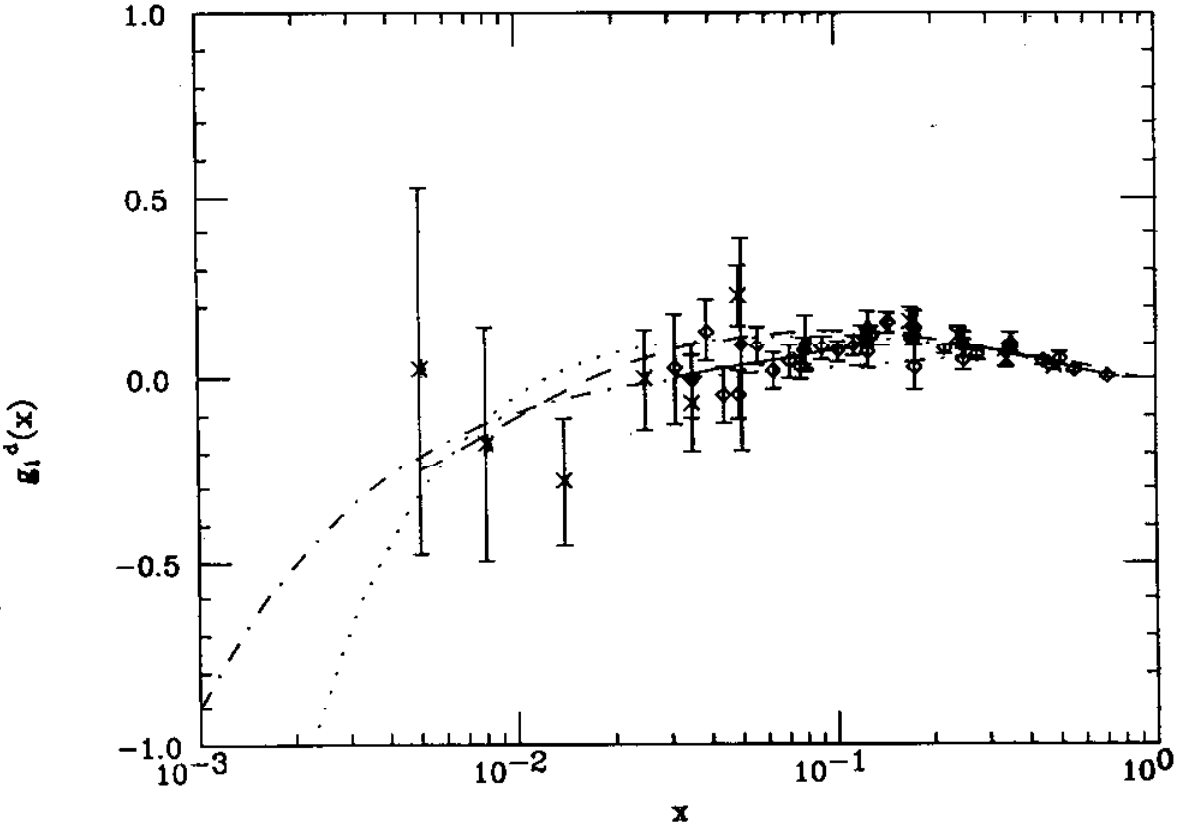
FIT "B"

g_1 (PROTON)



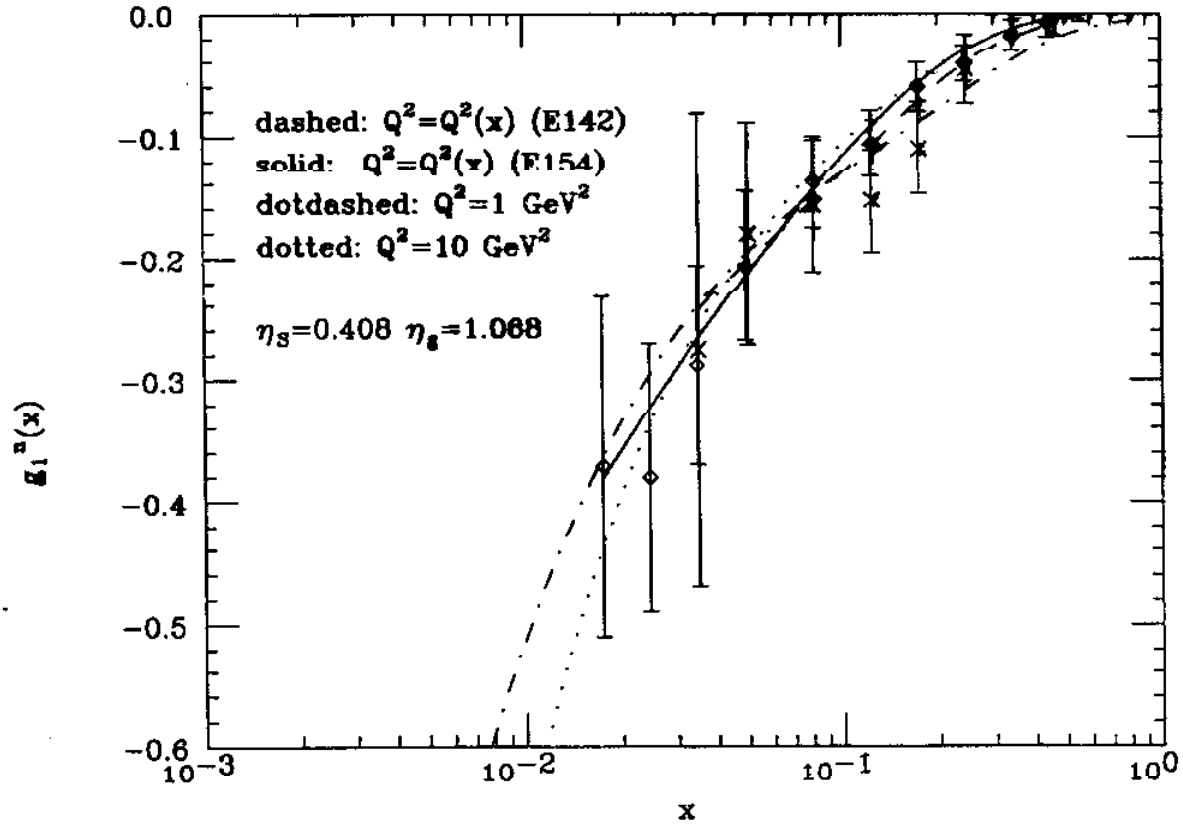
FIT "A"

g_1 (DEUTERON)



FIT "A"

g_1 (NEUTRON)



FIT PARAMETERS

Parameters	A	B	C	D
d.o.f.	114 − 11	114 − 11	114 − 8	114 − 8
Q_0^2/GeV^2	1	1	0.3	0.3
η_Σ	0.408 ± 0.041	0.410 ± 0.039	0.422 ± 0.026	0.492 ± 0.036
α_Σ	0.741 ± 0.353	1.710 ± 0.416	2.600 ± 0.964	0.5 (fixed)
β_Σ	3.105 ± 1.049	2.735 ± 0.466	3.359 ± 1.210	1.039 ± 0.241
γ_Σ	0.185 ± 2.496	0 (fixed)	0 (fixed)	0 (fixed)
η_g	1.068 ± 0.403	1.032 ± 0.330	0.479 ± 0.095	0.650 ± 0.104
α_g	−0.597 ± 0.286	2.970 ± 0.611	0.217 ± 0.319	0.5 (fixed)
β_g	0.831 ± 2.322	1.286 ± 0.895	15 (fixed)	13.19 ± 9.57
γ_g	0.185 ± 2.496	21.2 ± 22.5	0 (fixed)	−0.548 ± 9.139
g_A	1.168 ± 0.052	1.234 + 0.066	1.146 ± 0.038	1.141 ± 0.036
a_8	0.579 (fixed)	0.579 (fixed)	0.579 (fixed)	0.579 (fixed)
α_{NS}	−0.537 ± 0.057	1.656 ± 0.166	0.765 ± 0.228	0.5 (fixed)
β_{NS}	2.503 ± 0.274	5.320 ± 0.251	2.087 ± 0.448	2.622 ± 0.410
γ_{NS}	17.46 ± 8.43	−0.229 ± 0.105	0 (fixed)	5.024 ± 4.647
χ^2	83.7	83.0	83.8	90.9
χ^2/d.o.f.	0.813	0.806	0.790	0.858
$\Delta g(1, 1GeV^2)$	1.07 ± 0.40	1.03 ± 0.33	1.61 ± 0.32	2.08 ± 0.34
$a_0(10GeV^2)$	0.15 ± 0.07	0.16 ± 0.05	0.05 ± 0.04	0.02 ± 0.04

	SMC : p	E143 : p	SMC : d	E143 : d	E142 : n	E154 : n
$\langle Q^2 \rangle/GeV^2$	10	3	10	3	2	5
Meas. Range: Exp.	0.1310	0.1200	0.0379	0.0400	−0.0280	−0.0370
Exp. Error	±0.0156	±0.0089	±0.0079	±0.0050	±0.0085	±0.0108
A_1 ind. Q^2	0.1350	0.1059	0.0442	0.0398	−0.0293	−0.0364
Meas. Range: A	0.1256	0.1070	0.0430	0.0378	−0.0328	−0.0338
Meas. Range: B	0.1268	0.1061	0.0425	0.0373	−0.0326	−0.0342
Meas. Range: C	0.1280	0.1084	0.0462	0.0401	−0.0289	−0.0316
Meas. Range: D	0.1308	0.1083	0.0492	0.0402	−0.0306	−0.0308
Full Range: A	0.1171	0.1137	0.0275	0.0265	−0.0600	−0.0614
Full Range: B	0.1232	0.1197	0.0286	0.0276	−0.0637	−0.0654
Full Range: C	0.1039	0.0999	0.0160	0.0144	−0.0707	−0.0716
Full Range: D	0.0990	0.0946	0.0115	0.0094	−0.0754	−0.0759

THIRD POSSIBILITY : GENERATE

log BEHAVIOR AT 1 GeV^2 BY

EVOLUTION → CHOOSE $Q_0^2 = 0.3$ GeV^2

FIT C: $\Delta f = N_f \eta_f x^{\alpha_f}(1-x)^{\beta_f}(1+\gamma_f x^{\delta_f})$

$\gamma_\Sigma = \gamma_g = \gamma_{NS} = 0$

$\alpha_f = 1.5$ (fixed)

RESULT : GOOD FIT;

ALL α_f POSITIVE

QUALITATIVE AGREEMENT WITH REGGE EXPECTATIONS. IN FACT,

FIT D: $\Delta f = N_f \eta_f x^{\alpha_f}(1-x)^{\beta_f}(1+\gamma_f x^{\delta_f})$

$Q_0^2 = 0.3$ GeV^2

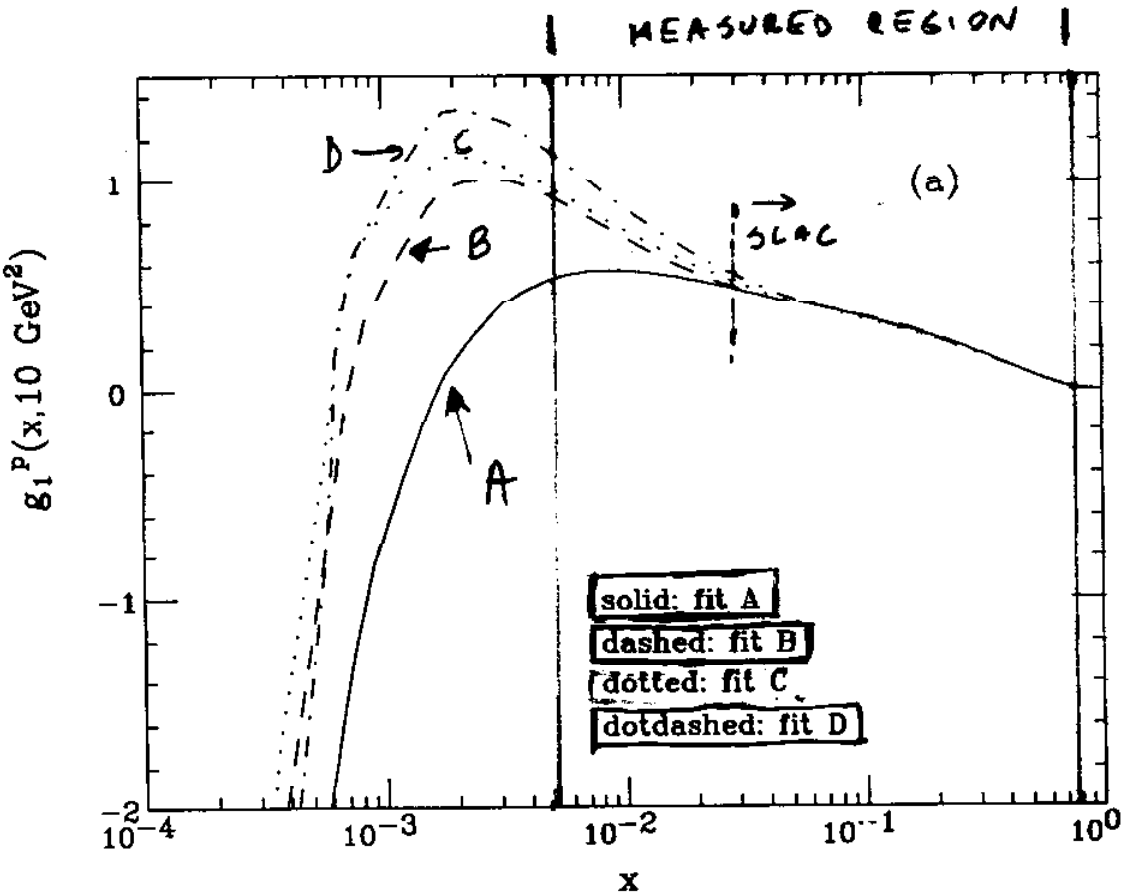
$\gamma_\Sigma = 0 \qquad \delta_g = \delta_{NS} = 1$

$\alpha_g = \alpha_\Sigma = \alpha_{NS} = 0.5$ (fixed)

GIVE SIMILAR RESULTS.

FITTED $g_1^p(x; 10\ \mathrm{GeV}^2)$

$\alpha_s(m_Z) = 0.118$



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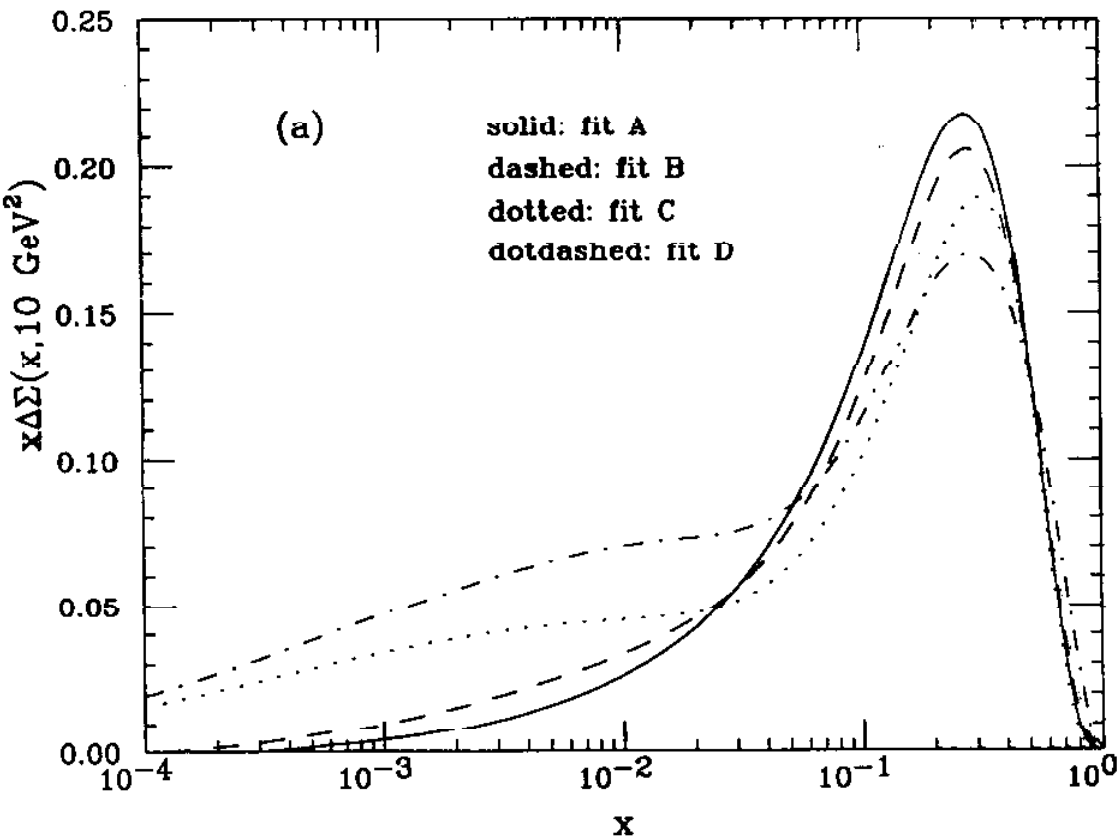
QUARK SINGLET

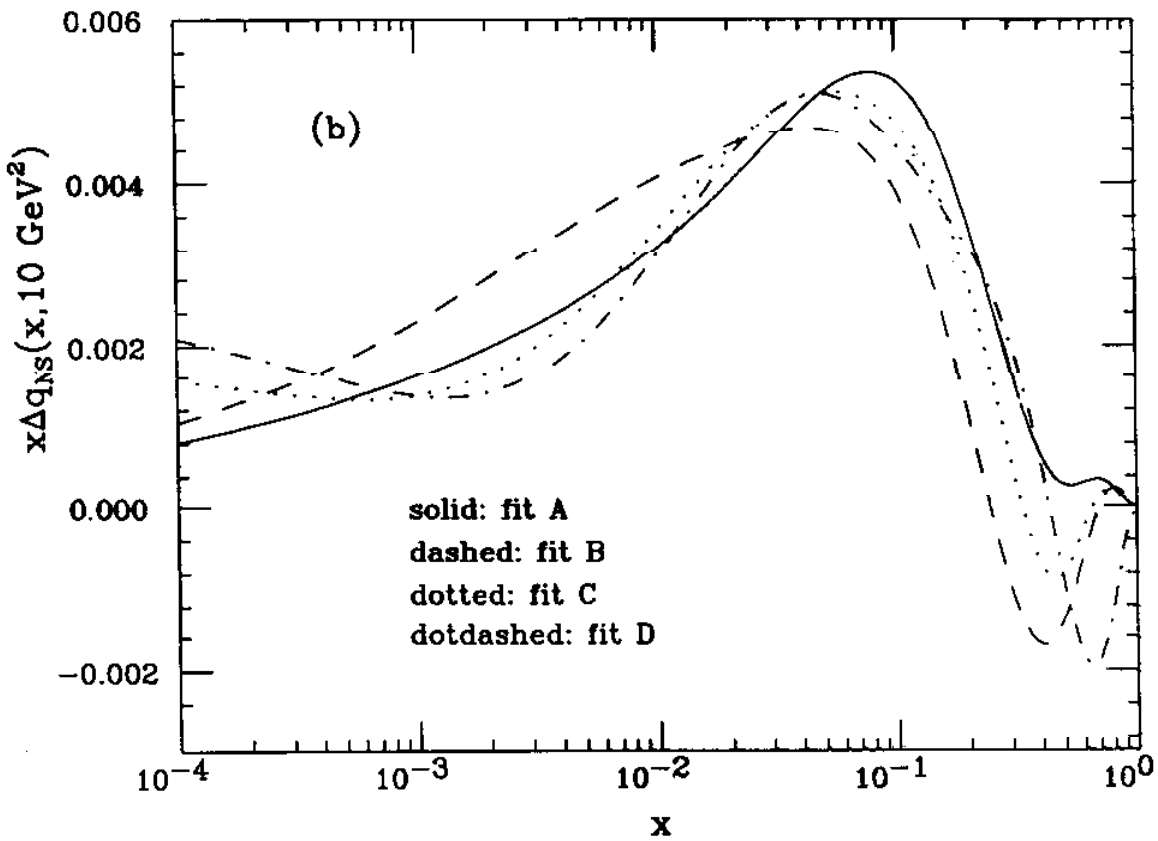
$Q^2 = 10$ GeV^2



ABFR

QUARK NON-SINGLET

$Q^2 = 10 \ GeV^2$



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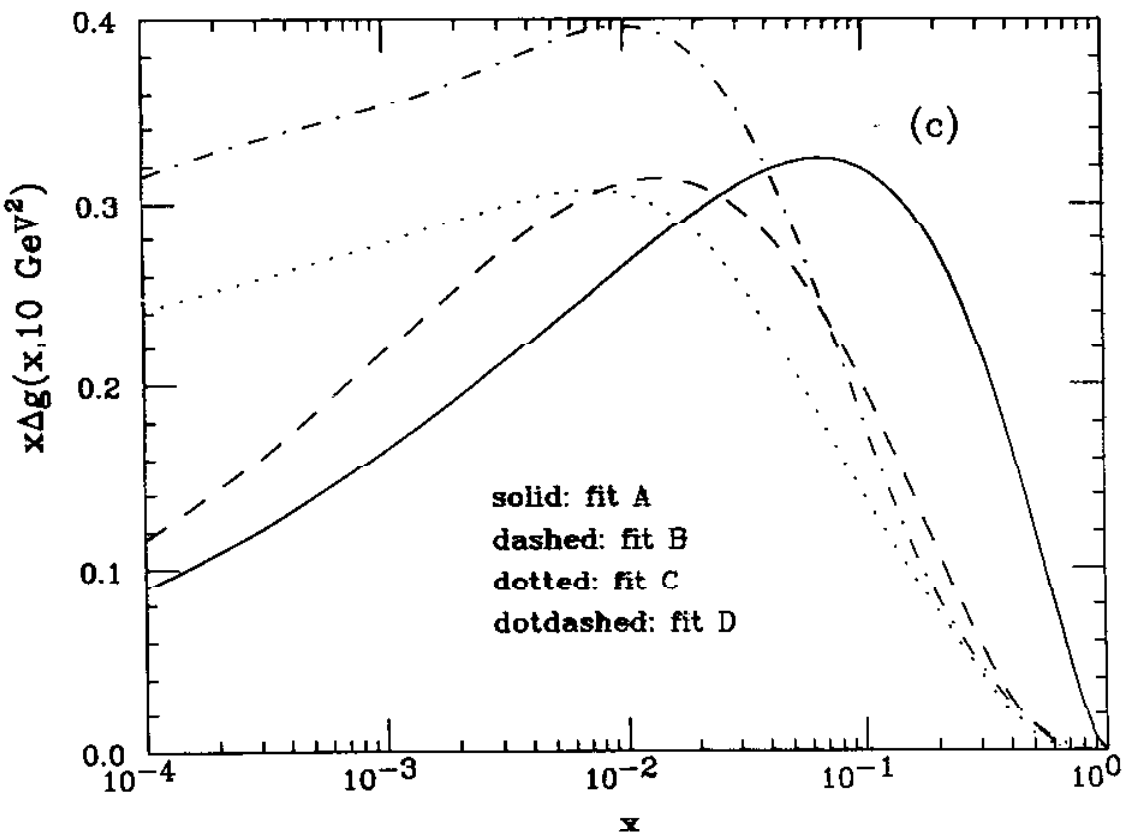
GLUON

$Q^2 = 10\ GeV^2$



ABFR

MAIN COMMENTS:

- EVOLUTION EFFECTS ARE NOT SO IMPORTANT IN THE MEASURED x RANGE, BUT THEY AFFECT ENORMOUSLY THE SMALL-x EXTRAPOLATION.

- NAIVE CONSTANT EXTRAPOLATION WITH 100% ERROR OVERESTIMATES Γ_1^p AND UNDERESTIMATES THE TOTAL UNCERTAINTY

$\Downarrow$

Q^2-EVOLUTION AND SMALL-x EXTRAPOLATION CLOSELY RELATED.

FIRST MOMENTS IN THE AB SCHEME:

QUARK SINGLET:

$$\Delta\Sigma(1) = 0.45 \pm 0.04\,(\mathrm{EXP}) \pm 0.08\,(\mathrm{TH})$$

$$= 0.45 \pm 0.09$$

COMPARE WITH $a_8 \simeq 0.58$

GLUON:

$$\Delta g\,(1,1\,\mathrm{GeV}^2) = 1.6 \pm 0.4\,(\mathrm{EXP}) \pm 0.8\,(\mathrm{TH})$$

$$= 1.6 \pm 0.9$$

$\boxed{\text{COMPATIBLE WITH } \overline{\mathrm{MS}} \text{ RESULT}}$

AXIAL CHARGE:

$$a_0\,(Q^2 = \infty) = 0.10 \pm 0.05\,(\mathrm{EXP}) \pm^{0.17}_{0.10}\,(\mathrm{TH})$$

$$= 0.10\,^{+0.17}_{-0.11}$$

($\sim 0.30 \pm 0.04$ WITH REGGE SMALL-x EXTRAPOLATION)

DETERMINATION OF g_A

UNCERTAINTIES:

- EXPERIMENTAL ERRORS
- INITIAL PARAMETRIZATION
  (INCLUDES SMALL x EXTR.!)
- ERRORS ON α_s, Q_8:

$$\alpha_s(M_Z) = 0.118 \pm 0.005$$

$$Q_8 = 0.579 \pm 0.025$$

- HIGHER ORDERS, HIGHER TWISTS

WE GET

$$g_A = 1.18 \pm 0.05\,(\text{EXP}) \pm 0.07\,(\text{TH})$$

$$= 1.18 \pm 0.09$$

$$\left(\text{VS. } g_A^{\text{EXP}} = 1.2573 \pm 0.0028\right)$$

BJORKEN S.R. OK AT 1σ, 8% ACCURACY.

g_A INCREASES WITH α_s.

PROSPECTS

- HERA WITH POLARIZED BEAMS:

  ERROR ON η_g DOWN TO ~ 0.2

  EVEN WITH $L = 200\ pb^{-1}$

- DIRECT MEASUREMENTS OF THE POLARIZED GLUON DENSITY (JETS, HEAVY QUARKS)

  → A BETTER ESTIMATE OF Δg

  → A BETTER MEASUREMENT OF α_s