Goodbye to Large ΔG?

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nucleon spin

quark helicities:

$$\Delta q = \int_0^1 \left[q_\uparrow(x) - q_\downarrow(x)\right] + \left[\bar{q}_\uparrow(x) - \bar{q}_\downarrow(x)\right]$$

sources of information about Δq-s:

(a) weak decays

$$g_A = \Delta u - \Delta d\,; \qquad\qquad g_8 = \Delta u + \Delta d - 2\Delta s$$

(b) polarized DIS on nucleon

$$g_1^p(x) = \frac{1}{2}\sum_q\; e_q^2[q_\uparrow(x) - q_\downarrow(x) + \bar{q}_\uparrow(x) - \bar{q}_\downarrow(x)] = \frac{1}{2}\sum_q\; e_q^2\;\Delta q(x)$$

$+$ QCD & higher twist corrections

and $n \Longleftrightarrow p$

global fit to p and d polarized DIS data:

$$\begin{aligned} \Delta u &= 0.82 \pm 0.03 \pm \ldots \\ \Delta d &= -0.44 \pm 0.03 \pm \ldots \\ \Delta s &= -0.11 \pm 0.03 \pm \ldots \end{aligned}$$

and

$$\Delta\Sigma = \Delta u + \Delta d + \Delta s = 0.27 \pm 0.04 \pm \ldots$$

$\Longrightarrow$ **"Spin Crisis"**

Angular momentum sum rule:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_z$$

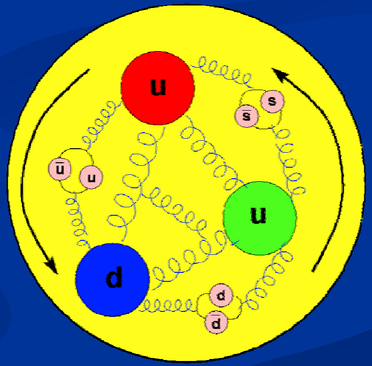
Why Should the Nucleon be Strange?

- the vacuum is strange:
  chiral symmetry for π, K mesons

$\rightarrow$ $$\langle 0 \bar{s}s | 0 \rangle = (0.8 \pm 0.1) \langle 0 \bar{q}q | 0 \rangle$$

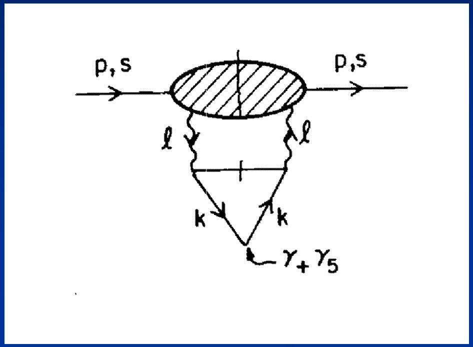
- cannot be expected to disappear when one inserts qqq 'test charge' into the vacuum

- generated in pQCD: $q \longrightarrow g \longrightarrow \bar{s}s$



- also by non-perturbative effect: instantons, chiral soliton models axial anomaly: "the last hope" of the naïve quark model:

$$\Delta q \to \widetilde{\Delta q} \equiv \Delta q - \frac{\alpha_s}{2\pi}\Delta G$$



2nd term on rhs due to gluon axial current.

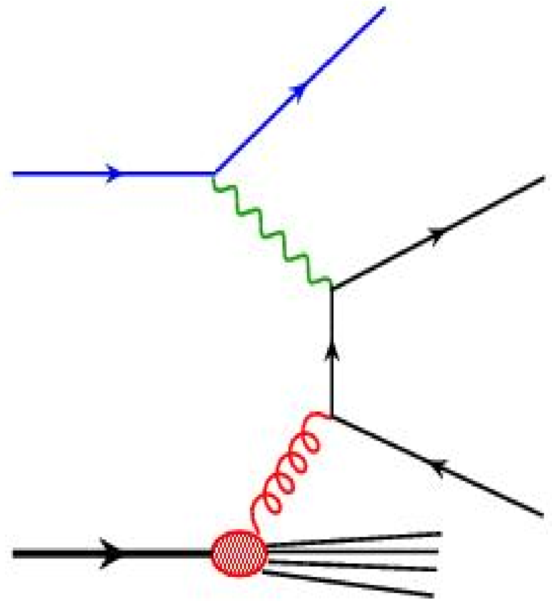
observables: $\widetilde{\Delta q}$-s, rather than Δq-s, so in principle can resurrect the NRQM by

$$\widetilde{\Delta s} = \Delta s - \frac{\alpha_s}{2\pi}\Delta G \neq 0 \ : \qquad \Delta s = 0, \ \Delta G \neq 0$$

$\Longrightarrow$ large $\Delta G \simeq 2$ at $Q^2 \simeq 3$ GeV^2.

How to measure $\Delta G/G$

Photon-Gluon Fusion (PGF)

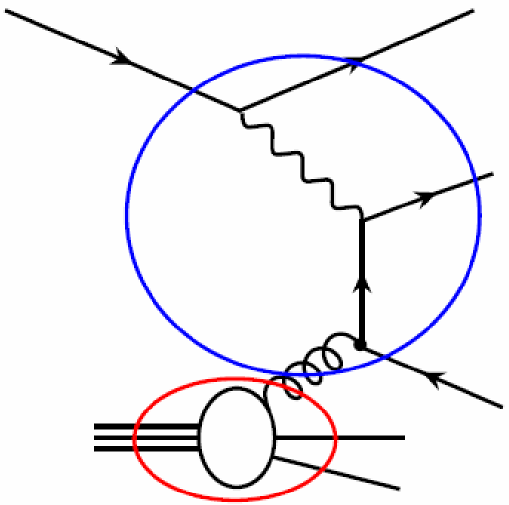


$$A_{\mu N}^{PGF} = \langle a_{LL} \rangle \frac{\Delta G}{G}$$

Two tagging methods:

- High p_T hadron pairs
- Open charm

Photon-Gluon Fusion (PGF)

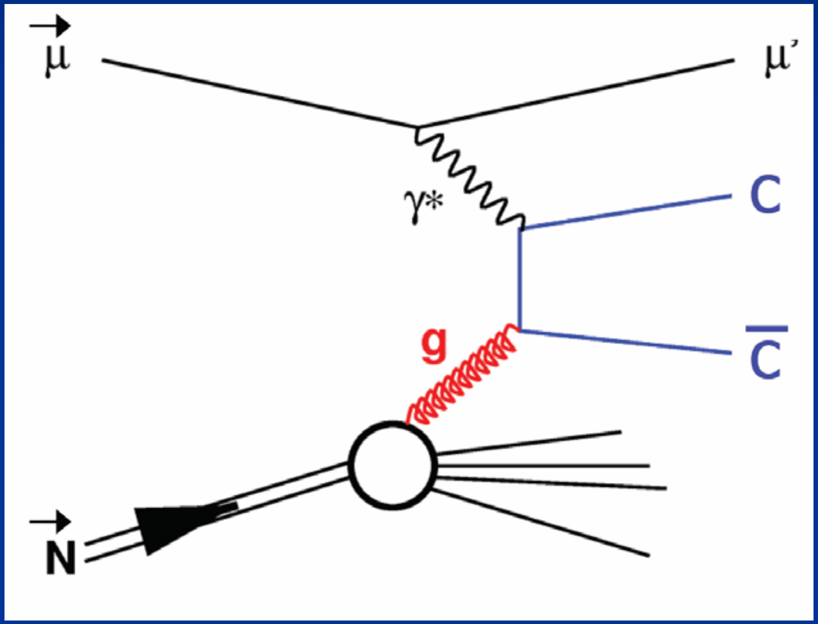


$$A_{pgf} \equiv \frac{\sigma_{pgf}^{\leftarrow\rightarrow} - \sigma_{pgf}^{\leftarrow\leftarrow}}{\sigma_{pgf}^{\leftarrow\rightarrow} + \sigma_{pgf}^{\leftarrow\leftarrow}} = \langle \hat{a}_{pgf} \rangle \frac{\Delta G}{G}$$

COMPASS cuts for jet asymmetry:
each hadron $p_T > 0.7$ GeV/c, $\left({p_T}_1{}^2 + {p_T}_2{}^2\right) > 2.5$ (GeV/c)^2

current fragmentation: $x_F > 0.1$, $z > 0.1$

$\Delta G/G$ from open charm



$D^0 \longrightarrow K^- \pi^+$ (BR 4%)

$D^{*+} \longrightarrow D^0 \pi^+ + \text{c.c.}$

$$A_{\gamma N}^{c\bar{c}} = \langle a_{LL} \rangle \frac{\Delta G}{G}$$

Compilation of ΔG measurements

Indirect, using polarized structure function data:

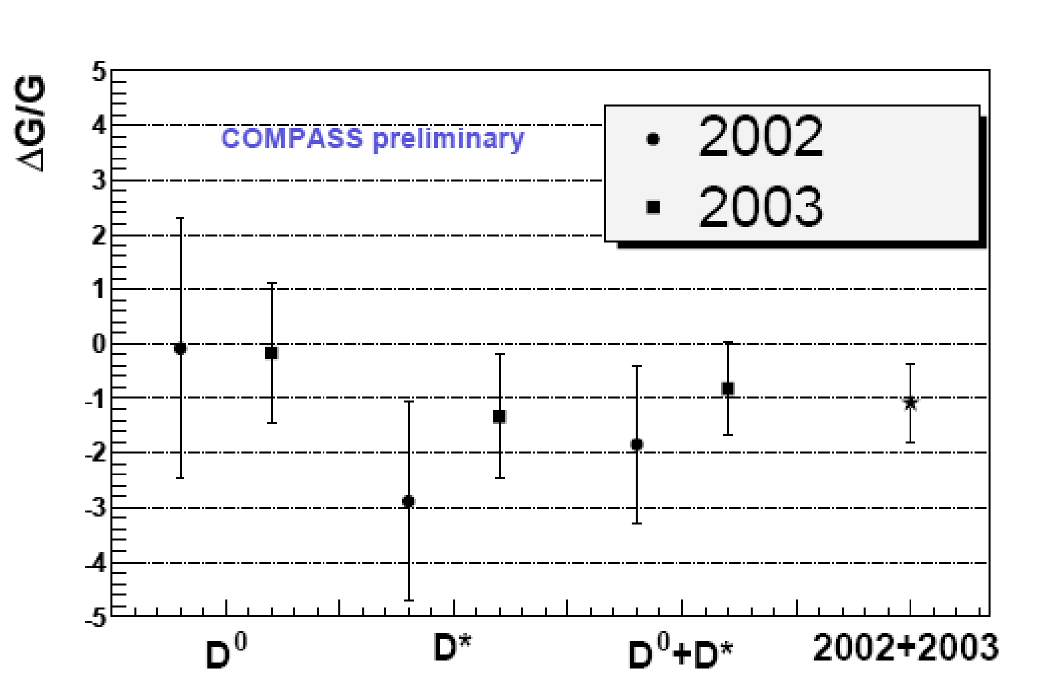
BBA: $\Delta G = 1.026 \pm 0.549$
BBB: $\Delta G = 0.031 \pm 0.669$
AAC: $\Delta G = 0.533 \pm 1.931$

Direct, using hadron production asymmetries:

HERMES :	$\Delta G/G = 0.41 \pm 0.18 \pm 0.03$	$0.06 < x_G < 0.28$,
SMC :	$\Delta G/G = -0.20 \pm 0.28 \pm 0.10$	$\langle x_G \rangle = 0.07$,
COMPASS :	$\Delta G/G = 0.06 \pm 0.31 \pm 0.06$	$\langle x_G \rangle = 0.13$, $Q^2 > 1$ GeV^2
COMPASS :	$\Delta G/G = 0.024 \pm 0.089 \pm 0.057$	$\langle x_G \rangle = 0.095$. $Q^2 < 1$ GeV^2

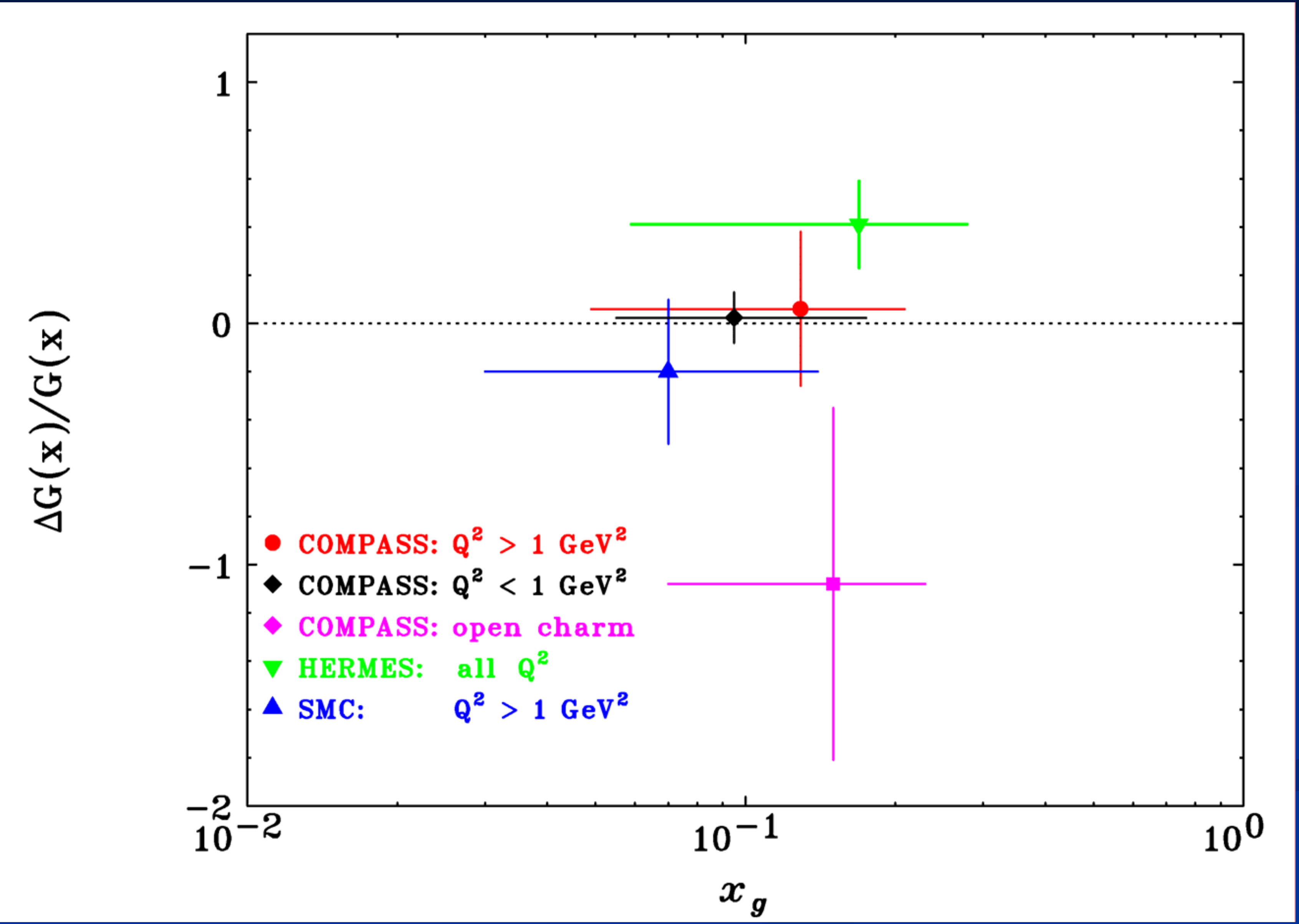
2002-2003 results from open charm

- no physics background
- but much less data than hadron asymmetry



$\Delta G/G = -1.08 \pm 0.73$ $\qquad$ $x_G = 0.15 \pm 0.08$

ΔG/G from hadron polarization asymmetries

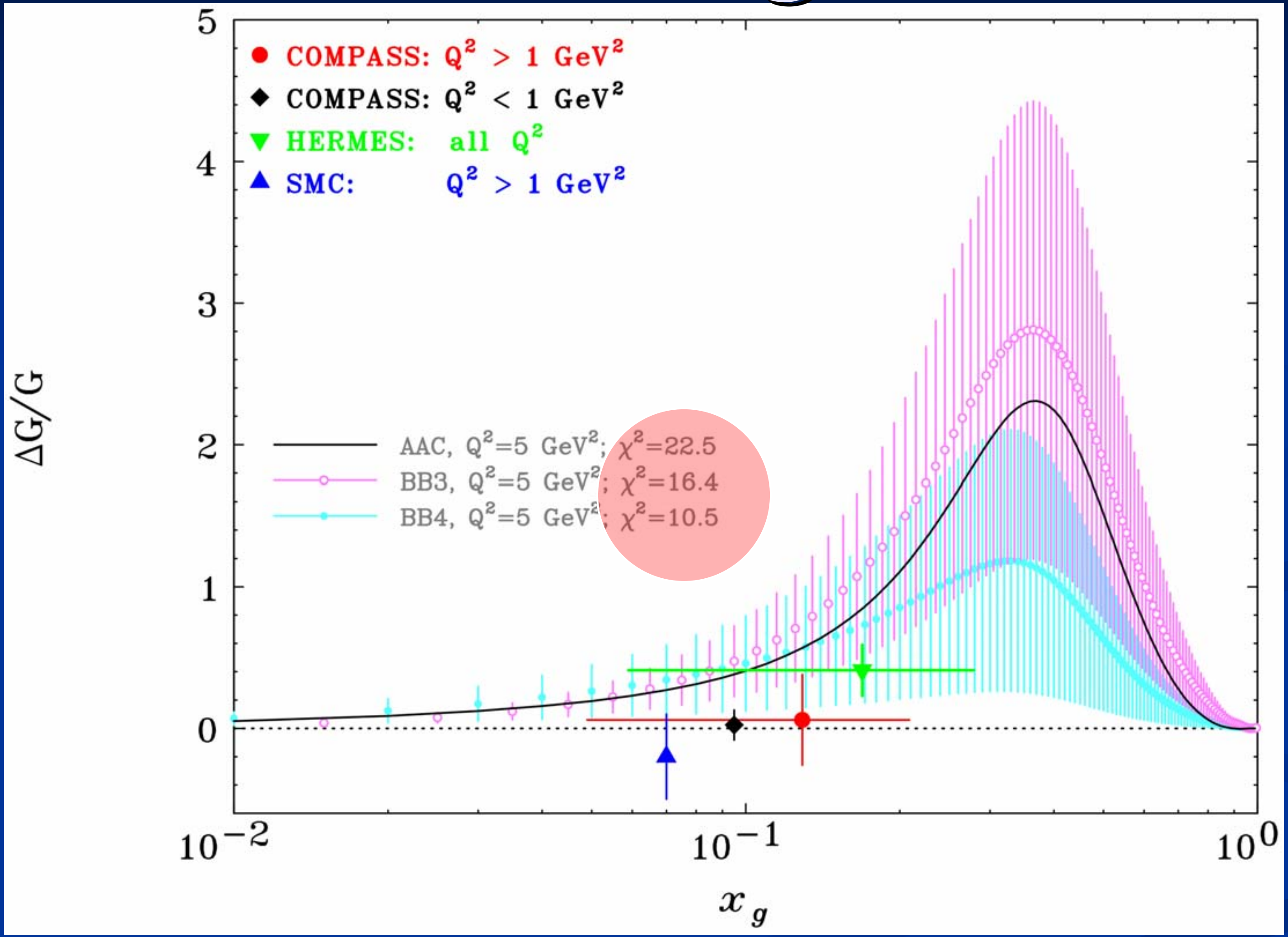


fits to asymmetry data

- data not precise enough (yet?) for a full-fledged fit
- but good enough to estimate ΔG magnitude
- assume the three trial forms BB3, BB4, AAC for $\Delta G(x, Q^2)$;
- normalization A_{ijk} left as a free parameter

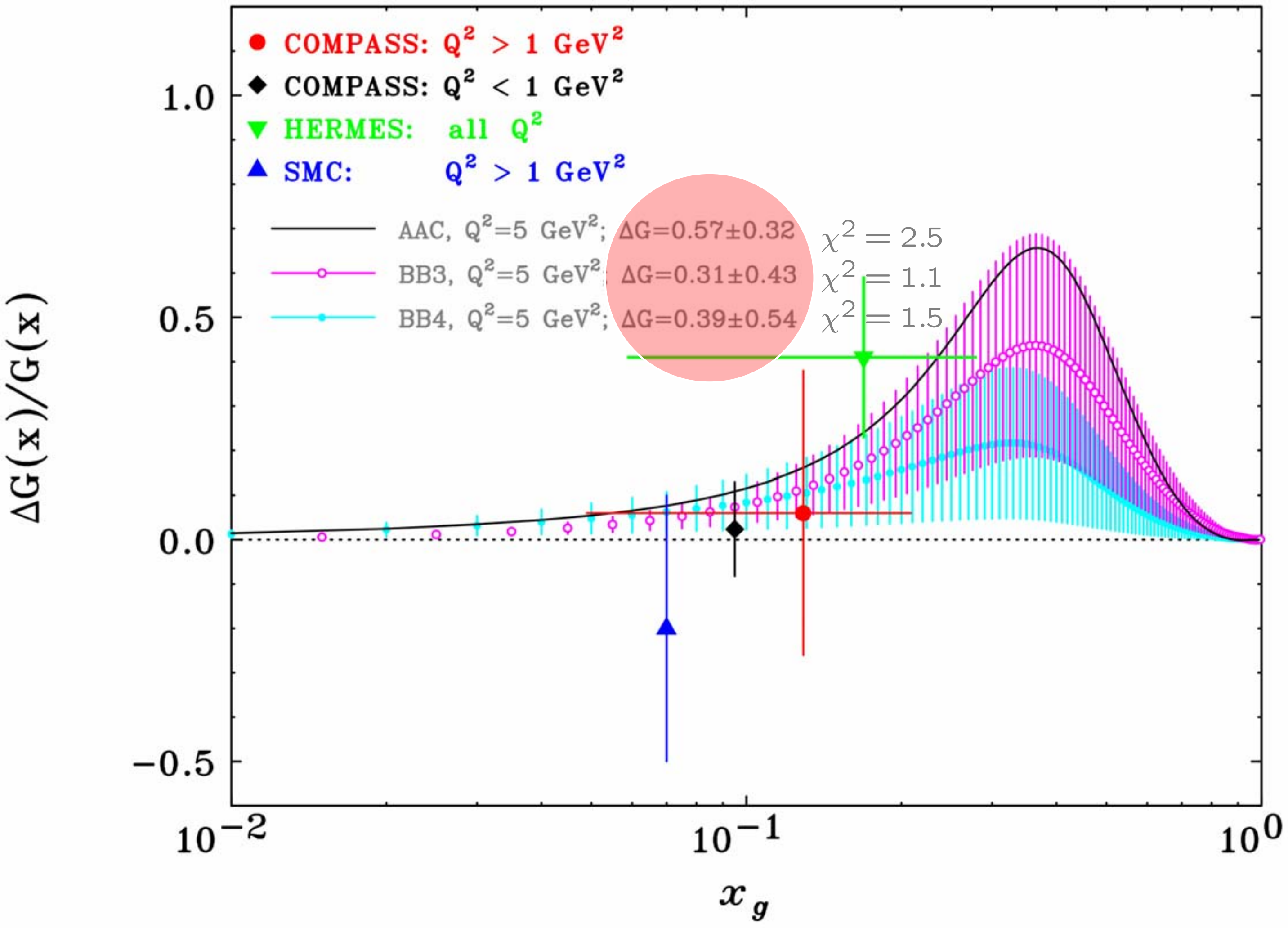
$$\begin{aligned}
\text{BB3}: \quad \Delta G(x,Q^2) &= A_{BB3}\cdot f_{BB3}(x,Q^2)\,,\\
\text{BB4}: \quad \Delta G(x,Q^2) &= A_{BB4}\cdot f_{BB4}(x,Q^2)\,,\\
\text{AAC}: \quad \Delta G(x,Q^2) &= A_{AAC}\cdot f_{AAC}(x,Q^2)\,.
\end{aligned}$$

first, fit forcing ΔG=2



a very bad fit

fit with normalization allowed to float



significantly better fit

Q^2 GeV^2	BB4			BB3			AAC		
	ΔG	χ^2 best fit	χ^2 for ΔG=2	ΔG	χ^2 best fit	χ^2 for ΔG=2	ΔG	χ^2 best fit	χ^2 for ΔG=2
1.5	0.31±0.40	1.6	19.7	0.46±0.44	1.0	13.4	0.58±0.31	2.2	22.8
2.0	0.33±0.43	1.5	16.5	0.33±0.37	1.2	21.2	0.57±0.31	2.3	23.4
5.0	0.39±0.54	1.5	10.5	0.31±0.43	1.1	16.4	0.57±0.32	2.5	22.5
10.0	0.43±0.62	1.5	6.5	0.30±0.48	1.1	13.5	0.58±0.33	2.6	20.6

Fits to the HERMES, SMC and COMPASS $\Delta G/G$ data, for $Q^2 = 1.5$, 2, 5 and 10 GeV^2. For each parametrization we list the best-fit value of ΔG and its χ^2, as well as the χ^2 value corresponding to $\Delta G = 2$.

Goodbye to Large ΔG.

Long Live $\Delta s \neq 0$!

- recent exp. evidence on strange magnetic moment of the nucleon from JLab
- lattice