SPIN STRUCTURE OF THE NUCLEON AT SLAC

Sum Rules, Gluon Spin and Nuclear Corrections

P. Bosted, April 2002

- Final Results on g_1, NLO Fit
- Nearly Final Results for g_2, Sum Rules
- *Future:* Open Charm Photoproduction and $\Delta G(x)$.
- *Future:* GDH Sum Rule

POLARIZED DEEP INELASTIC SCATTERING

$$A_{\parallel} = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}} = f_k\Big[g_1(x,Q^2)[E+E'\cos(\theta)] - \frac{Q^2}{\nu}g_2(x,Q^2)\Big]$$

$$A_{\perp} = \frac{\sigma^{\downarrow\leftarrow} - \sigma^{\uparrow\leftarrow}}{\sigma^{\downarrow\leftarrow} + \sigma^{\uparrow\leftarrow}} = f_k E'\sin(\theta)\Big[g_1(x,Q^2) + \frac{2E}{\nu}g_2(x,Q^2)\Big]$$

g_1 and g_2 are the polarized structure functions.

$\rightarrow$ $A_{\parallel}$ is primarily sensitive to g_1

$\rightarrow$ $A_{\perp}$ is more sensitive to g_2

$\rightarrow$ f_k includes contribution from kinematics and unpolarized structure functions

E155 MEASUREMENTS OF g_1^p and g_1^n

- Measured in 1997: published 2000.
- Electron beam 48 GeV, polarization $P_b = 0.83$
- NH_3 target for protons, polarization $P_t = 0.8$, dilution factor $f = 0.16$
- LiD target for deuterons, $P_t = 0.25$, $f = 0.22$. ^{6}Li treated like unpolarized α plus polarized d.
- Neutron results from proton and deuteron.
- Spectrometers at 2.75, 5.5 and 10.5 degrees.
- Kinematics: $0.014 < x < 0.9$, $1 < Q^2 < 40$ GeV^2.

Nuclear Target Corrections

$$A_{\parallel} = \frac{R^{\uparrow\downarrow} - R^{\uparrow\uparrow}}{R^{\uparrow\downarrow} + R^{\uparrow\uparrow}} \frac{1}{C_1 P_B P_T f} (1 + \frac{C_2 A_p}{A_d})$$

$\rightarrow$ $P_B P_T f$ accounts for beam polarization, target polarization, and dilution factor. [Radiative corrections are also made].

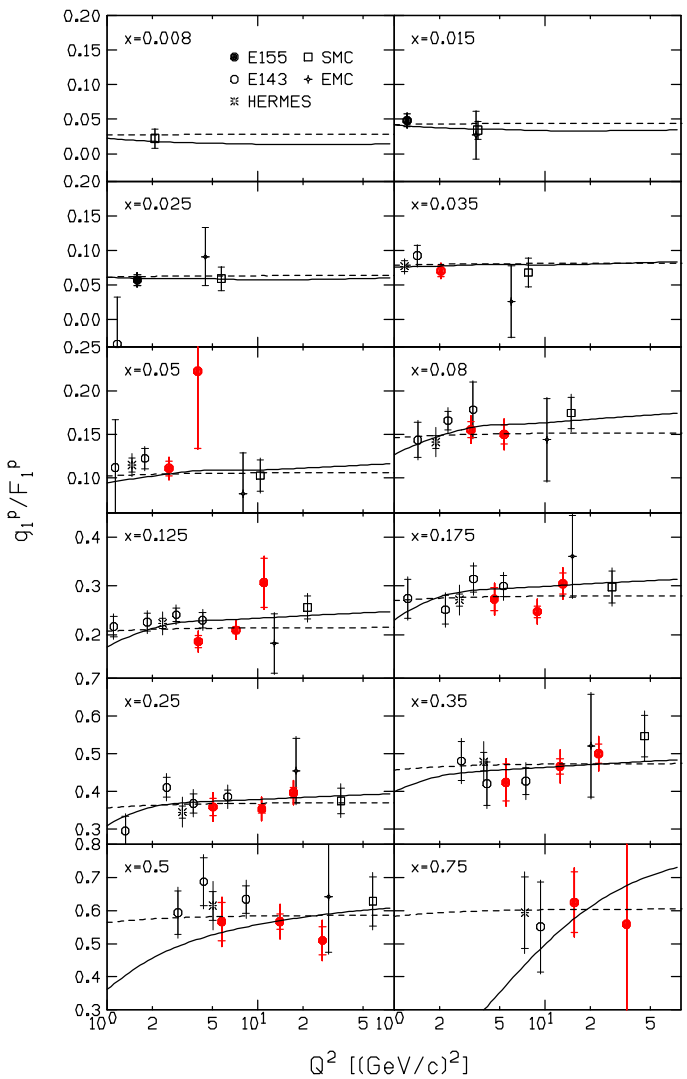
$\rightarrow$ for NH3 $C_2 = 0$ and C_1 accounts for polarized ^{15}N, polarized opposite to free protons because acts like single proton "hole".

$\rightarrow$ for NH3 $C_1 \approx 1 - 0.11 * P_N/P_p$ ranges from 1.01 to 1.04.

$\rightarrow$ for LiD $C_1 \approx 1.86$ because ^6Li very much like 0.86 of a free deuteron, plus spectator α particle.

$\rightarrow$ LiD also has 6% ^7Li, which has an unpaired proton, and gives a non-negligible C_2 correction.

RESULTS FOR g_1 PROTON VRS Q^2



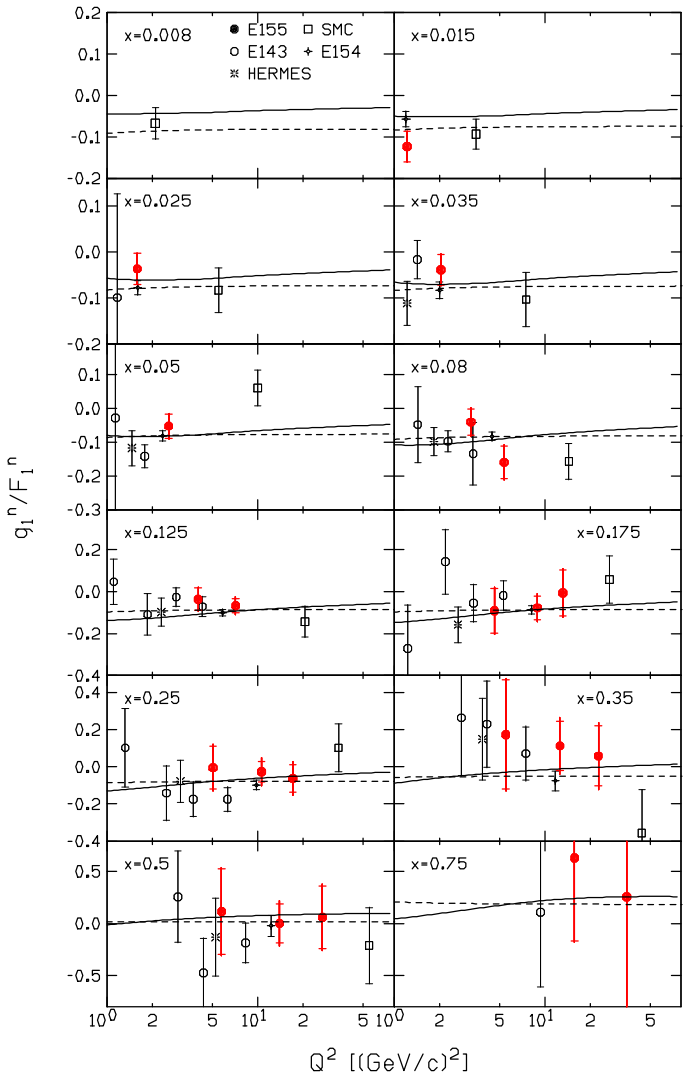
g1 for Proton

Dashed curve:
Empirical Fit

Solid curve:
pQCD fit

g1/F1 consistent with slight Q^2 dependence

RESULTS FOR g_1 NEUTRON VRS Q^2



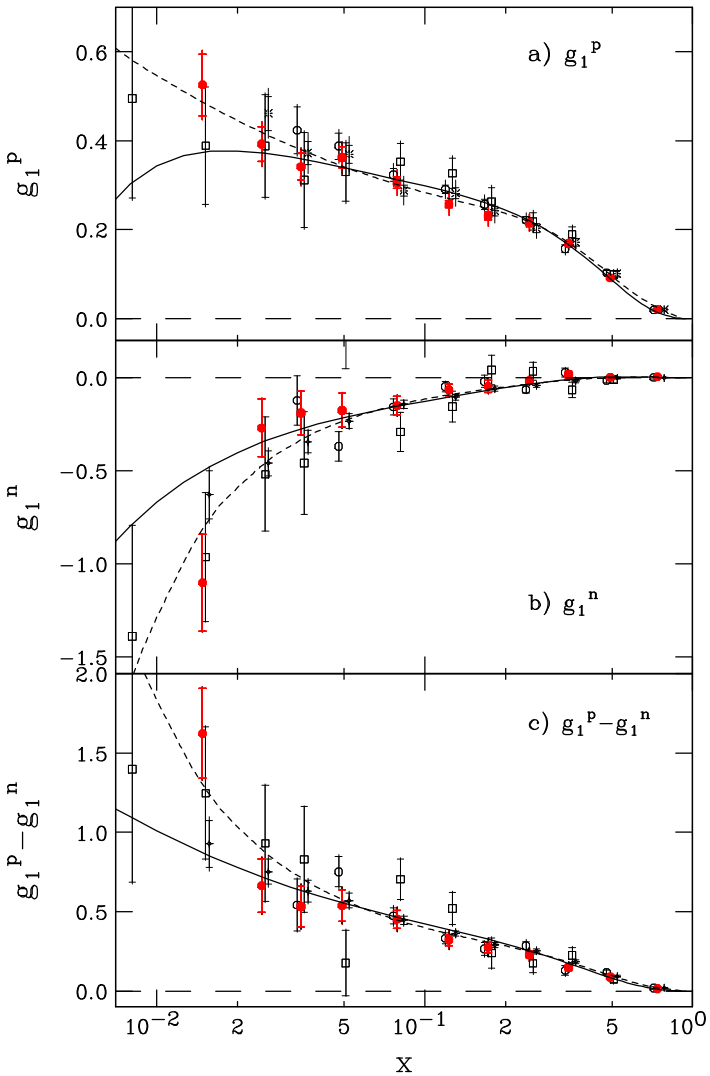
g1 for Neutron

Dashed curve:
Empirical Fit

Solid curve:
pQCD fit

g1/F1 consistent with slight Q^2 dependence (also no Q^2) dependence

RESULTS FOR g_1 VRS x



g1 at Q^2=5 GeV^2

Proton well-determined for x>0.02

Neutron has larger errors

Low-x extrapolation uncertain (less so for p−n)

GLOBAL PQCD FIT TO g_1

- At $Q^2 = 5$ GeV^2 find quark singlet contribution:

  $$\Delta\Sigma = 0.23 \pm 0.04(stat) \pm 0.06(syst)$$

  (low compared to Ellis-Jaffe prediction of 0.58).

- Proton first moment:

  $$\Gamma_1^p = 0.118 \pm 0.004 \pm 0.007$$

- Neutron first moment:

  $$\Gamma_1^n = -0.058 \pm 0.005 \pm 0.008$$

- Bjorken Sum Rule:

  $$\Gamma_1^p - \Gamma_1^n = 0.176 \pm 0.003 \pm 0.007$$

  (in agreement prediction 0.182 ± 0.005).

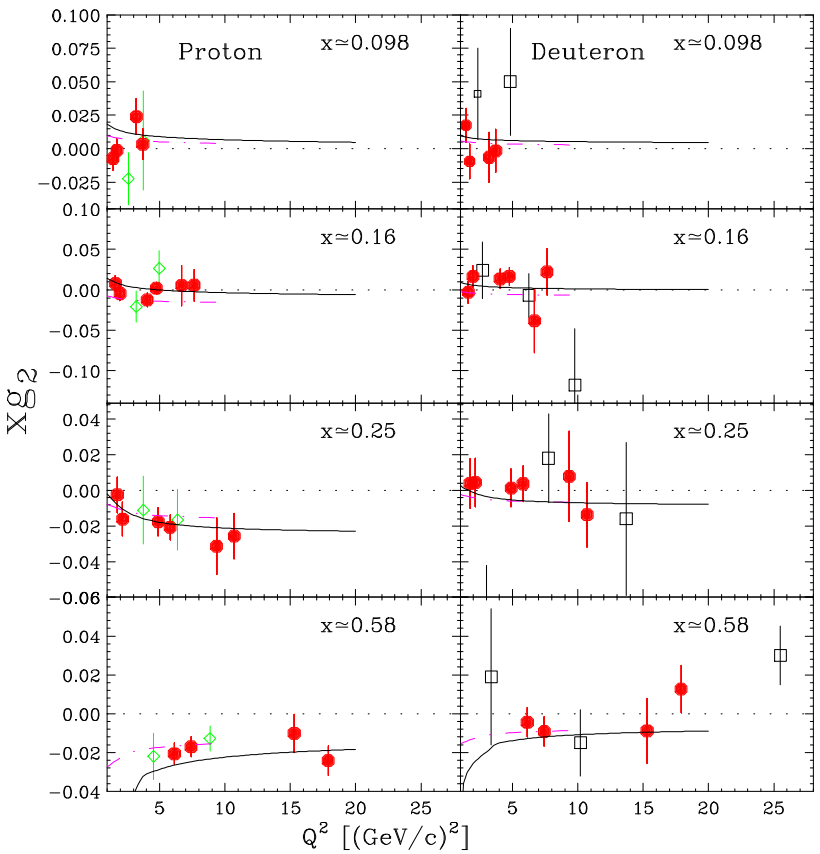
published: Phys. Rev. Lett. B463 (1999) 339; B493 (2000) 19.

E155x MEASUREMENTS OF g_2^p and g_2^d

- Measured in 1999: to be published soon.
- Electron beam 29 GeV and 32 GeV, polarization $P_b = 0.83$
- NH_3 and LiD targets as in E155.
- Spectrometers at 2.75, 5.5 and 10.5 degrees.
- Kinematics: $0.02 < x < 0.8$, $1 < Q^2 < 30$ GeV^2.
- Compare to Twist-2 Wandzura-Wilczek:

$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 \frac{dy}{y} g_1(y,Q^2)$$

RESULTS FOR g_2 VRS Q^2



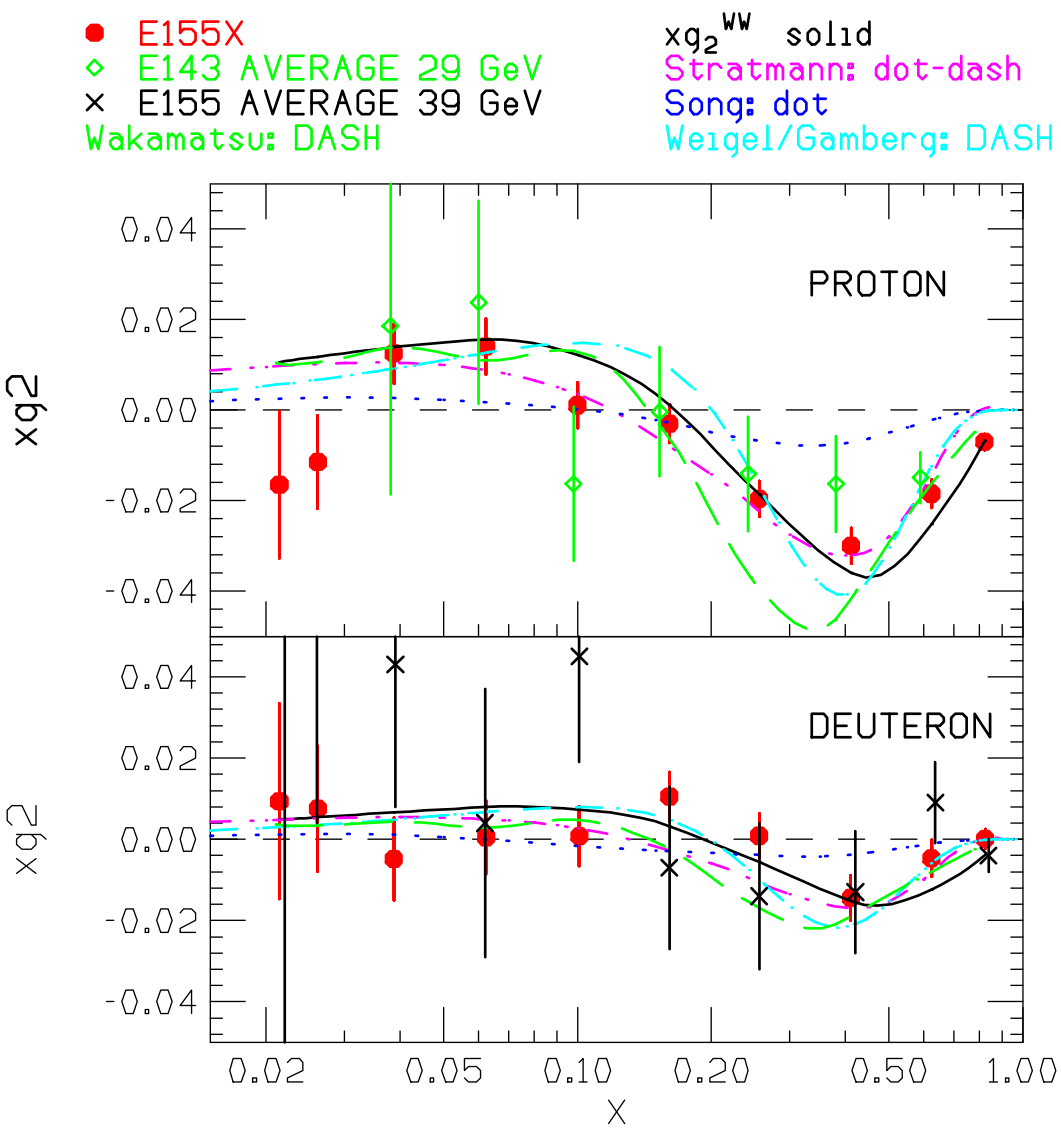
solid curve:
twist−2 g2ww

Q^2 dependence
is weak: agrees
with g2ww

Deuteron errors
larger: consistent
no Q^2 dependence

proton negative
at high x

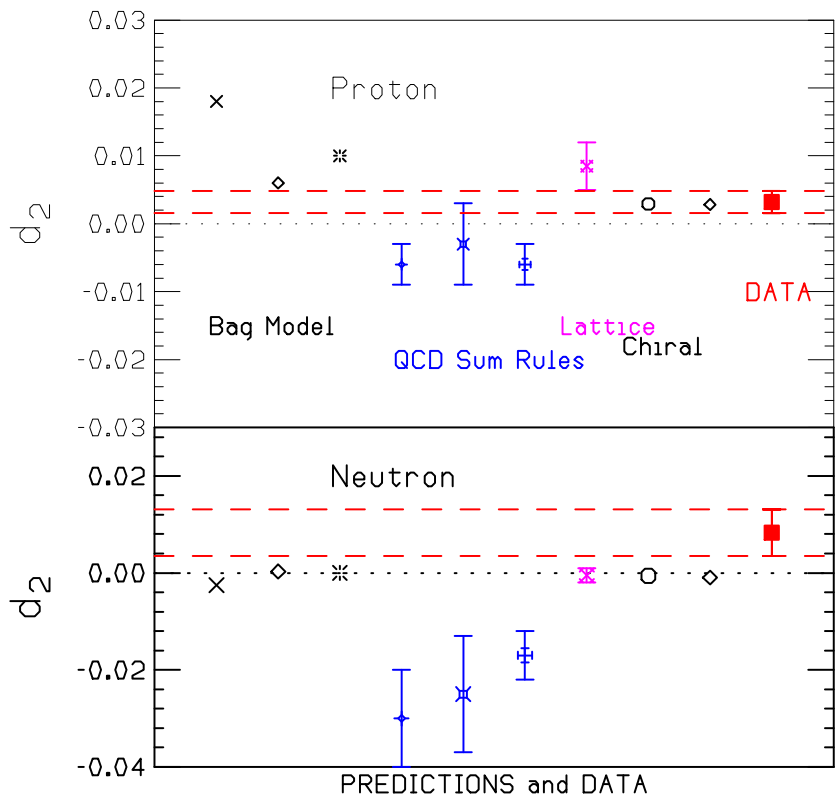
RESULTS FOR g_2 VRS x



THE TWIST-3 d_2 MATRIX ELEMENT

$$d_2 = 3\int_0^1 x^2[g_2(x,Q^2) - g_2^{WW}(x,Q^2)]dx$$

is a measure of twist-3 quark-gluon correlations (if $m_q h_T/M_n$ neglected).



TWO MORE g_2 SUM RULES

- The Burkhardt-Cottingham sum rule predicts:

$$\int_0^1 g_2(x)dx = 0,$$

- For $0.02 \leq x \leq 0.8$ at $Q^2 = 5$ (GeV/c)^2. we find -0.034 ± 0.008 for proton and -0.002 ± 0.011 for deuteron.
- Disagreement for proton could be due to low-x.
- Efremov-Leader-Teryaev Sum Rule (assuming isospin symmetry):

$$\int_0^1 x[g_1^p(x)+2g_2^p(x)-g_1^n(x)-2g_2^n(x)]dx = 0.$$

- We find -0.009 ± 0.008 at $Q^2 - 2.5$ GeV^2, consistent with prediction.
- Low-x region suppressed by x-weighing in integral, test more conclusive than for B.C. Sum Rule.

E155x MEASUREMENTS OF A_2^p and A_2^d

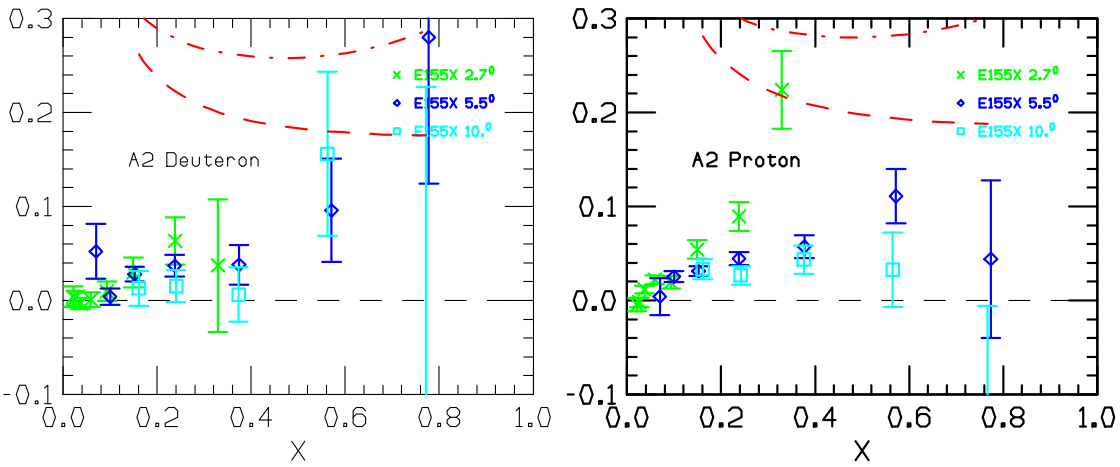
$$A_2(x,Q^2) = \frac{2\sigma_{TL}}{\sigma_T^{1/2} + \sigma_T^{3/2}} = \gamma \frac{g_1(x,Q^2) + g_2(x,Q^2)}{F_1(x,Q^2)}$$

Compare to positivity limit

$$A_2 < \sqrt{R(x,Q^2)}$$

and Soffer limit

$$A_2 < \sqrt{R(x,Q^2)(1 + A_1(x,Q^2))/2}$$



INCLUSIVE POLARIZED HADRON PHOTOPRODUCTION

- Measured $A_{\parallel}$ at $E = 48$ GeV and $A_{\perp}$ at 29 and 32 GeV.
- Photons generated in target from real plus virtual Bremsstrahlung
- Photon polarization $P_k \approx P_e k/E$
- Measured asymmetries are a convolution of photon flux weighted by polarization and cross section asymmetry.
- Hadrons are mostly pions.
- Asymmetries are small but non-zero for proton, for both longitudinal and transverse target polarization.
- Not much theory yet.