Search for Higher Twist Effects in the Spin Structure Function $g_2^n(x,Q^2)$

DNP Meeting, Maui, October 19, 2001

Wolfgang Korsch, University of Kentucky
for the E97-103 Collaboration at Jefferson Lab

- Why is $g_2^n(x,Q^2)$ interesting?
- Experiment E97-103 in Hall A at Jefferson Lab
  - Experimental Procedure
  - Analysis Issues
  - Summary

List of Collaborators

D. Margaziotis
California State University, LA
B. Milbrath
Eastern Kentucky University
R. Roche
Florida State University
M. Roedelbronn
University of Illinois
F. Cusanno, S. Frullani, F. Garibaldi
INFN
J.P. Chen, J. Gomez, K. de Jager, O. Hansen, J. LeRose, N. Liyanage, R. Michaels, S. Nanda, B. Reitz
Jefferson Lab
K. McCormick
Kent State University
W. Korsch, P. Zolnierczuk
University of Kentucky
T. Horn, J. Kelly, N. Savvinov
University of Maryland
A. Vacheret
University of Massachusetts
W. Bertozzi, D. Dutta, H. Gao, D. Higinbotham, S. Sirca, R. Suleiman, Y. Xiao, X. Zheng, J. Zhou, L. Zhu
Massachusetts Institute of Technology
V. Punjabi
Norfolk State University
W. Hinton
Old Dominion University
E. Busato, R. Gilman, X. Jiang, R. Ransome
Rutgers University
G. Ron *Tel Aviv University*
Z.-E. Meziani, K. Slifer, P. Solvignon
Temple University
S. Binet, A. Camsonne, G. Cates, A. Deur, J. Singh, A. Tobias
University of Virginia
D. Armstrong, T. Averett, C. Butuceanu, P. Djawotho, M. Finn, O. Gayou, K. Griffioen, K. Kramer, C. Perdrisat, J. Roche, J. Secrets, D. Steiner, V. Sulkosky, X. Zhu
College of William&Mary

Why is $g_2^n(x,Q^2)$ interesting?

Two spin structure functions accessible in polarized *inclusive* DIS: $g_1(x,Q^2)$, $g_2(x,Q^2)$.

$$A_{\parallel} = \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}} = D \cdot \{(E + E' cos(\vartheta)) g_1(x,Q^2) - \frac{Q^2}{\nu} g_2(x,Q^2)\}$$

$$A_{\perp} = \frac{\sigma^{\rightarrow\downarrow} - \sigma^{\rightarrow\uparrow}}{\sigma^{\rightarrow\downarrow} + \sigma^{\rightarrow\uparrow}} = D \cdot E' sin(\vartheta)\{g_1(x,Q^2) + \frac{2E}{\nu} g_2(x,Q^2)\}$$

$$D = \frac{1}{F_1(x,Q^2)} \cdot \frac{1}{\nu} \cdot \frac{1-\epsilon}{1+\epsilon R(x,Q^2)}$$

$F_1(x,Q^2)$ unpolarized s.f., $R(x,Q^2) = \frac{\sigma_L}{\sigma_T}$, both quantities well known (CERN, DESY, SLAC).

Recall: $g_1(x) = \frac{1}{2}\sum_j Q_j^2[\Delta q_j(x) + \Delta\bar{q}_j(x)]$

In contrast, $g_2(x)$ does not have a simple parton model interpretation, since it is a higher-twist structure function $\Rightarrow$ *coherent* lepton-parton scattering with more than one parton involved in scattering process.

Deep inelastic lepton-nucleon scattering (DIS)

($Q^2 \to \infty$, $\nu \to \infty$, $\frac{Q^2}{\nu}$ fixed) $\Rightarrow$ asymptotic freedom

- leptons scatter incoherently off quarks
- probes electromagnetic quark currents at *short* distances

Hadron structure is described by hadronic tensor:

$$W_{\mu\nu}(q, P, S) = \frac{1}{4\pi} \int d^4 z e^{iq \cdot z} \langle PS | [J_\mu(z), J_\nu(0)] | PS \rangle$$

In pQCD $J_\mu(z) \cdot J_\nu(0)$ can be expanded in a power series in $\frac{1}{Q^2}$ (OPE) and the moments of hadronic structure functions can be expressed as:

$$\int_{-1}^{1} x^{n-1} W(Q^2, x) dx = \frac{1}{4} \sum_{\tau=2}^{\infty} \bar{C}_n^\tau(Q^2, \mu^2) \bar{\mathcal{O}}_n^\tau(\mu^2) \left(\frac{1}{Q^2} \right)^{\frac{\tau}{2}-1}$$

- τ is the twist of the operator $\bar{\mathcal{O}}$ (μ scale parameter).
- DIS is dominated by $\tau = 2$ (twist-2).

$\Rightarrow$ Higher twist effects are suppressed at large Q^2 in DIS.

To understand $g_2(x,Q^2)$ lets look at the moments of the spin structure functions using the OPE:

$$\int_0^1 x^n g_1(x,Q^2)dx = \frac{1}{4}\bar{\mathcal{O}}_n^{\{2\}} = \frac{1}{4}a_n \quad n = 0,2,4,...$$

$$\int_0^1 x^n g_2(x,Q^2)dx = \frac{1}{4}\frac{n}{n+1}(\bar{\mathcal{O}}_n^{\{3\}} - \bar{\mathcal{O}}_n^{\{2\}}) = \frac{1}{4}\frac{n}{n+1}(d_n - a_n)$$

$n = 2,4,6,...$

If the $\bar{\mathcal{O}}_n^{\{3\}} = 0$:

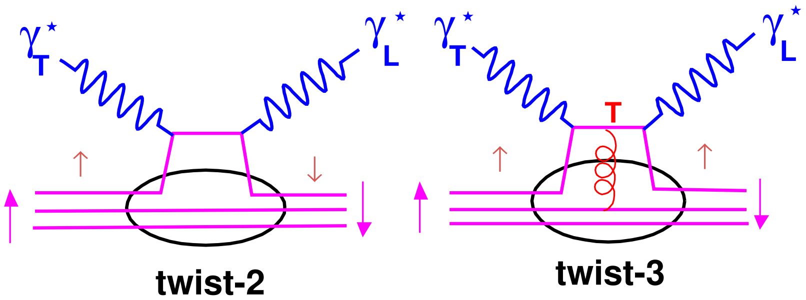
$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_{x'}^1 \frac{dx'}{x'} g_1(x',Q^2)$$

S. Wandzura and F. Wilczek, Phys. Lett. B 72 (1977)

- leading twist part of $g_2(x,Q^2)$ is completely determined by twist-2 part of $g_1(x,Q^2)$:

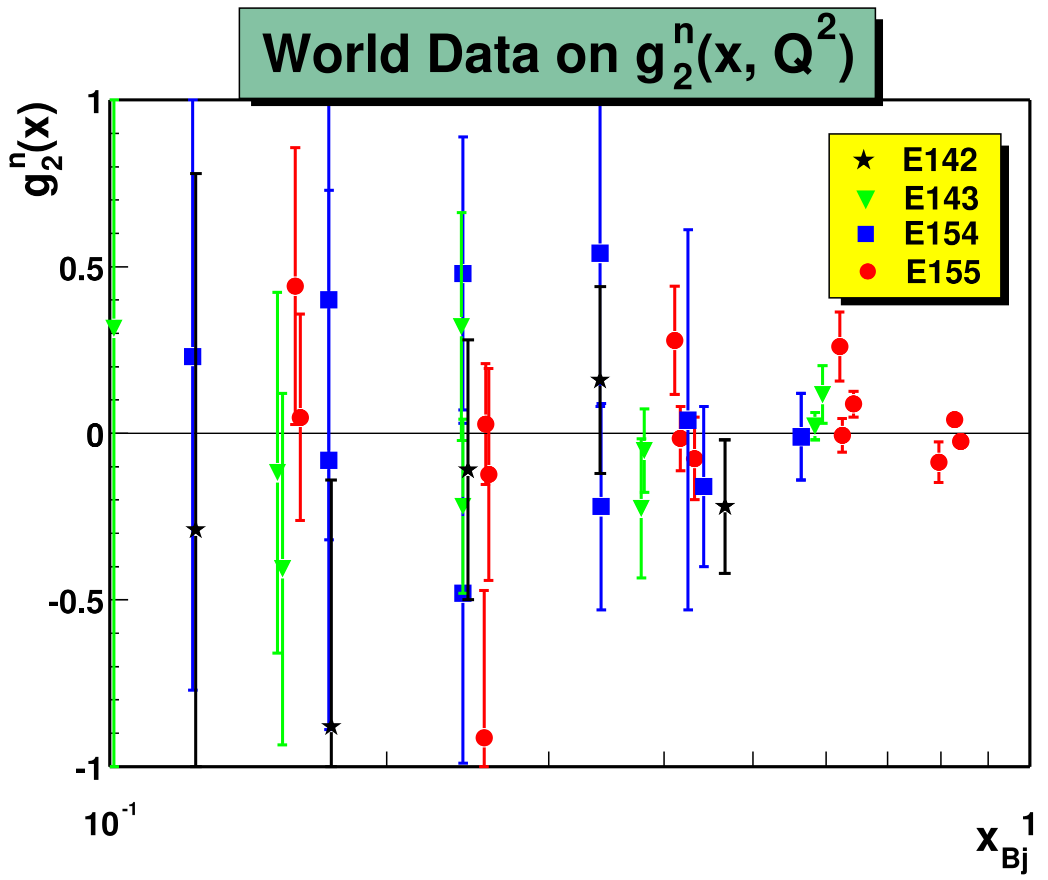
$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) + g_2^{H.T.}(x,Q^2)$$

- higher twist (twist-3 and higher) contributions can be directly separated. $\rightarrow$ $g_2(x,Q^2)$ is a unique s.f.!!!
- twist-3 contribution is larger at low Q^2 ($\propto \frac{1}{Q}$)



$\Rightarrow$ sensitive to quark-gluon correlations.

Measurement of $g_2^n(x,Q^2)$ at Jefferson Lab



$$\Rightarrow d_2 = 0.004 \pm 0.010 \quad \langle Q^2 \rangle = 5\ GeV^2/c^2$$

E155 Collaboration (P.L. Anthony et al.), Phys.Lett. B 458, 53(1999)

- $g_2^n(x, Q^2)$ is not well known
- difficult to measure Q^2 dependence of moments
- E97-103 decided to measure g_2^n at different values of Q^2 and nearly constant x

Experimental conditions for E97-103:

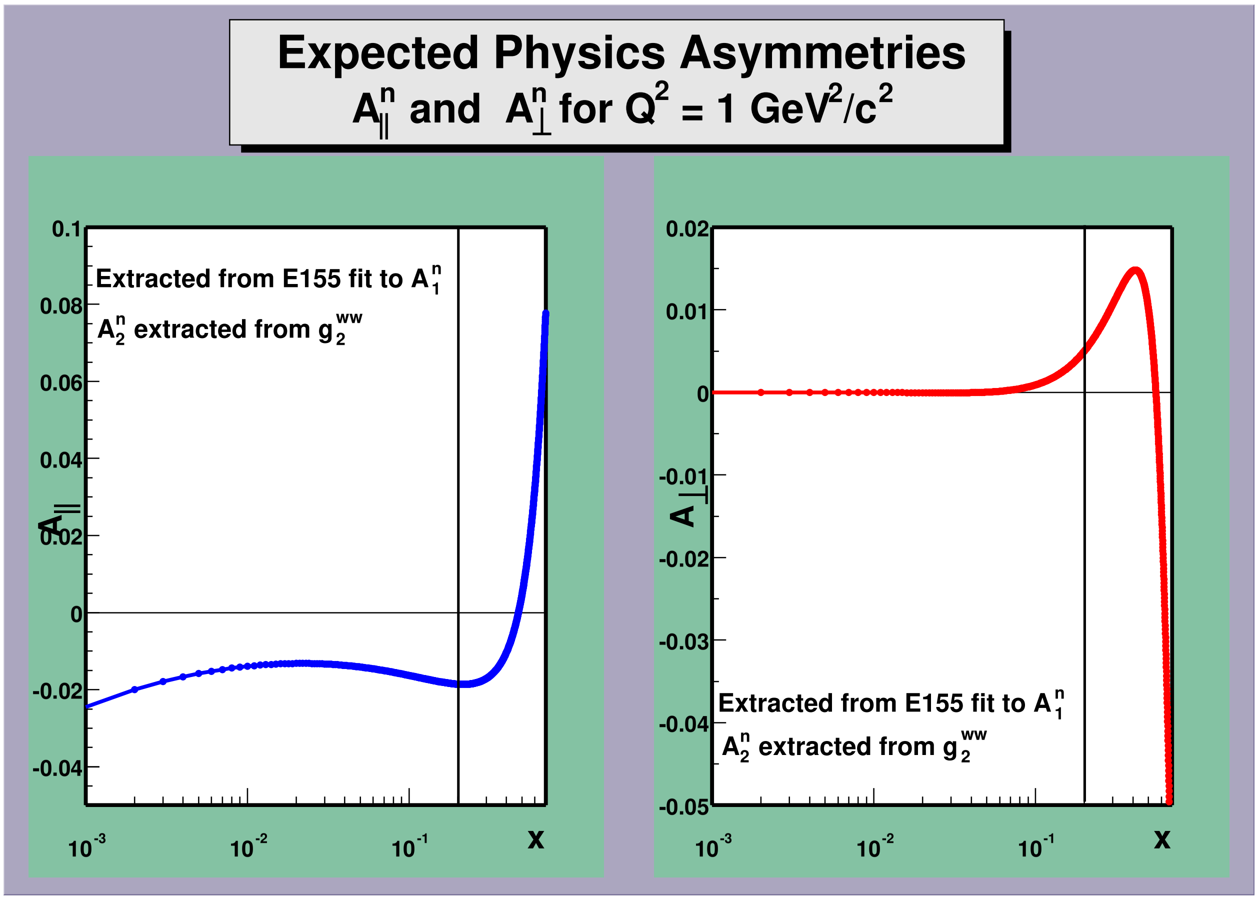
- Used Hall A polarized ^{3}He target (40 cm long cell), $P_{^3He} \approx 45\%$ ($\|$) and $\approx 40\%$ ($\perp$)
- CEBAF electron beam: (10-12)μA, $P_e : 71\% - 82\%$, helicity flip rate: 30 Hz
- beam energies: 3.47, 4.60, 5.73 GeV
- both Hall A HRS's in symmetric configuration

$\rightarrow$ talks by K. Slifer and X. Zheng

E97-103 kinematics:

Q^2 [GeV^2/c^2]	x	W^2 [GeV^2]
0.58	0.17	3.82
0.80	0.18	4.43
0.96	0.20	4.83
1.14	0.20	5.57
1.36	0.21	6.03

What do we expect?



$\Rightarrow \; A_{phys} \lesssim \; 2\%(\parallel), \; 0.5\%(\perp)$

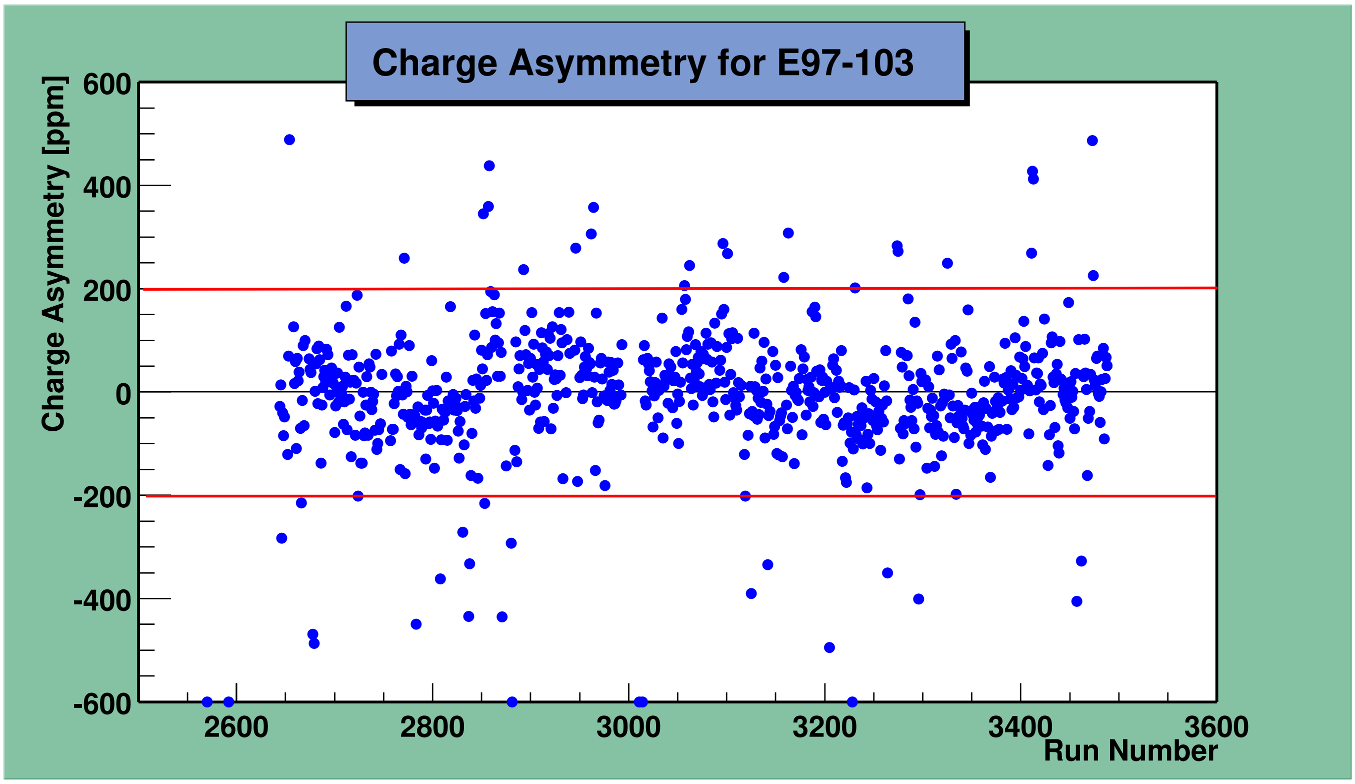
For $f = 0.3, \; P_t = 0.4, P_b = 0.8$ (typical values)

$\Rightarrow \; A_{meas} = f \cdot P_t \cdot P_b \; \lesssim 0.2\%(\parallel), \; 500ppm(\perp)$

☞ good PID, π^- rejection, $\gtrsim 2 \cdot 10^4$

☞ small charge asymmetries

History of the charge asymmetry for E97-103:

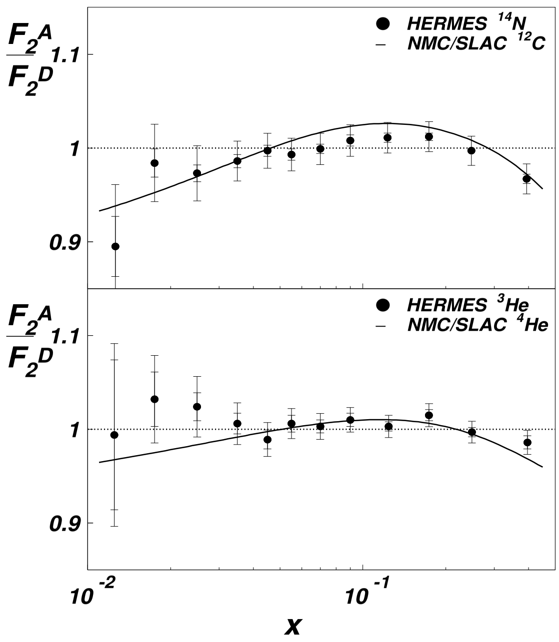


Corrections to Asymmetries

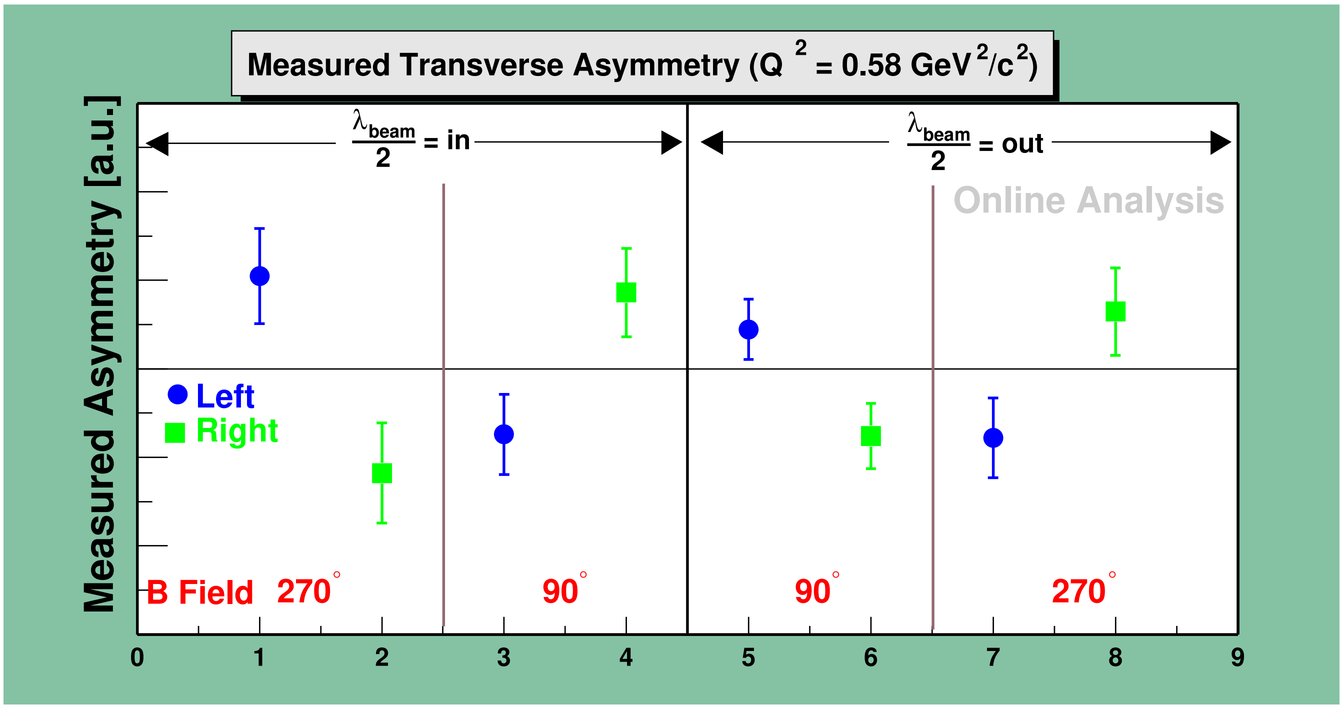
Measured Asymmetry:

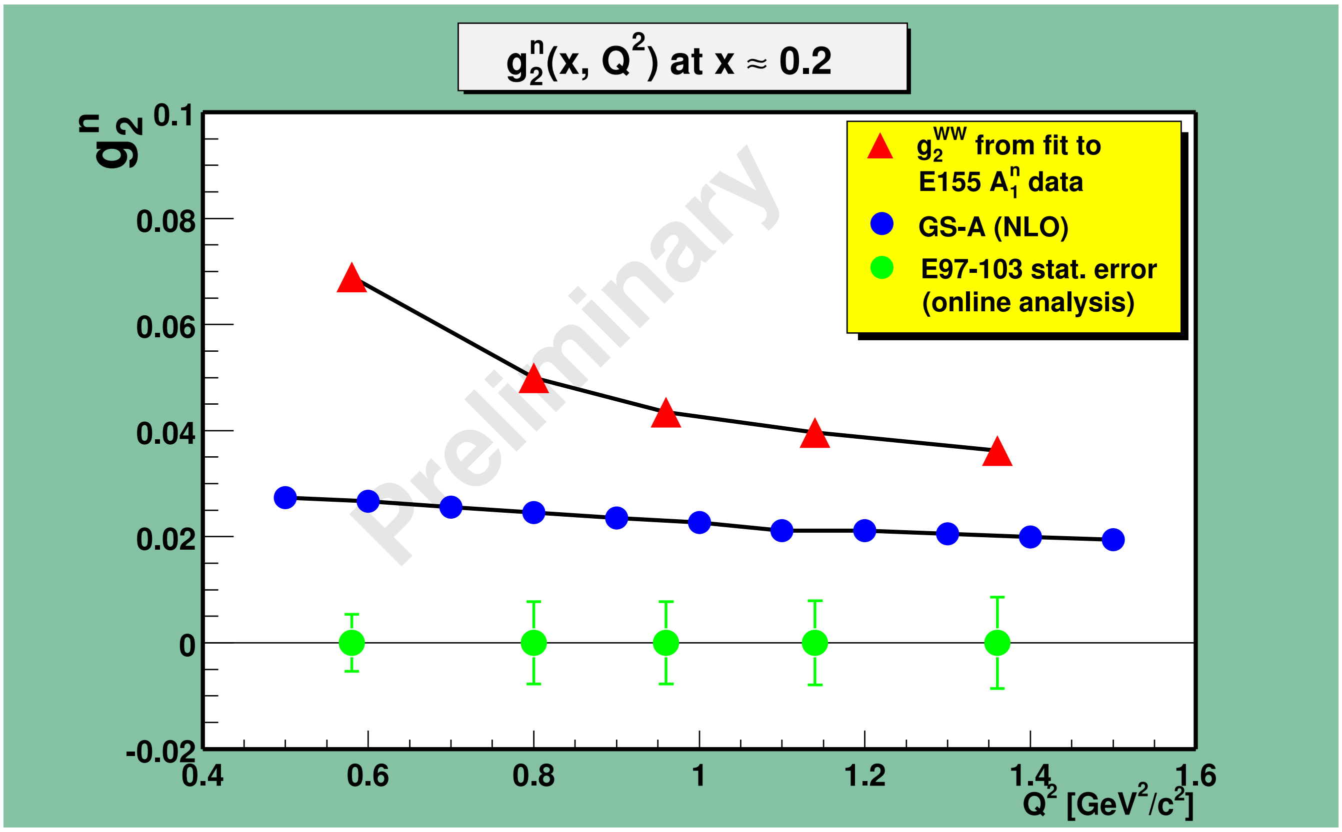
$$A_{meas} = f_n \cdot P_n \cdot P_B \cdot A^n + f_p \cdot P_p \cdot P_B \cdot A^p$$

- f_n, f_p dilution factors. Here $f_n \approx 0.27$ and $f_p \approx 0.34$, using s.f. of free nucleons
- $A_p \rightarrow$ need $g_2^p(x, Q^2)$, *i)* $g_2^{p\;WW}$ from fit to g_1^p data, *ii)* use positivity limit: $\frac{Q^2}{\nu^2}(g_1 + g_2)^2 \leq R \cdot F_1^2$ (*note:* contribution strongly suppressed by P_p)
- $P_n = 0.86 \pm 0.02$, $P_p = -0.028 \pm 0.004$
  J.L. Friar et al., Phys. Rev. C 42 (1990) 2310
- small correction for Δ isobar
  F. Bissey et al., hep-ph/0109069 (2001)
- nuclear medium effects:
  small x = 0.2
  HERMES Collaboration, K. Ackerstaff et al., Phys. Lett. B 475, 386 (2000)



Some preliminary results:





Summary and Conclusions

- ✗ E97-103 improved statistical error bars on $g_2^n(x, Q^2)$ at $x \approx 0.2$ for $0.58\ GeV^2/c^2 \leq Q^2 \leq 1.36\ GeV^2/c^2$ by approximately factor of 10 for $W > 1.9\ GeV$.
- ✗ High precision data on $g_1^n(x, Q^2)$ in same x and Q^2 range.
- ✗ Interesting data on π^- asymmetries.
- ✗ JLab at 12 GeV will allow us to measure moments of $g_2^n(x, Q^2)$ with high precision.