Duality in Polarized Structure Functions

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Open Questions in Parton-Hadron Duality
UVA
March 13, 2015

Bloom-Gilman Local Duality (1971)

- Integral of proton $W_2(\nu,Q^2)$ at fixed Q^2 over limited ranges of ν (in the region 1.071 GeV $\leq W \leq$ 2 GeV) equals the integral of the scaling function $F_2(\omega') = \nu W_2(\omega')$ over the matching ω' range.

$$\frac{2M}{Q^2}\int_{\nu_a}^{\nu_b} d\nu\,\nu W_2(\nu,Q^2) = \int_{\omega'_a}^{\omega'_b} d\omega' F_2(\omega')$$

$$\nu_{a,b} = \frac{W_{a,b}^2 - M^2 + Q^2}{2M} \qquad \omega'_{a,b} = 1 + \frac{W_{a,b}^2}{Q^2}$$

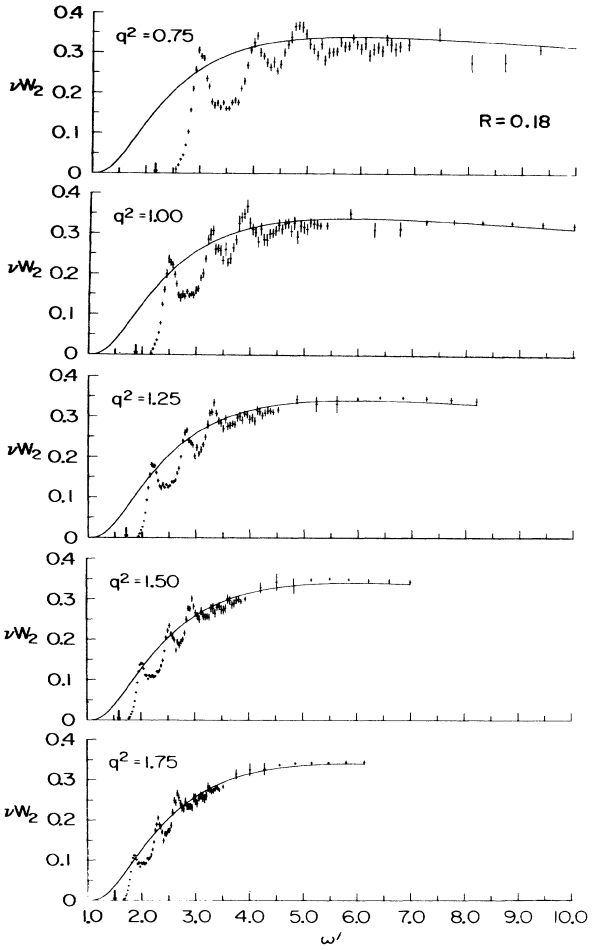


FIG. 3. The function $\nu W_2(\nu, q^2)$ plotted versus $\omega' = 1 + W^2/q^2$ from an interpolation of data to fixed q^2 values of 0.75, 1.00, 1.25, 1.50, and 1.75 GeV^2. The solid line is the scaling-limit curve, $\nu W_2(\omega')$, a smooth fit (Ref. 12) to the data in the scaling region. The arrow indicates the position of the elastic peak.

Early looks at Spin B-G (SBG)

Proposal: PR-95-005, Hall C

Spokespersons: O. Rondon-Aramayo

Title: Precision Measurement of the Nucleon Spin Structure Functions in the Region of the Nucleon Resonances

Motivation:

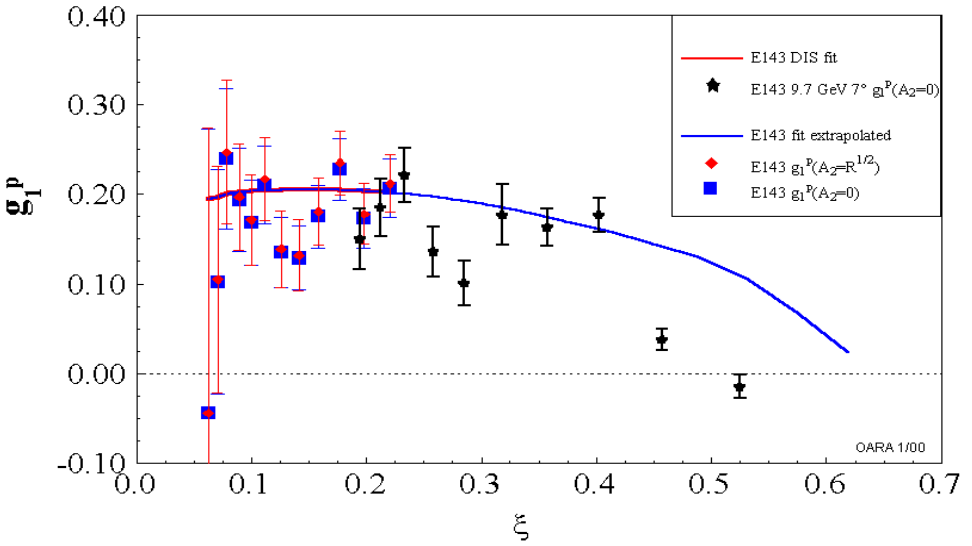
This experiment seeks to measure inclusive asymmetries in the resonance region on polarized NH_3 and ND_3 targets. Two values of Q^2 (1 and 5.5 $(GeV/c)^2$) would be studied. Physics goals include studying duality in spin observables, twist-3 processes via the transverse asymmetry and testing the pQCD prediction that $E_{1+}/M_{1+} \rightarrow 1$ for Delta excitation at high Q^2.

- Polarized local duality first mentioned in JLab PR95-005 (E01-006 *RSS*)

  Carlson & Mukhopadhyay 1997

- E143 9.7 GeV 7° g_1^p data in resonances compared with fit to DIS g_1^p and to DIS data

- No clear signal of SBG



Proton Spin Structure Functions

- g_1, g_2 from measured A_1 and A_2

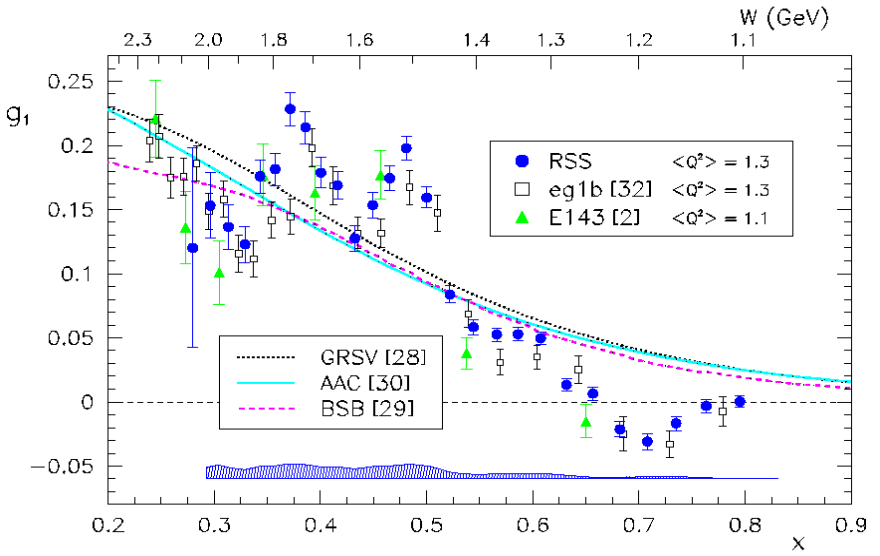
$$g_1 = \frac{F_1}{1+\gamma^2}\left(A_1 + \gamma A_2\right)$$

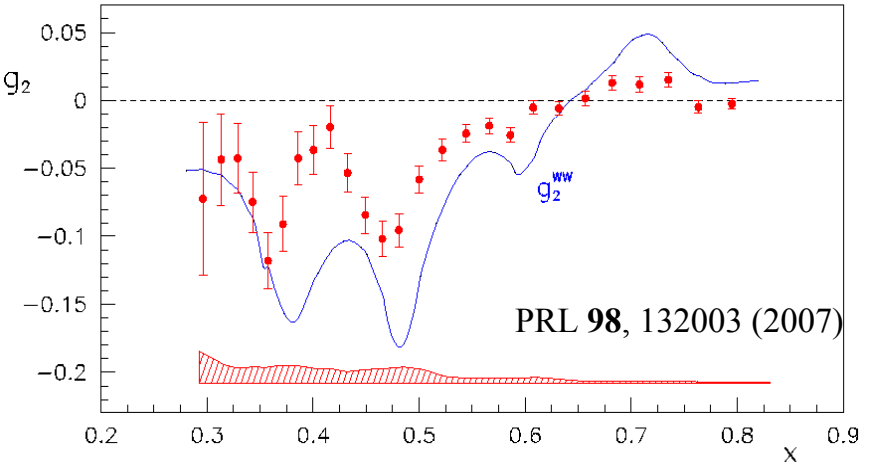
$$g_2 = \frac{F_1}{1+\gamma^2}\left(\frac{A_2}{\gamma} - A_1\right); \quad \gamma = \frac{2xM}{\sqrt{Q^2}}$$

  - F_1 from F1F209

- Precision proton data from JLab E01-006 (*RSS*)
  - First g_2^p world resonances data

- New SANE HMS data at lower x same Q^2 and also higher Q^2





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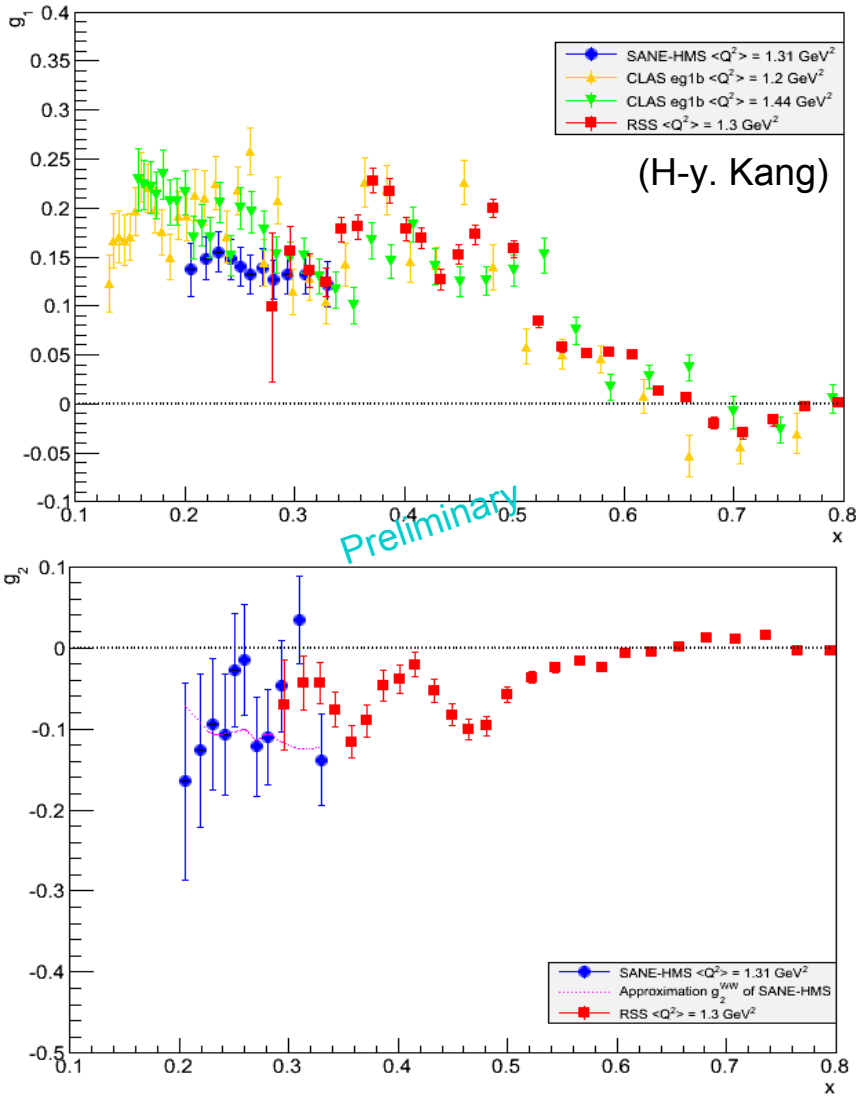

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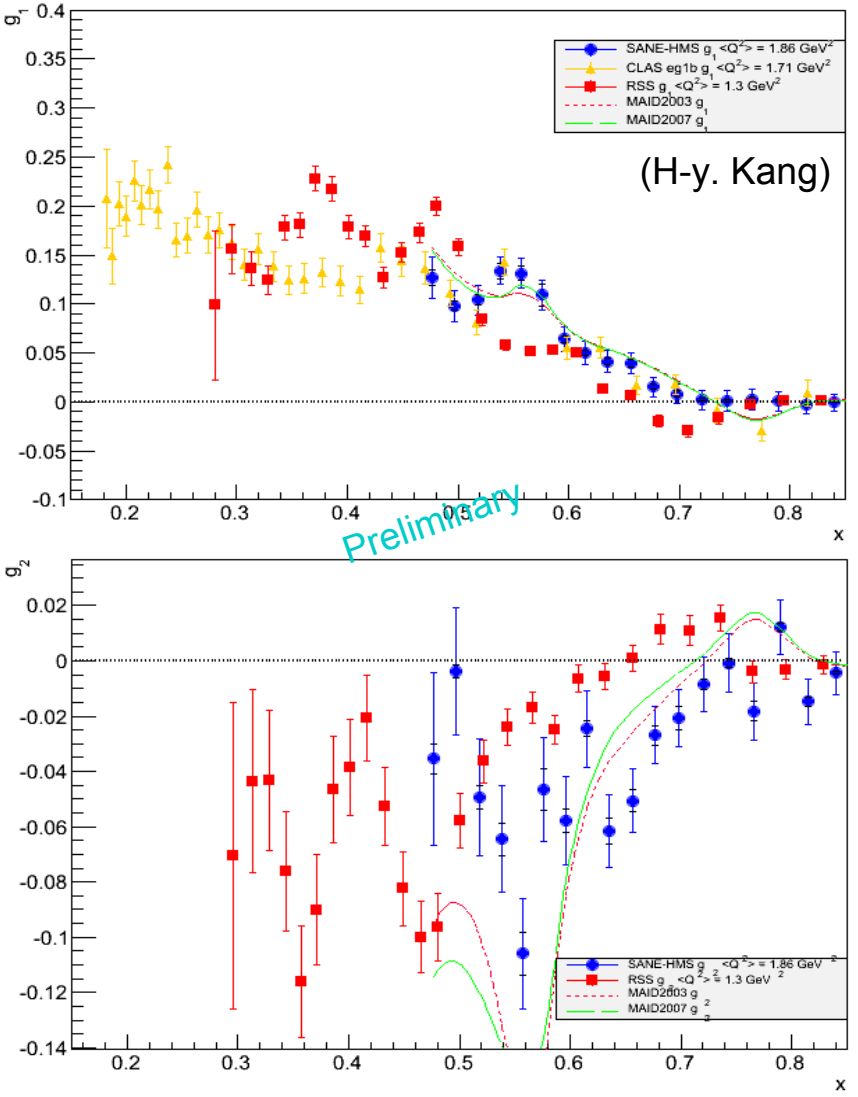


Bloom-Gilman Local Duality for g_1^p

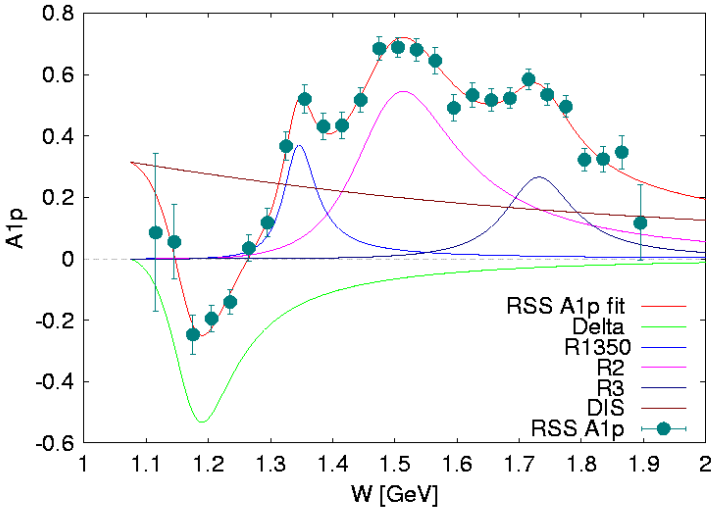
- Ratio of local integrals $\Gamma_1^{res} / \Gamma_1^{DIS}$

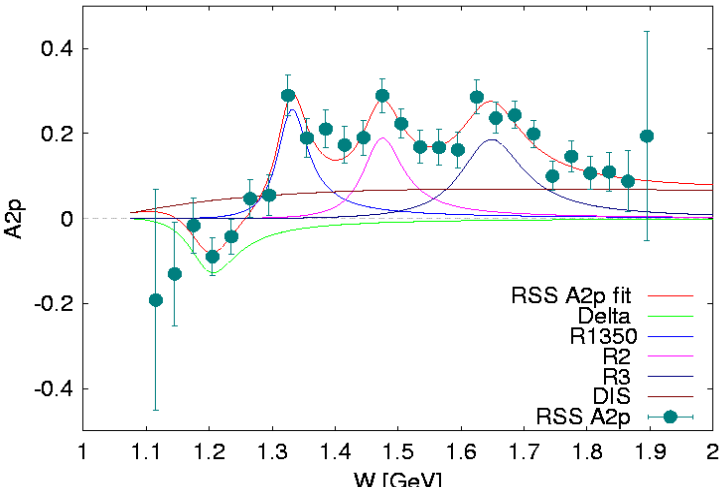
$$\Gamma_1(Q_0^2) = \int_{W\,lo}^{W\,hi} dW\, g_1(W, Q_0^2)$$

$$(dW \Leftrightarrow dx \text{ at fixed } Q^2)$$

  - use fit to g_1 in the resonances + g_1 from PDF's, evolved to same fixed Q^2 with TMC's

			Integral ratios Resonances/PDFs	Error	
Resonances	W low	W high	Average	Data	PDFs
Delta	1.11	1.30	**-0.26**	0.03	0.02
R1350	1.30	1.39	**0.74**	0.05	0.03
R2	1.39	1.68	**1.28**	0.09	0.03
R3	1.68	1.81	**1.26**	0.09	0.03
Global	1.08	1.91	**0.86**	0.06	0.02





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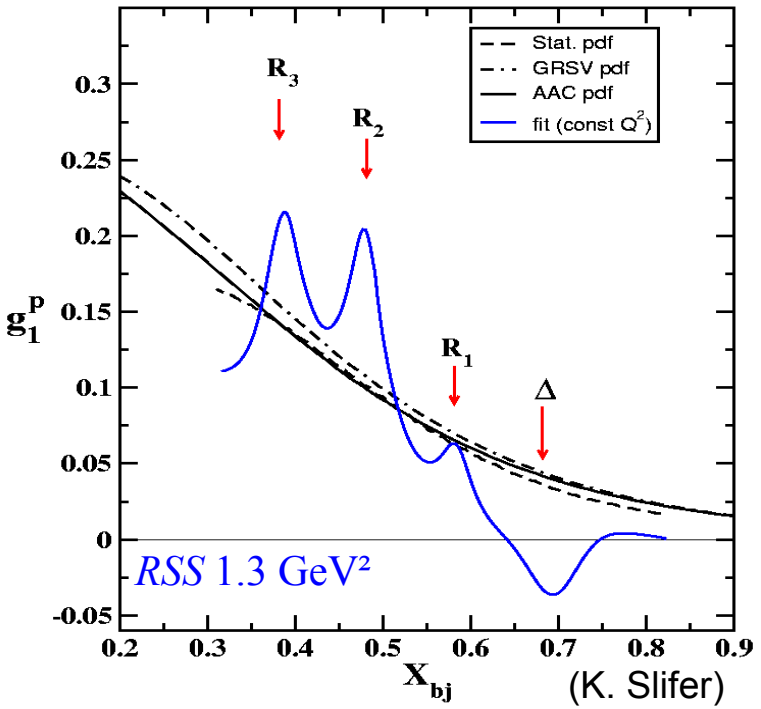

Only *approximate* Global Duality in *RSS*

Large x resummations increase discrepancy by 1.3

(PR **D69** (2004) 014505)

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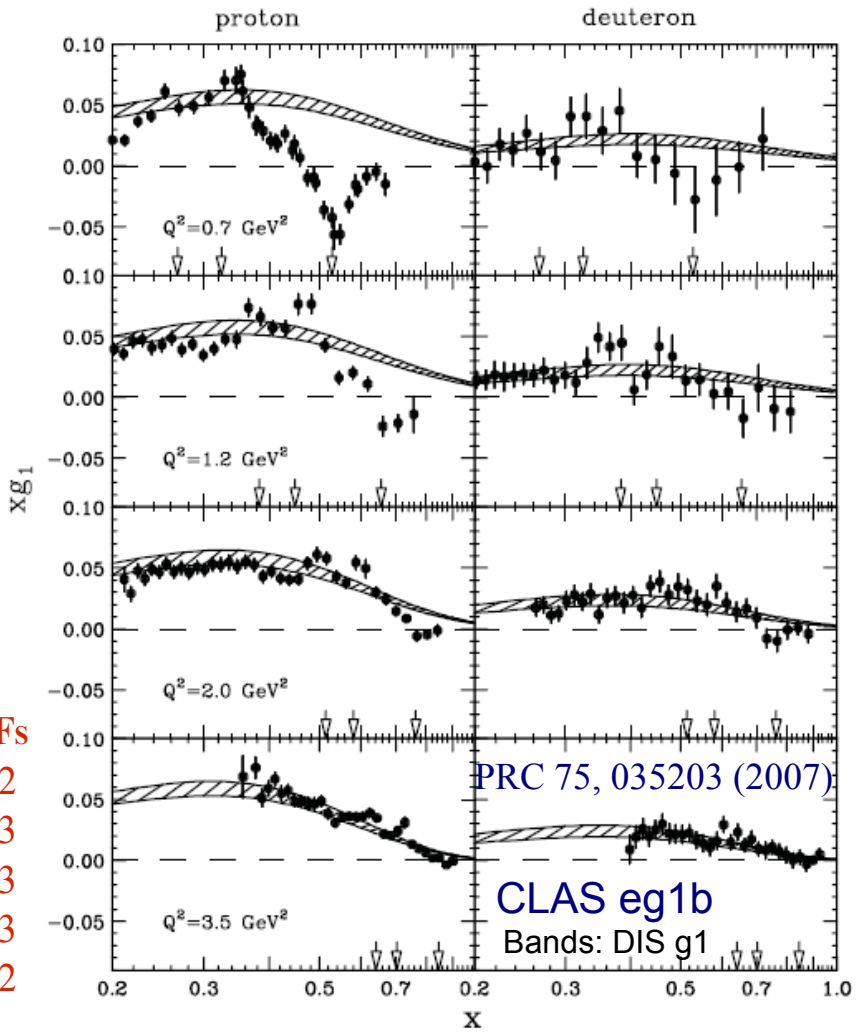
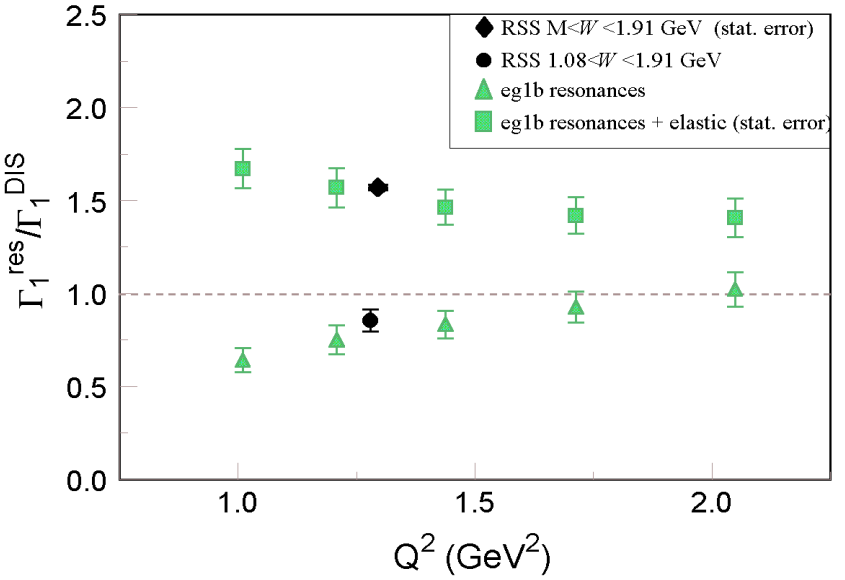
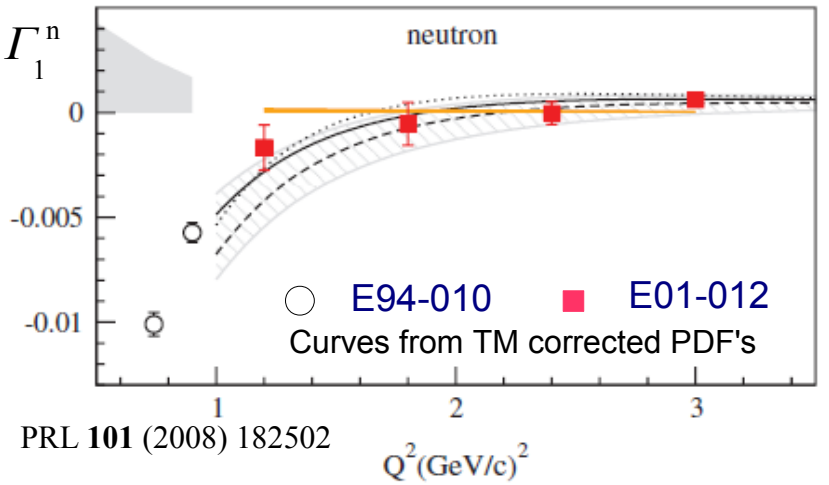


Global Spin Duality

- Bloom – Gilman duality for g_1
  - Approximate Local Duality works only above $\Delta(1232)$
  - Global duality (from $W > \pi$ threshold or from elastic) obtains above $Q^2 > 1.8$ GeV^2
  - seen in p, d, and ^{3}He
- No DIS g_2 yet (only g_2^{WW}):
  - PDF's not yet available. No $g_2(x,Q^2)$ models, either.
  - DIS g_2 SANE and Hall A E06-014 data coming



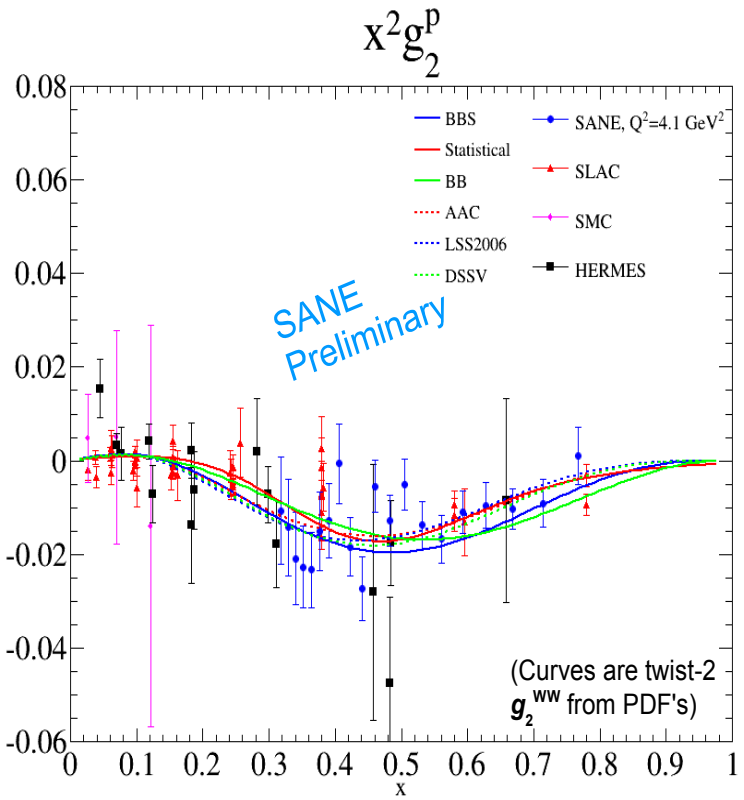


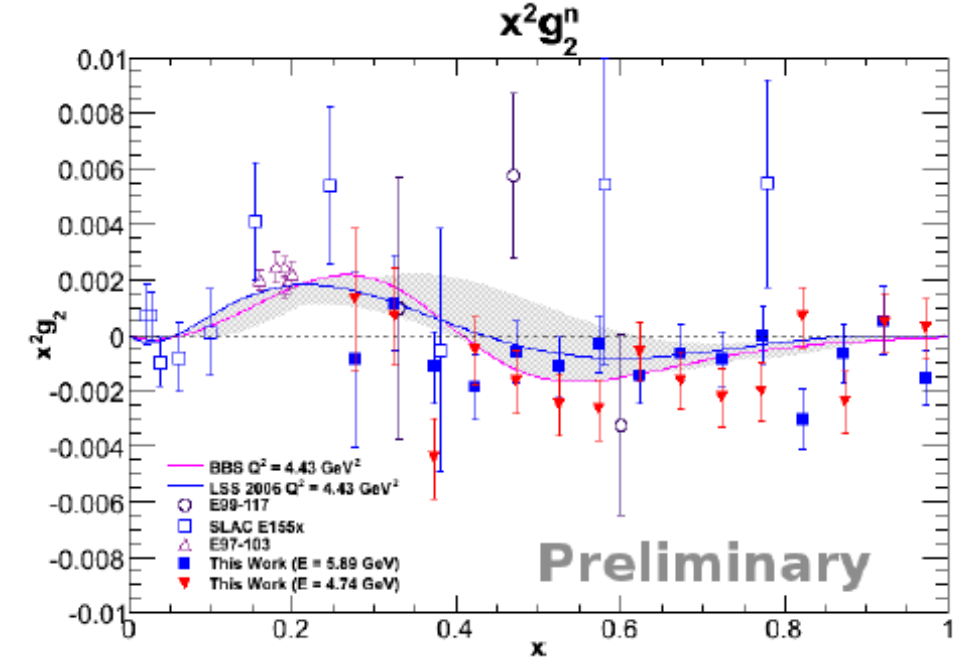
PRL **101** (2008) 182502

Future Possibilities

- Global duality works for $g_1(Q^2>1.8\ \text{GeV}^2)$: apply it to moments
  - Need both g_1 and g_2 for Nachtmann moments.
  - Region of integration: for nth. moment, perturbative HT's require
    - $n \ll Q^2/M_0^2$; $M_0^2 \sim$ (0.4-0.5GeV)^2; $n = 4 < 1.3\ \text{GeV}^2/M_0^2 \sim 8$ (Ji & Unrau, PRD 52 (1995)72)
    - Local region of integration $|\xi| \leq M_0^2/Q^2$: narrows at high Q^2
- Test g_1^p local duality at 1.8 GeV^2
  - Q^2 trends, especially P(1232); estimate moment's errors from duality.
- g_2^p Duality?
  - Take ratios of x, Q^2 dependent fits to global DIS data over resonances data; JAM PDF's with twist-3; any g_2 models?

g_2 in DIS and Resonances





(M. Posik)

(No external radiative corrections)

- Proton (NH_3)
  - Hall C SANE (E07-003)
  - $0.3 < x < 0.8 \quad 2.5 < Q^2 < 6.5$
- Neutron (on ^3He)
  - Hall A d2n (E06-014)

(g_2^{3He} PRL **113**, 022002 (2014))