Nucleon Resonance Spin Structure

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XV International Workshop on

Deep-Inelastic Scattering and Related Subjects

Resonant Spin Structure (RSS)
of the Proton and Deuteron

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Analysis

Karl Slifer, Shige Tajima, Frank Wesselmann
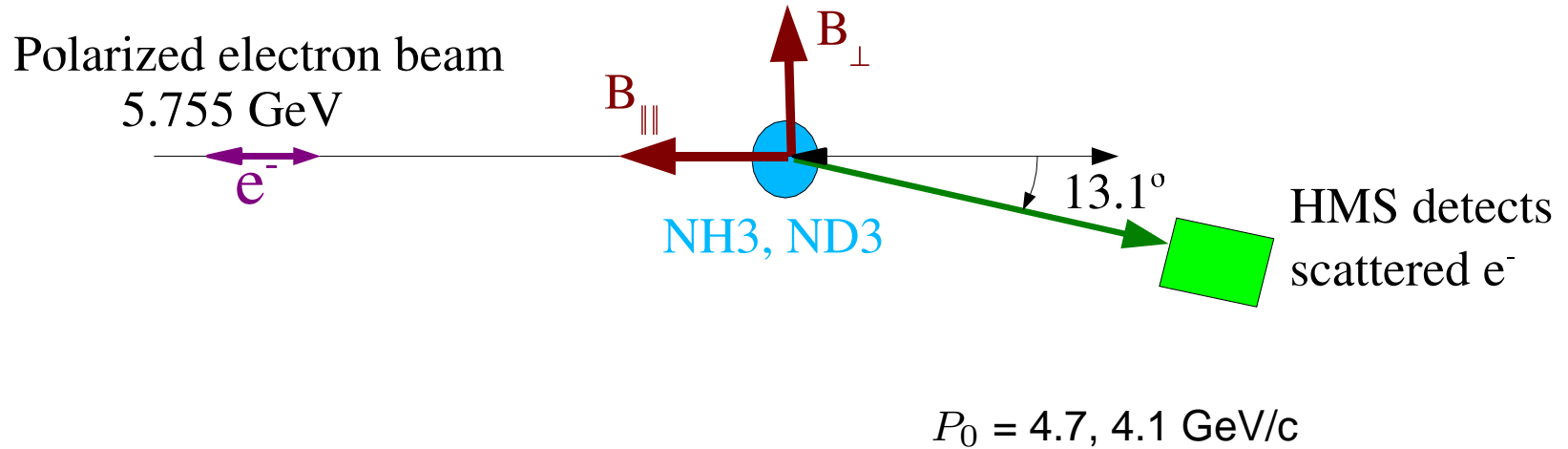
Peter Bosted, Eric Christy

E01-006 Collaboration

Univ. Basel, Florida International Univ., Hampton Univ., Univ. of Massachusetts, Univ. of Maryland, Mississippi State Univ.,North Carolina A&T Univ., Univ. of N. C. at Wilmington, Norfolk State Univ.,Old Dominion Univ.,S.U. at New Orleans, Univ. of Tel-Aviv, Jefferson Lab, Univ. of Virginia, Virginia P. I. & S.U., Yerevan Physics Institute
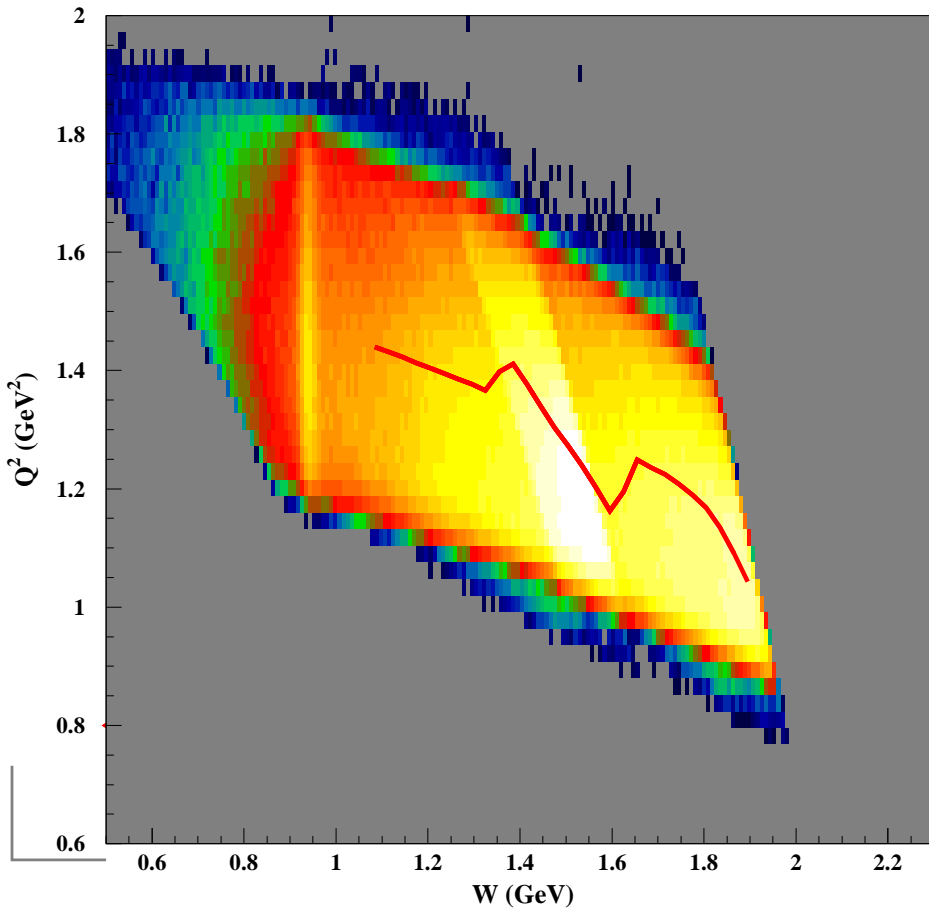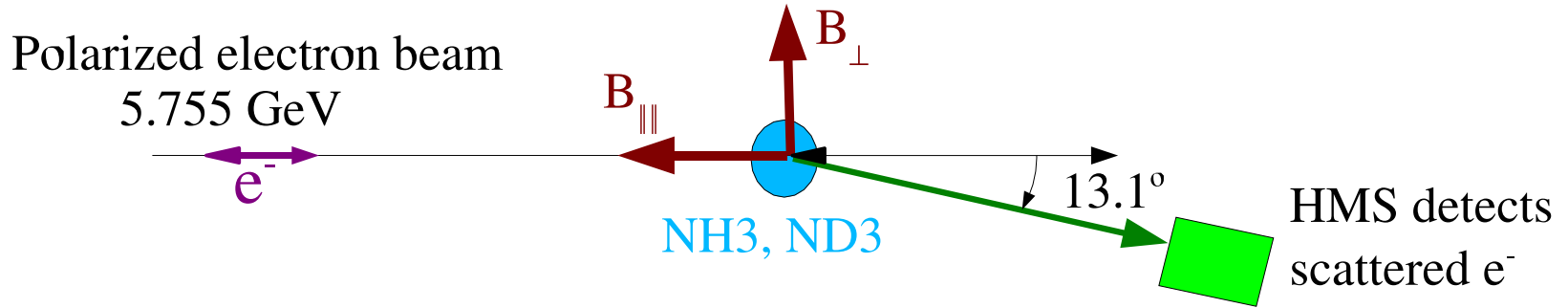
Overview

RSS : the first complete spin structure measurement on proton and deuteron in the resonance region.

- Measure $A_1(W, Q^2)$ and $A_2(W, Q^2)$
- Extract g_1 and g_2 structure functions
- Add to world data on $A_\perp$
- W–dependence
- Onset of polarized local duality
- Twist-3 effects in d_2 matrix element

- Extract asymmetries from inclusive polarized electron scattering on polarized nuclei.

Experimental set-up in Hall C

Polarized electron beam
5.755 GeV

$B_\perp$

$B_\parallel$

e^-

NH3, ND3

13.1°

HMS detects
scattered e^-

P_0 = 4.7, 4.1 GeV/c

Experimental set-up in Hall C

Polarized electron beam
5.755 GeV

e^-

$B_\perp$

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HMS detects
scattered e⁻

P_0 = 4.7, 4.1 GeV/c

$Q^2 \approx 1.3$ GeV^2
$W : 0.8 - 2.0$ GeV

P_b = 65.6 $\pm$ 2.6 for $B_\parallel$
P_b = 70.9 $\pm$ 1.7 for $B_\perp$

$I \approx 100$nA
Beam charge asym. < 0.1%

Polarized Target

Target Ladder

2 NH_3 cups

2 ND_3 cups

1 Carbon (7mm)

Target Field

5 Tesla

Para & perpendicular fields.

Polarization can be flipped by

$180°$. Ran $\pm$ for equal times.

Target Polarization

$NH_3 : P_t \approx 0.68 \pm 0.017$

$ND_3 : P_t \approx 0.18 \pm 0.007$

Proton Elastic Asymmetry

$$A_{el} = \frac{K_1 \cos\theta^\star + K_2 \frac{G_E}{G_M} \sin\theta^\star \cos\phi^\star}{G_E^2/G_M^2 + \tau/\epsilon}$$
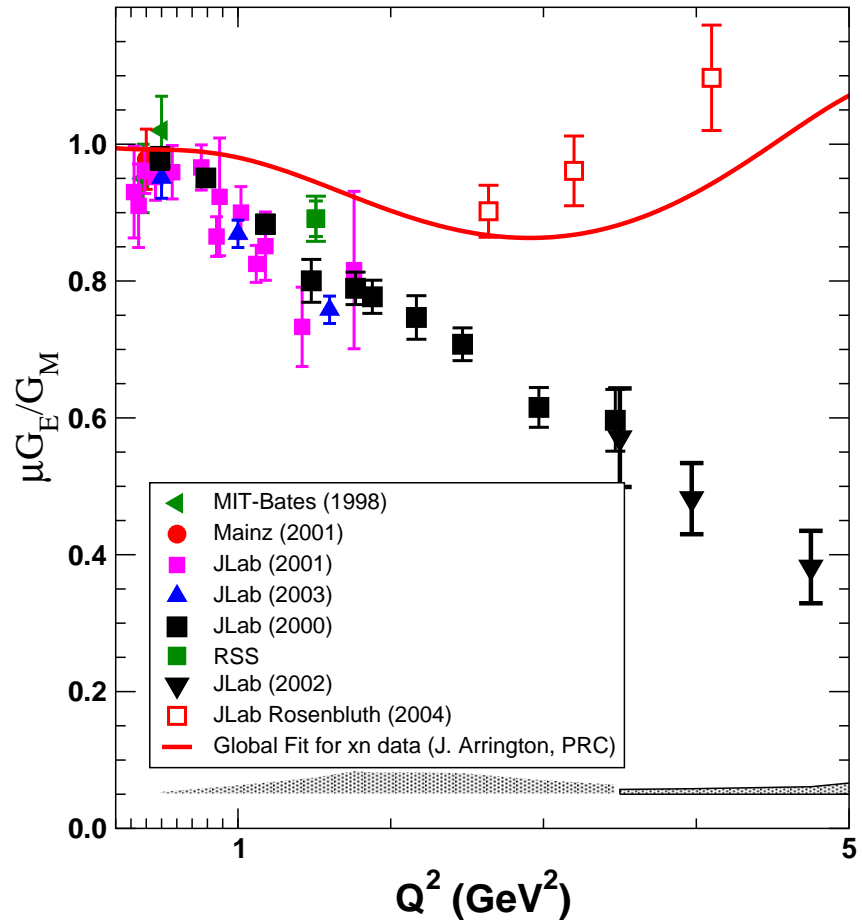
$\theta^\star, \phi^\star$ = polar and azimuthal angles
between $\vec{q}$ and target spin

K_1, K_2 = kinematic factors

Sensitivity	$\parallel$	$\perp$
$\dfrac{\Delta A_{el}/A_{el}}{\Delta \frac{G_E}{G_M}/\frac{G_E}{G_M}}$	0.02	1

● $A_\parallel$ used to determine $P_b P_t$

● $A_\perp$ measure $\dfrac{G_E}{G_M}$

Legend:
- ◀ MIT-Bates (1998)
- ● Mainz (2001)
- ■ JLab (2001)
- ▲ JLab (2003)
- ■ JLab (2000)
- ■ RSS
- ▼ JLab (2002)
- □ JLab Rosenbluth (2004)
- — Global Fit for xn data (J. Arrington, PRC)
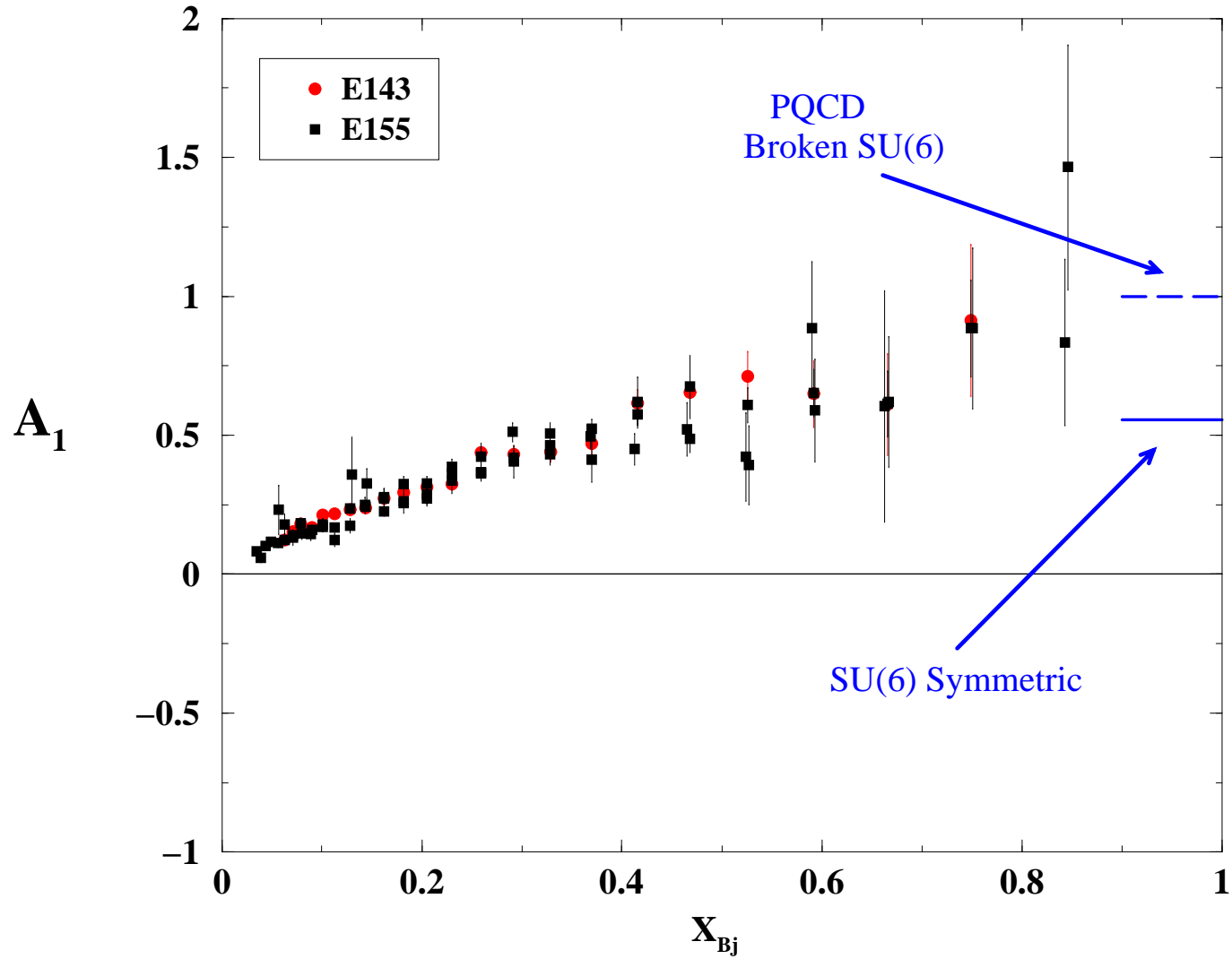
Axes: $\mu G_E/G_M$ versus Q^2 (GeV^2)

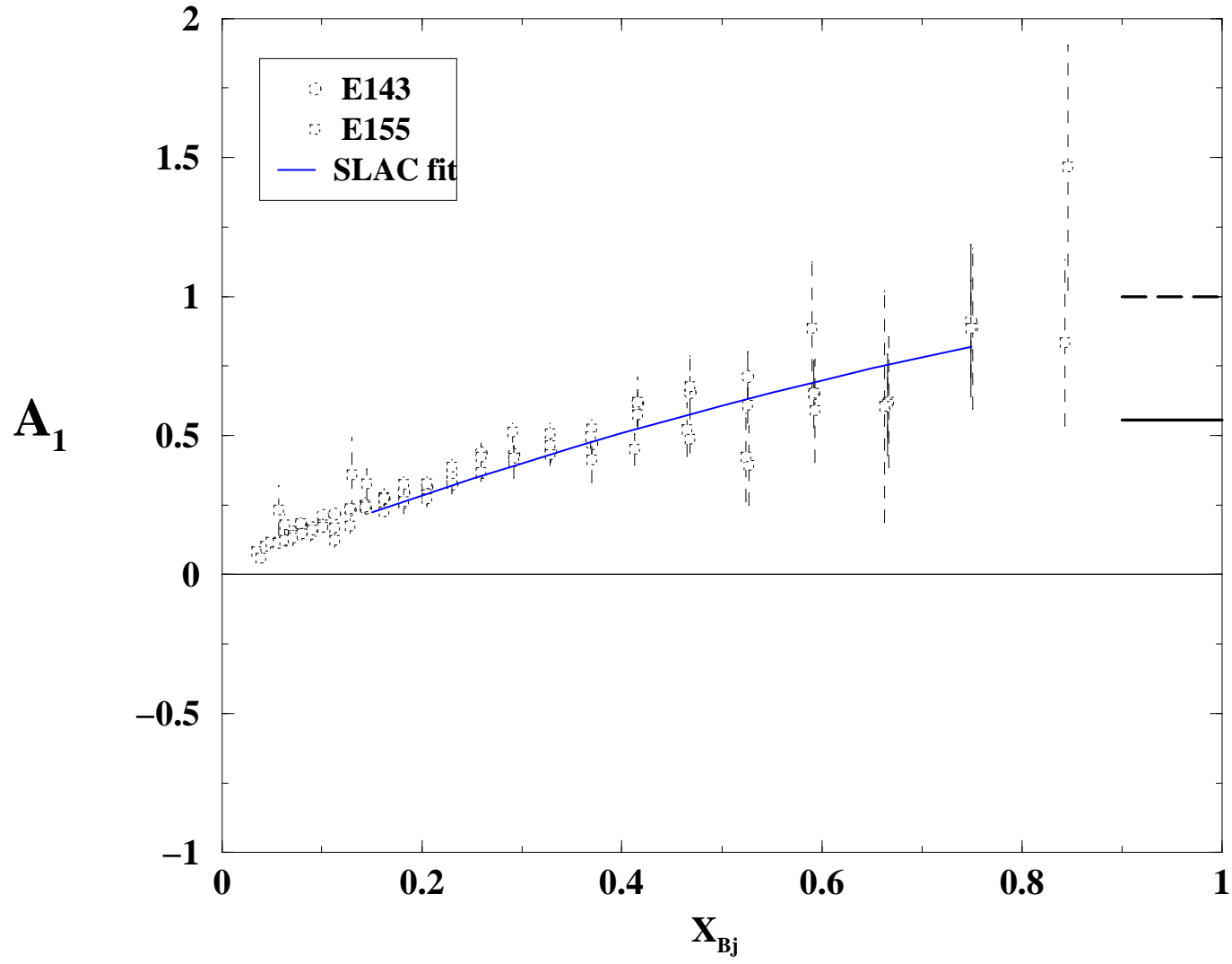# Asymmetries

Proton

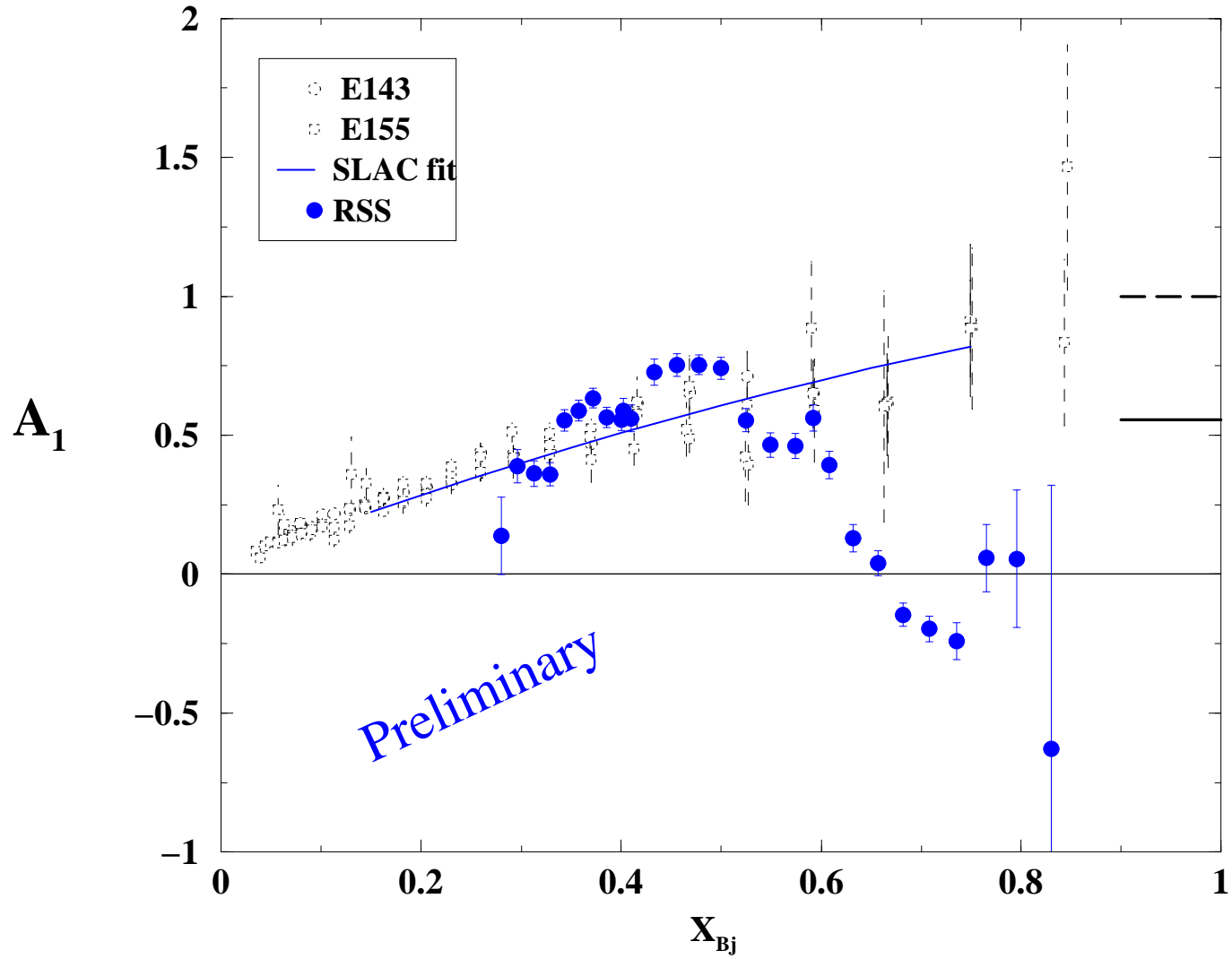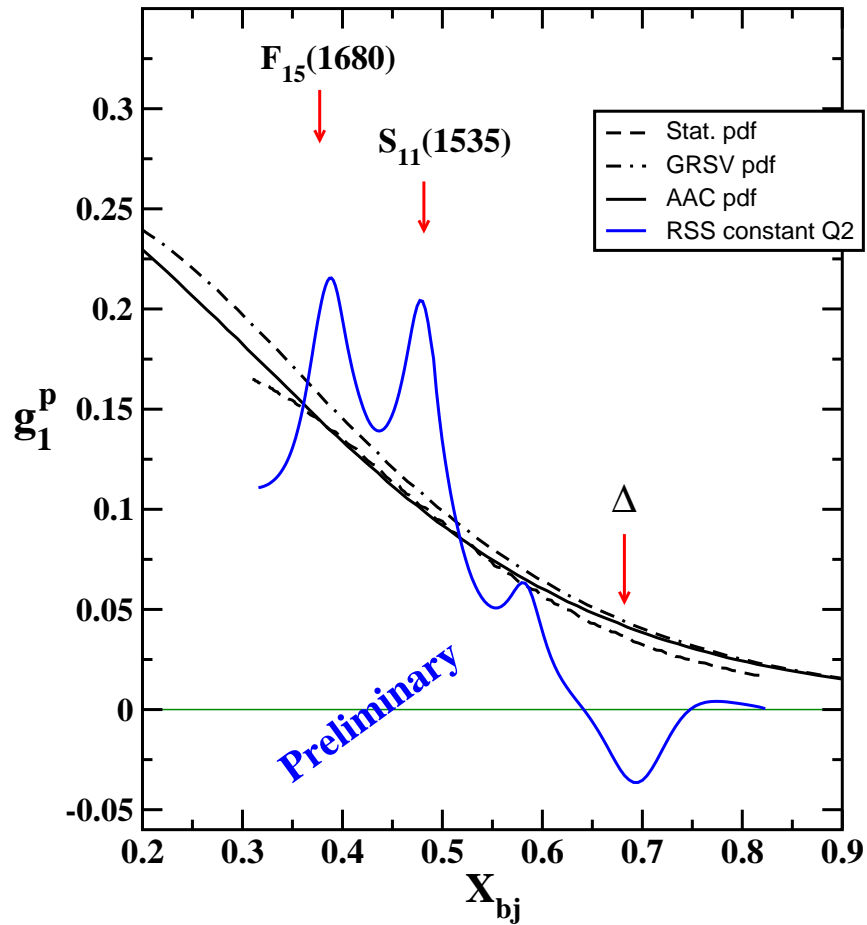Radiative Corrections Applied

Proton A_1

Proton A$_1$

Proton A_1

Proton g_1

All pdfs evolved to $Q^2 = 1.3$
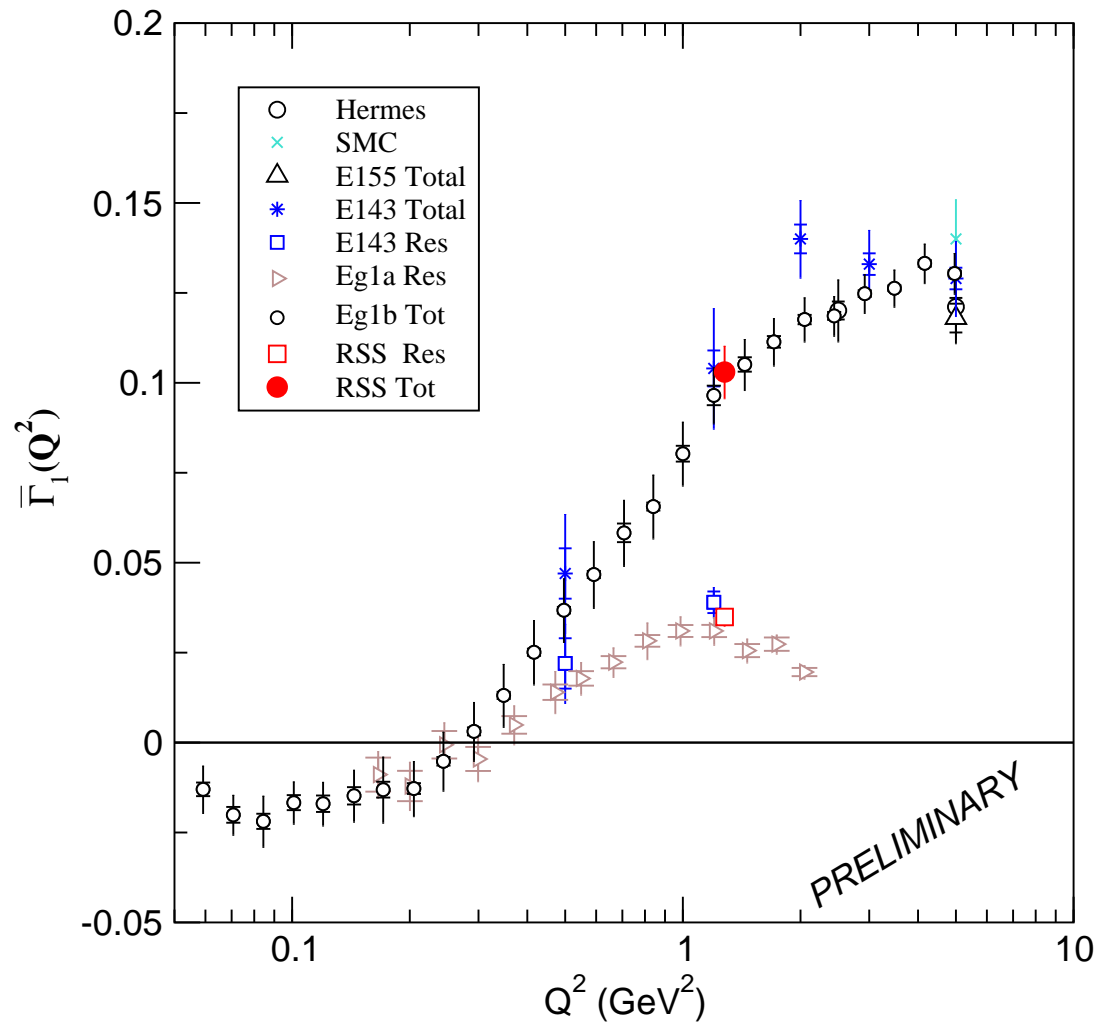
target mass corrections applied.

Integral Ratios (NEED TO UPDATE)

$$\text{Ratio} = \frac{\Gamma_1^{DIS}}{\Gamma_1^{Res}}$$
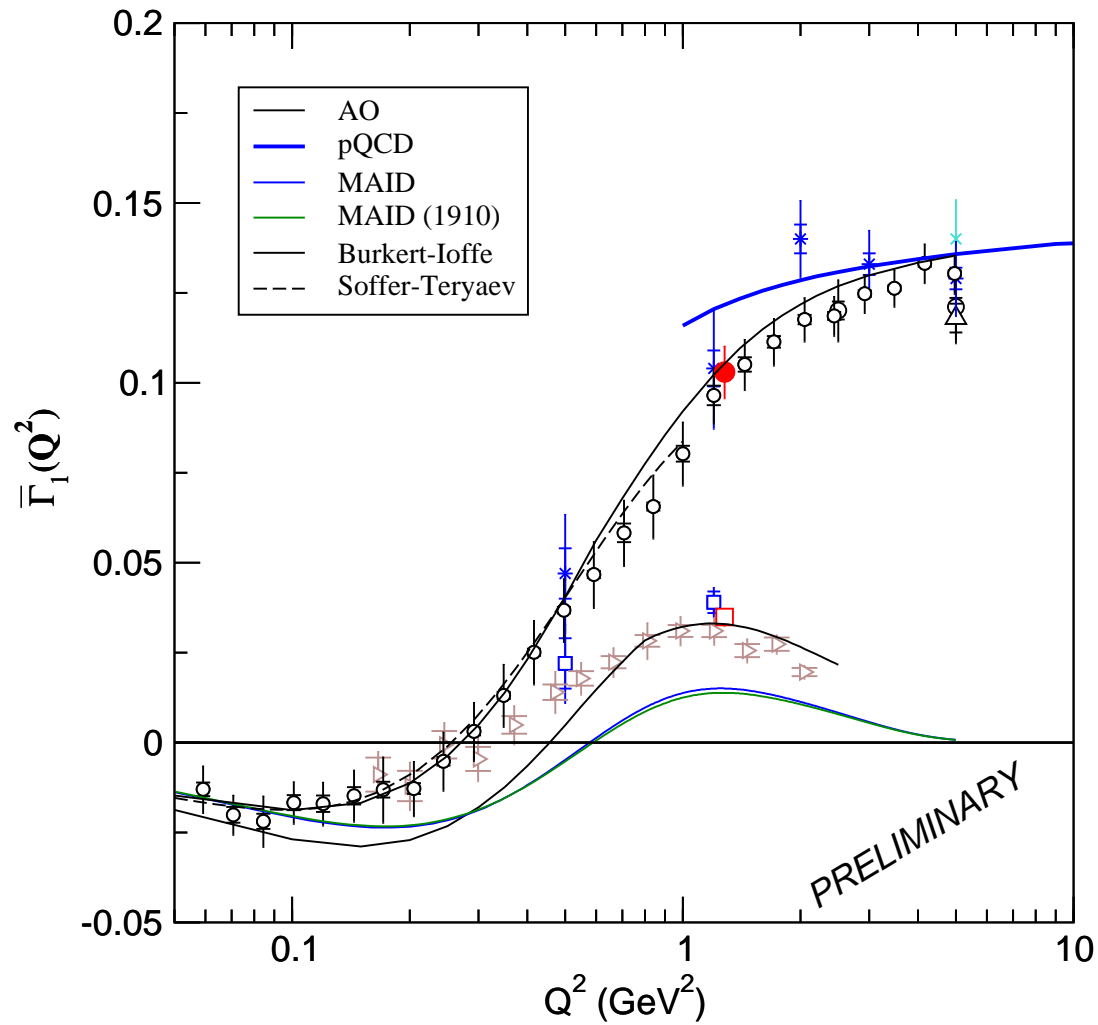
$$\Gamma_1(Q^2) = \int g_1(x, Q^2)dx$$

W	Stat PDF	GRSV1	AAC1	Ave
Global	1.10	1.22	1.13	1.16±0.06
1.12-1.31	4.18	5.09	4.82	4.79±0.78
1.31-1.39	1.23	1.36	1.27	1.30±0.07
1.39-1.68	0.76	0.80	0.74	0.77±0.04
1.68-1.79	0.76	0.82	0.75	0.78±0.04

First Moment of g_1^p
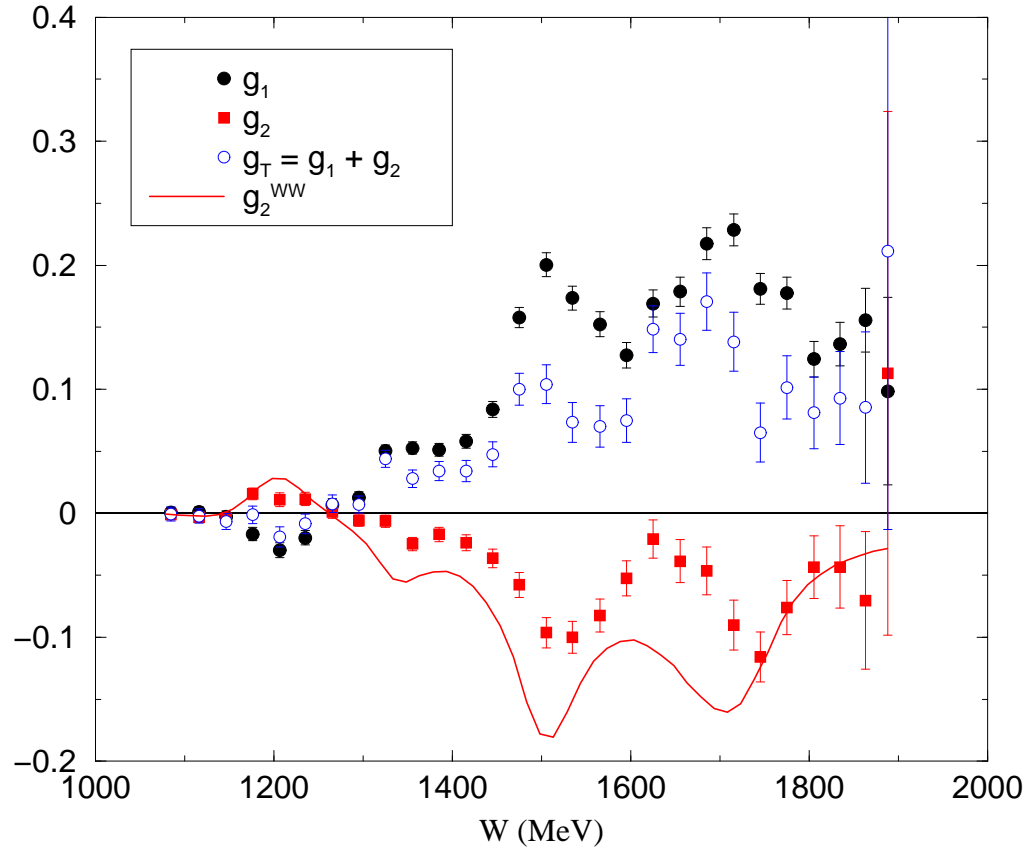

$$\Gamma_1(Q^2) = \int g_1(x, Q^2)\,dx$$

First Moment of g_1^p

$$\Gamma_1(Q^2) = \int g_1(x, Q^2)\,dx$$

Spin Structure Function $g_2(x, Q^2)$

Higher twist in g_2

$$g_2 = g_2^{\text{WW}} + \overline{g}_2$$

Twist-2 : $\quad g_2^{\text{WW}} = -g_1 + \int_x^1 \frac{g_1}{y} dy$
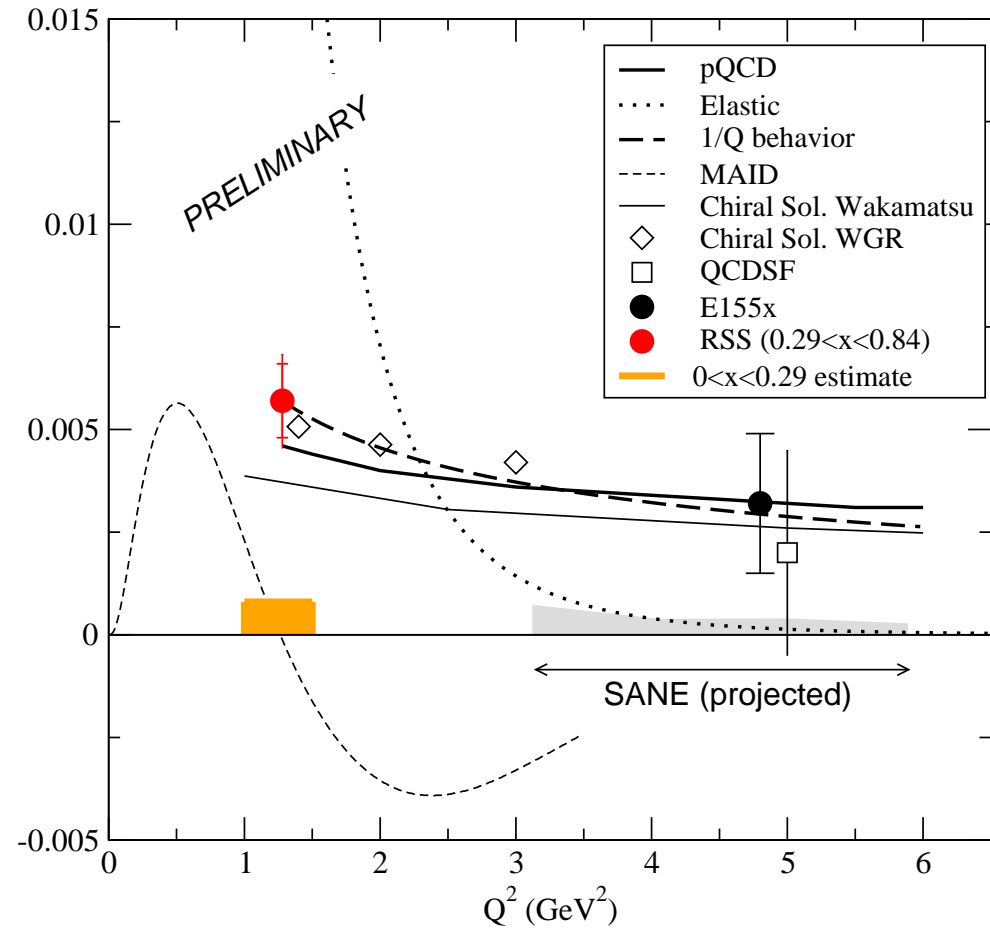
Twist-3 : d_2
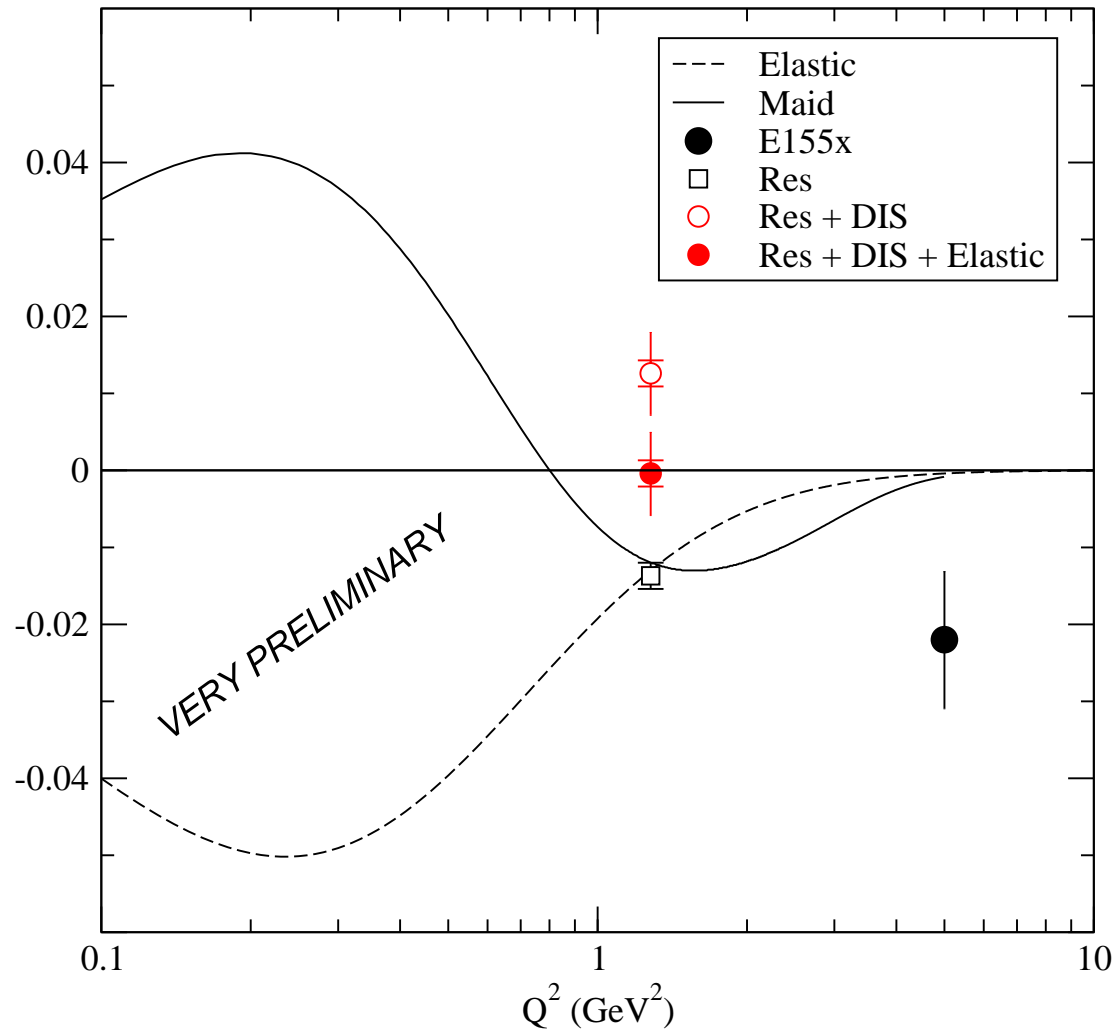
$$d_2 = 3 \int_0^1 x^2 (g_2 - g_2^{\text{WW}}) dx$$

Twist-3 : d_2

$$d_2 = 3 \int_0^1 x^2 (g_2 - g_2^{\mathrm{WW}}) dx$$

$$= 2 \int_0^1 x^2 \left(g_1 + \frac{3}{2} g_2 \right) dx$$

PRELIMINARY

Legend:
- pQCD
- Elastic
- 1/Q behavior
- MAID
- Chiral Sol. Wakamatsu
- ◇ Chiral Sol. WGR
- □ QCDSF
- ● E155x
- ● RSS (0.29<x<0.84)
- 0<x<0.29 estimate
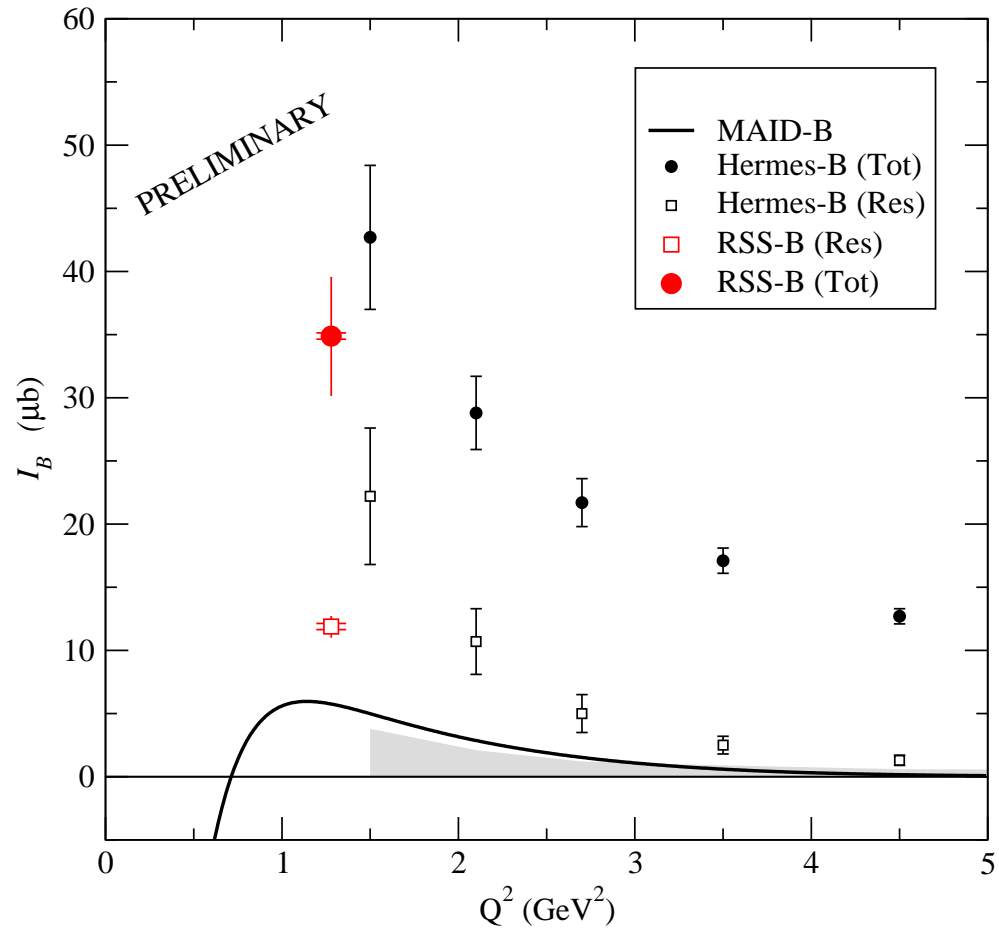
SANE (projected)

Q^2 (GeV^2)

Burkhart-Cottingham Sum Rule

$$\Gamma_2(Q^2) = \int g_2(x, Q^2)dx = 0$$

Extended GDH Sum

$$I_B = \frac{8\pi^2 \alpha}{M} \int_0^{x_0} \frac{g_1 - \gamma^2 g_2}{\nu} \frac{dx}{x}$$

Deuteron results

Neuteron extraction

RSS Summary

Measured proton/deuteron $A_\parallel$ and $A_\perp$.

$Q^2 \approx 1.3$ and $0.8 < W < 1.9$

Phys. Rev. Lett. 98, 132003 (2007)

Test of polarized duality at $Q^2 \approx 1.3$ GeV^2

Local Duality

- Violated strongly in the Delta region.
- Violated at 20%-30% level in the other resonances.

Global Duality

- Violated at 16% level