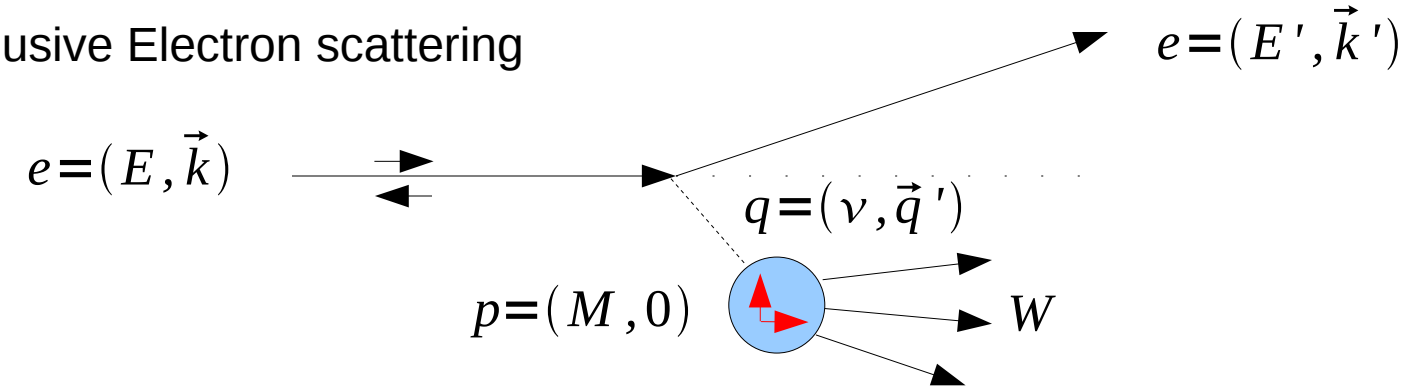
Spin Structure Function Measurements in Hall C at Jefferson Lab

Stephen Wood
For the RSS and SANE collaborations

November 10, 2008

Spin Structure Functions

Inclusive Electron scattering



$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}\left[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\frac{\theta}{2}\right]$$

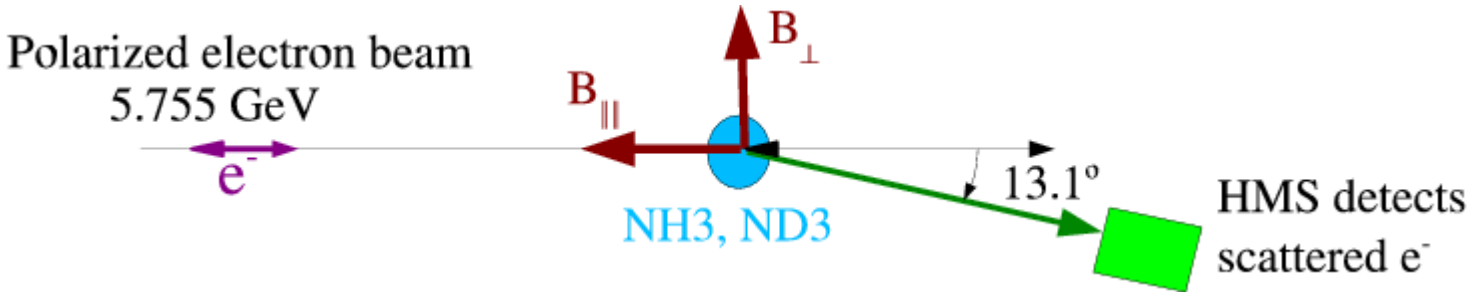
$$\frac{d^2\sigma^{\uparrow\Uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Uparrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\left[(E+E'\cos\theta)g_1(x,Q^2) - 2Mxg_2(x,Q^2)\right]$$

$$\frac{d^2\sigma^{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Rightarrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\sin\theta\left[g_1(x,Q^2) + \frac{2ME}{\nu}g_2(x,Q^2)\right]$$

Parallel and perpendicular target orientations needed to extract g_1 & g_2

Resonant Spin Structure

Of the Proton and Deuteron



Q2 ~ 1.3 GeV2, focus on resonance region

Spin SF g1 & g2 on proton and deuteron

Global and local polarized duality

Twist-3 effects

E01-006: Mark Jones (Jlab), Oscar Rondon (UVA)

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

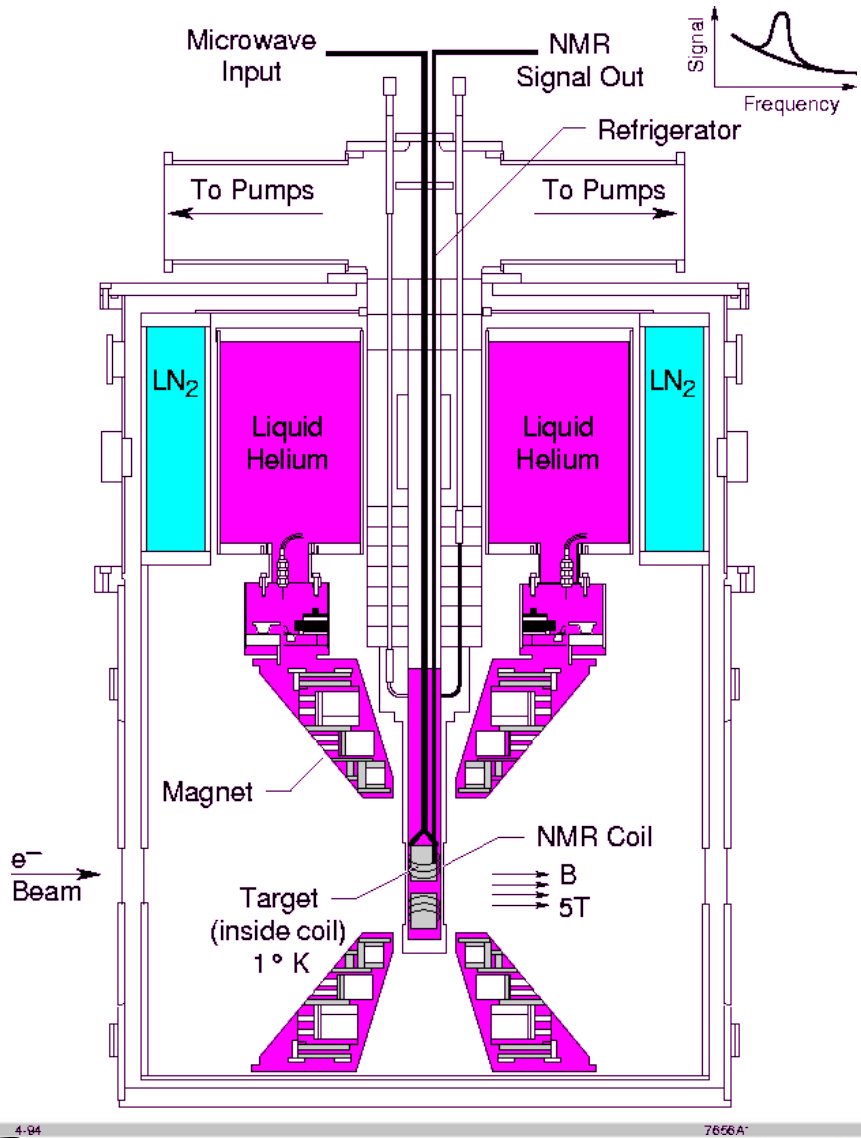
UVA Polarized Target

Target

- Frozen ND_3, NH_3, LiD
- ^{4}He evaporation refrigerator
- 5T polarizing field
- Dynamic nuclear polarization
- Polarization ∥ or ⊥ to beam
- Pre-target chicane for ⊥ polarization
- Open geometry

Experiments @ JLab

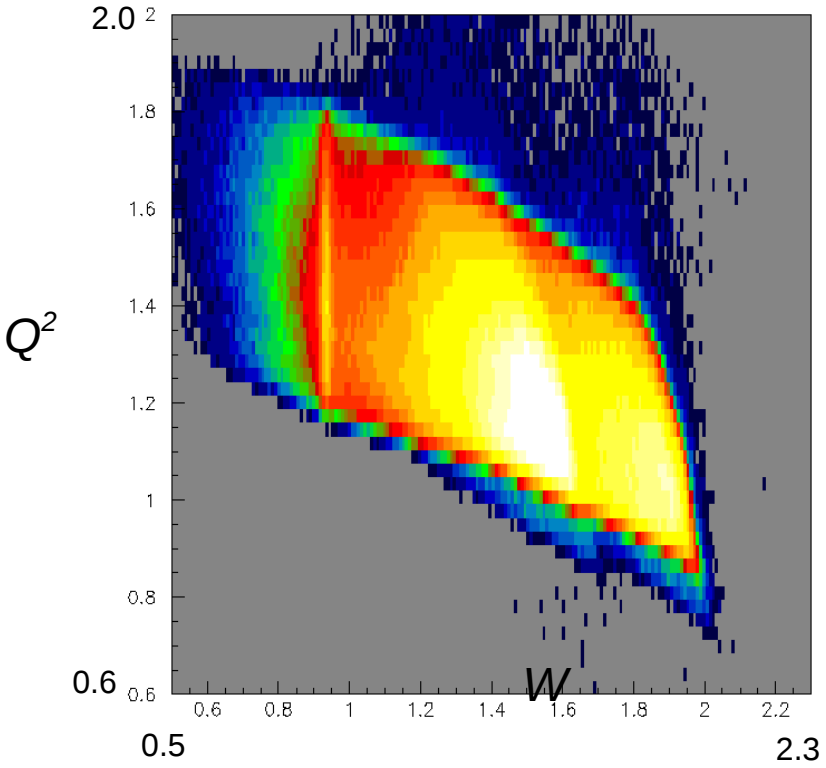
- Neutron Form Factor
- Resonance Spin Structure (g_1, g_2 on p and d @ Q^2 = 1.3 GeV^2)
- SANE: g_1, g_2 Q^2 = 4.5 GeV^2



RSS Kinematics

- Beam Energy 5.755 GeV
- HMS spectrometer
  - 13.15^{o}
  - P_0 4.71 GeV/c, 4.08 GeV/c
- Mass Range:
  - W: Elastic - 2.0 GeV
- $\langle Q^2 \rangle$ = 1.28 [GeV/c]^2
- 160 M proton events

  350 M deuteron events



Asymmetries

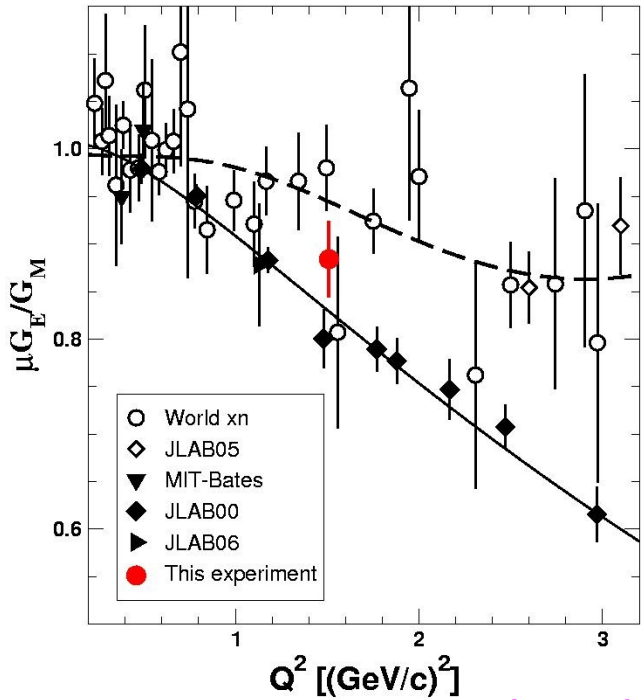
$$\epsilon = (N^- - N^+)/(N^- + N^+)$$

$$A_{\parallel,\perp} = \left(\frac{\epsilon}{f\, P_b\, P_t\, C_N} + C_D\right) + A_{rc}$$

- N^-, N^+ = Yields from +/- beam helicities
- P_b = beam polarization ~ 70%
- P_t = target polarization
  - NH3 ~ 70%
  - ND3 ~ 20%
- f = dilution from N, He
- C_N,C_D = polarized nucleons in N
- A_{rc} = radiative corrections

Proton elastic, $A_{\parallel}$ insensitive To G_E/G_M. Cross check on $P_b P_t$.

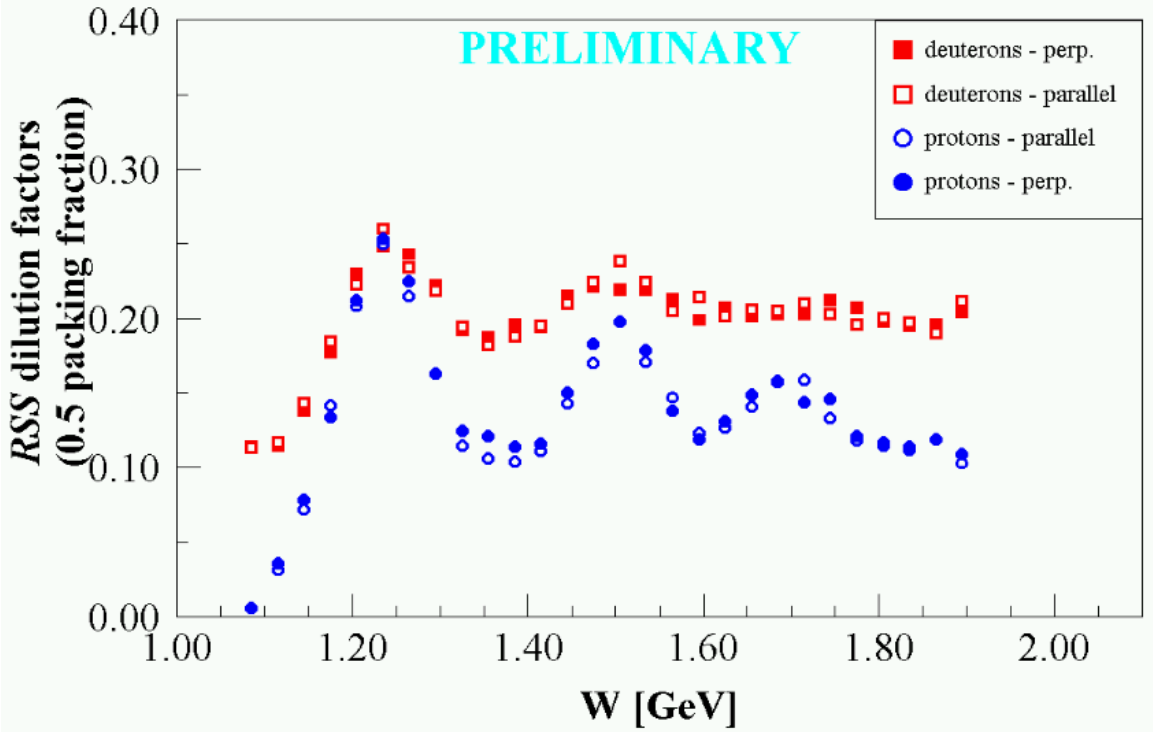
$A_{\perp}$ sensitive to G_E/G_M



PRC 74, 035201 (2006)

Dilution factor

- Scattering from unpolarized nuclei in target reduce asymmetries by factor of 5-10.
- *W* dependent due to resonance structure



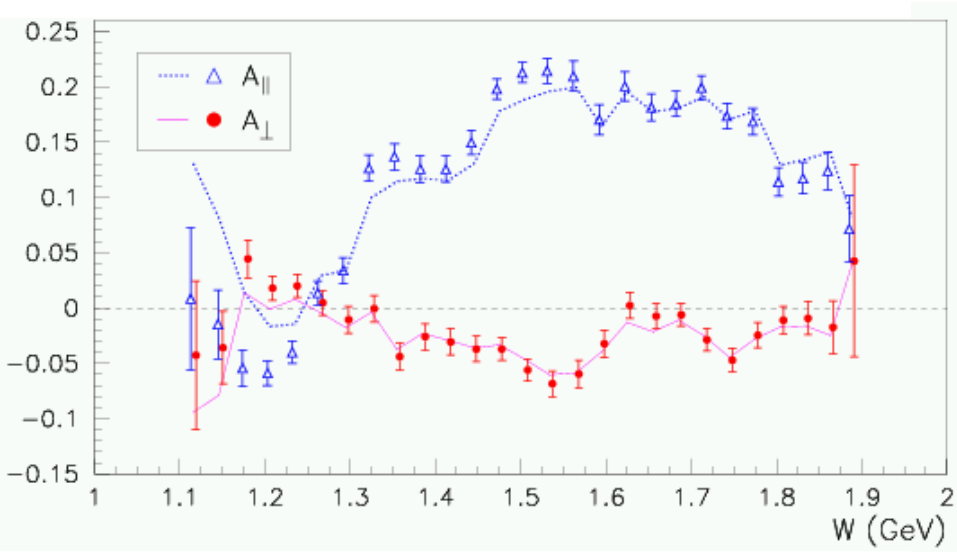
Proton Spin Asymmetries A_1, A_2

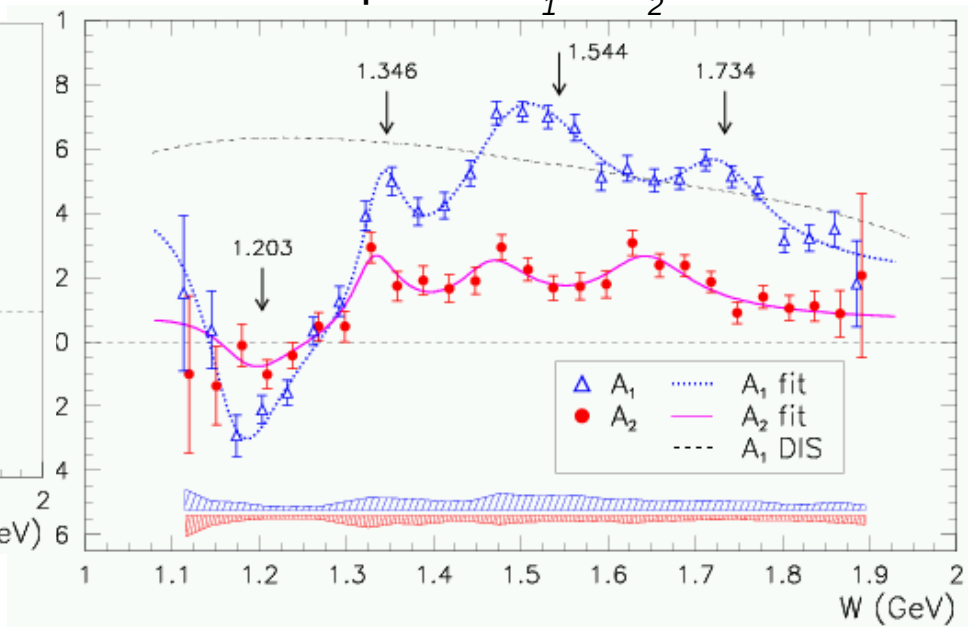
$$A_1 = \frac{1}{(E+E')D'}\left((E - E'\cos\theta)A_{\parallel} - \frac{E'\sin\theta}{\cos\phi}A_{\perp}\right)$$

$$A_2 = \frac{\sqrt{Q^2}}{2ED'}\left(A_{\parallel} + \frac{E - E'\cos\theta}{E'\sin\theta\cos\phi}A_{\perp}\right)$$

D' based on kinematics and F_1 & *R* from Christy/Bosted fits to e-p and e-d data

$A_{\perp}$ gives unique ability to separate A_1 & A_2





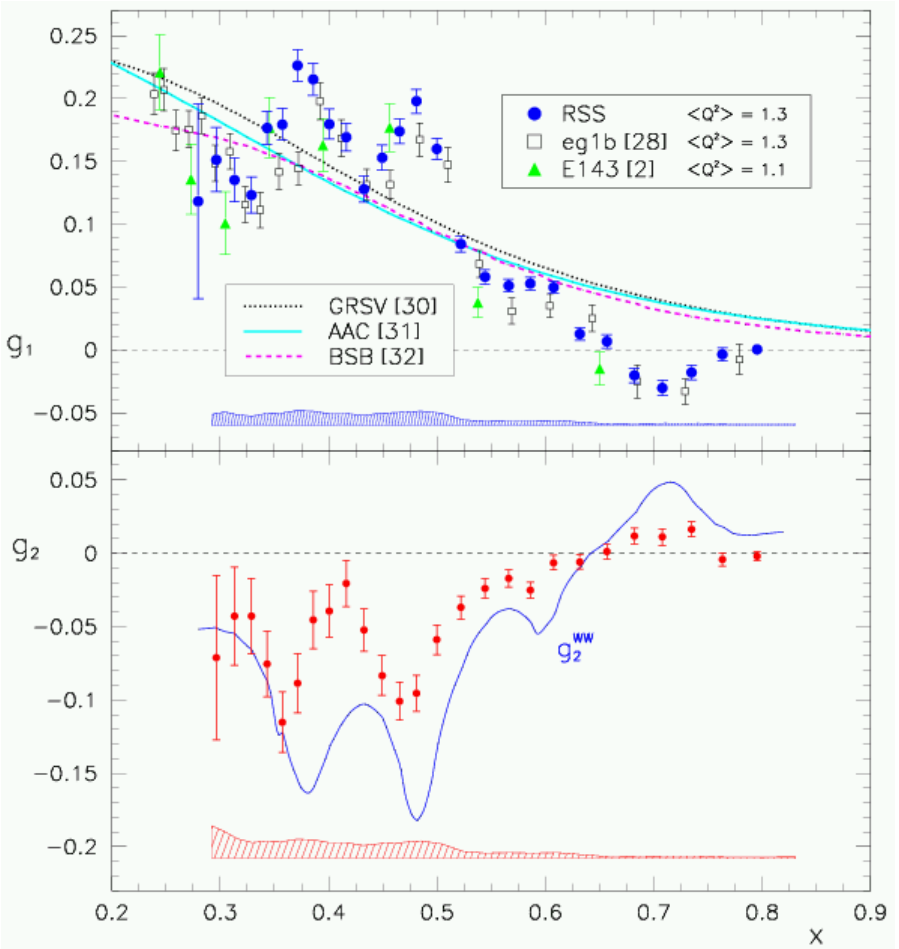
Proton

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

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

- Approximate global polarized Bloom-Gilman duality for resonance region
- Local duality (individual resonances does not hold at this Q^2
- Twist-3 contribution to g_2

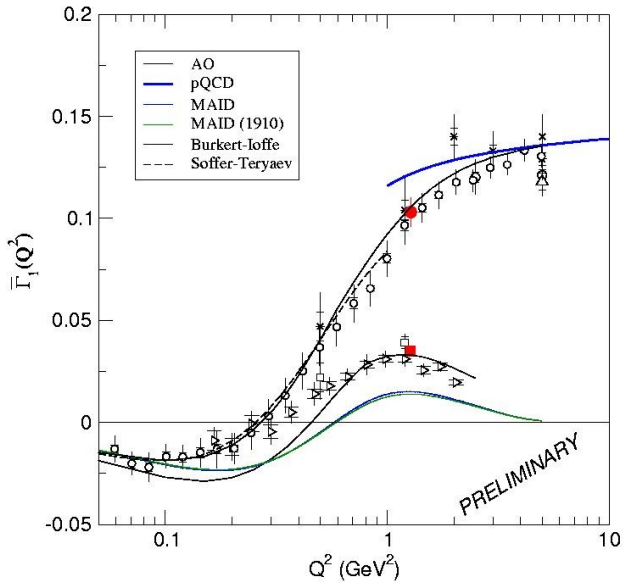
$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 g_1(y,Q^2)\frac{dy}{y}$$



Proton Sum Rules

- First moment of g_1

$$\overline{\Gamma_1}(Q^2) = \int_0^{1-el} g_1(x, Q^2)\,dx$$

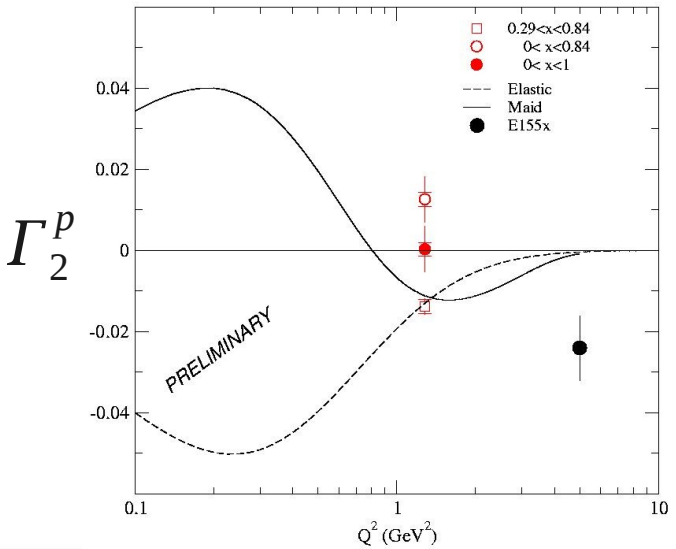


- First moment of g_2

  (Burkhardt-Cottingham)

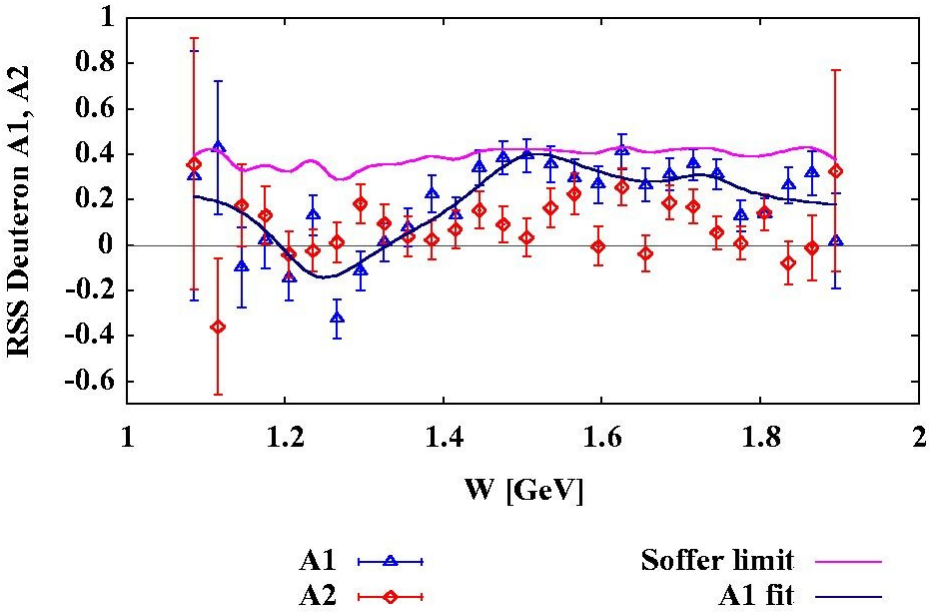
$$\Gamma_2(Q^2) = \int_0^1 g_2(x, Q^2)\,dx = 0$$

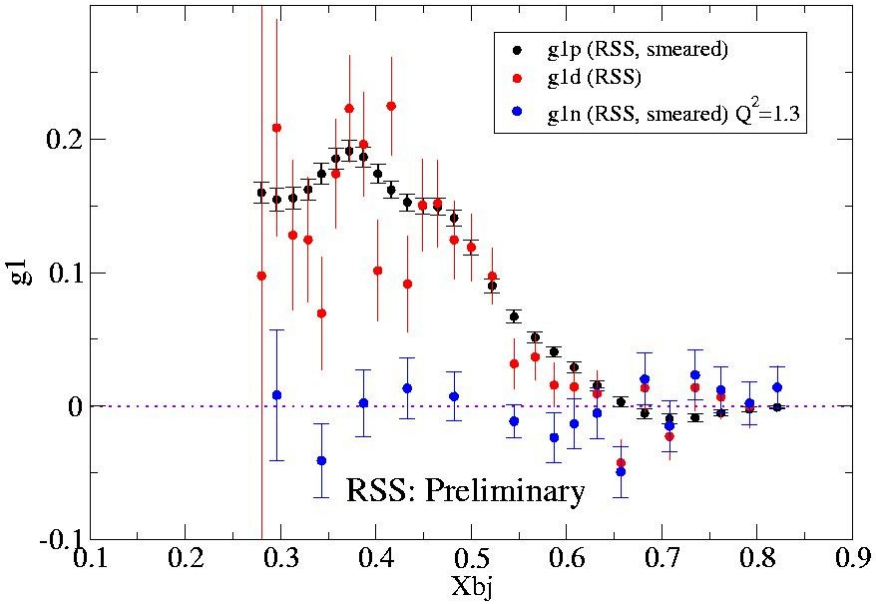
Resonance, DIS, elastic cancel



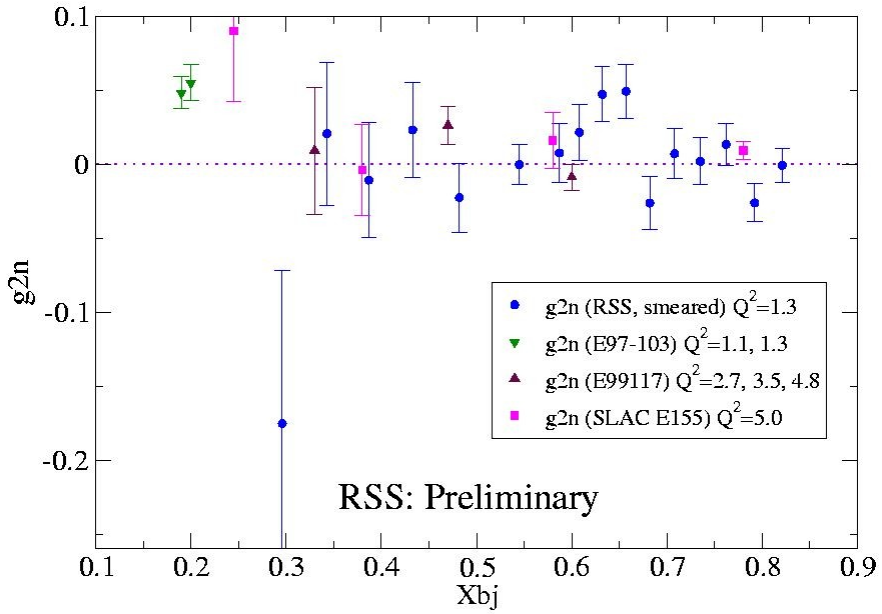
Deuteron

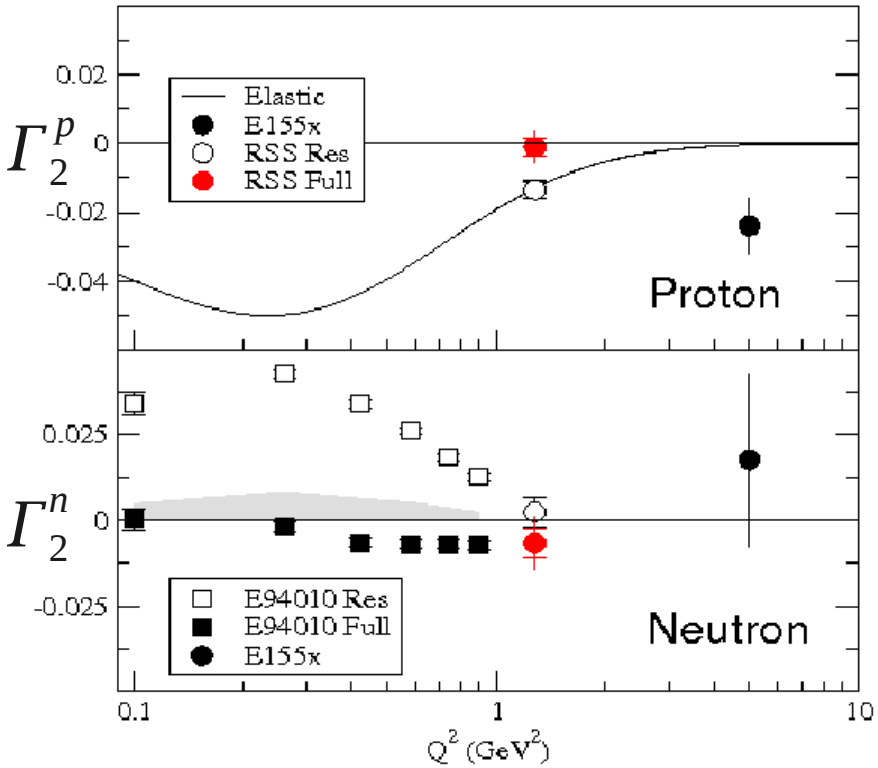
- Obtain neutron g_1, g_2 by subtracting smeared g_1^p, g_2^p from g_1^d, g_2^d





Neutron g_2


g2n
Xbj
RSS: Preliminary
g2n (RSS, smeared) Q²=1.3
g2n (E97-103) Q²=1.1, 1.3
g2n (E99117) Q²=2.7, 3.5, 4.8
g2n (SLAC E155) Q²=5.0


Elastic
E155x
RSS Res
RSS Full
Proton
E94010 Res
E94010 Full
E155x
Neutron
Q² (GeV²)

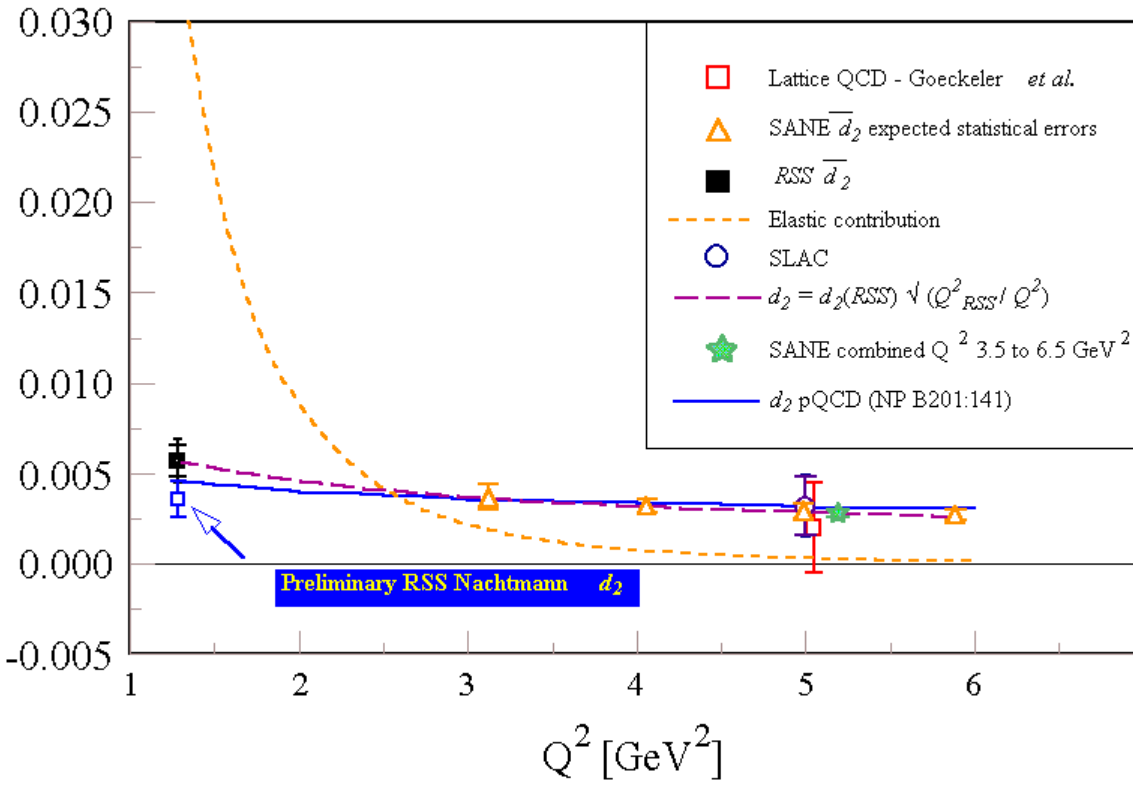
Twist-3 Matrix Element d_2

$$d_2 = \int_0^1 x^2(2g_1 + 3g_2)dx = 3\int_0^1 x^2(g_2 - g_2^{WW})dx$$

$$[\text{RSS}]\ \overline{d_2} = \int_{0.29}^{0.84} x^2(2g_1 + 3g_2)dx = 0.0057 \pm 0.0009 \pm 0.0007$$

$$d_2^{Nacht.}(Q^2) = \int_0^1 \xi^2\left(2\frac{\xi}{x}g_1 + 3\left(1 - \frac{\xi^2 M^2}{2Q^2}\right)g_2\right)dx$$

S. Matsuda and T. Uematsu, NP B168 (1980) 181



Proton

$d_2(Nachtman) = 0.0037 \pm 0.0004 \pm 0.0009$

Neutron

$d_2(Nachtman) = 0.0028 \pm 0.0035$

SANE: Spin Asymmetries on the Nucleon Experiment

Proton spin structure functions

$2.5 < Q^2 < 6.5$, $0.3 < x < 0.8$

Twist-3 effects from g1, g2 moments

Comparisons with Lattice QCD, sum rules, bag models

High – x

Test local duality for $W > 1.4$ GeV

Measure $A_{\parallel}$ and $A_{\perp}$

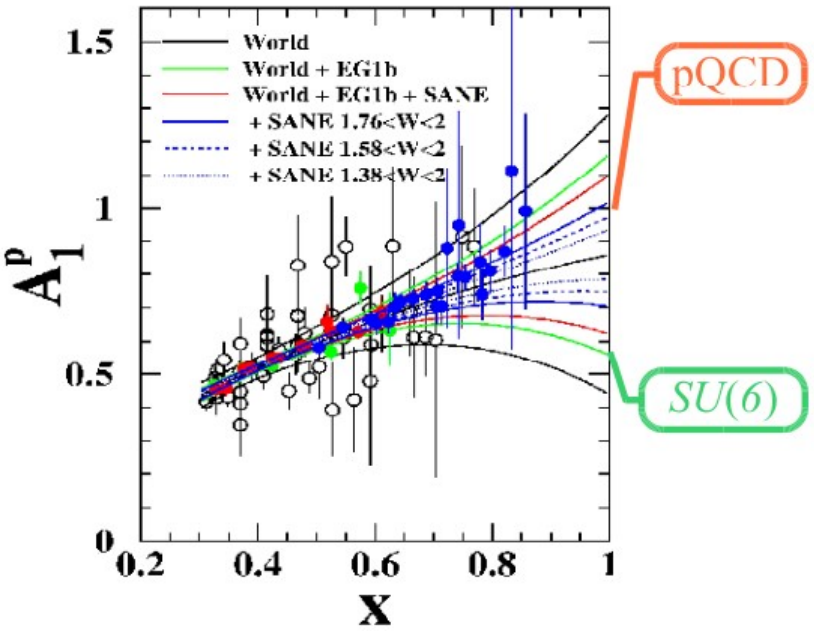
New large solid angle electron telescope BETA

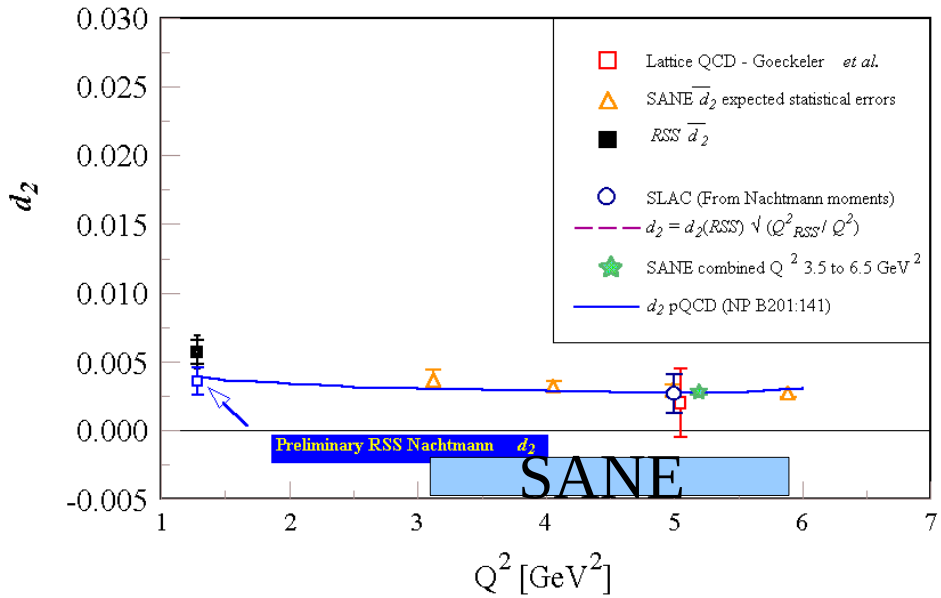
Currently starting in Hall C

E07-003: Senho Choi (Seoul U.), Mark Jones (JLab), Zein-Eddine Meziani (Temple), Oscar Rondon (UVA)

U. Basel, Christopher Newport U., Florida International U., Hampton U., Jefferson Lab, Norfolk State U., Mississippi State U., Norfolk State U., North Carolina A&T U., IHEP-Protvino, U. of Regina, Renselaer Polytechnic I., Rutgers U., Seoul National U., Temple U., U. of Virginia, College of William & Mary, Yerevan Physics Institute

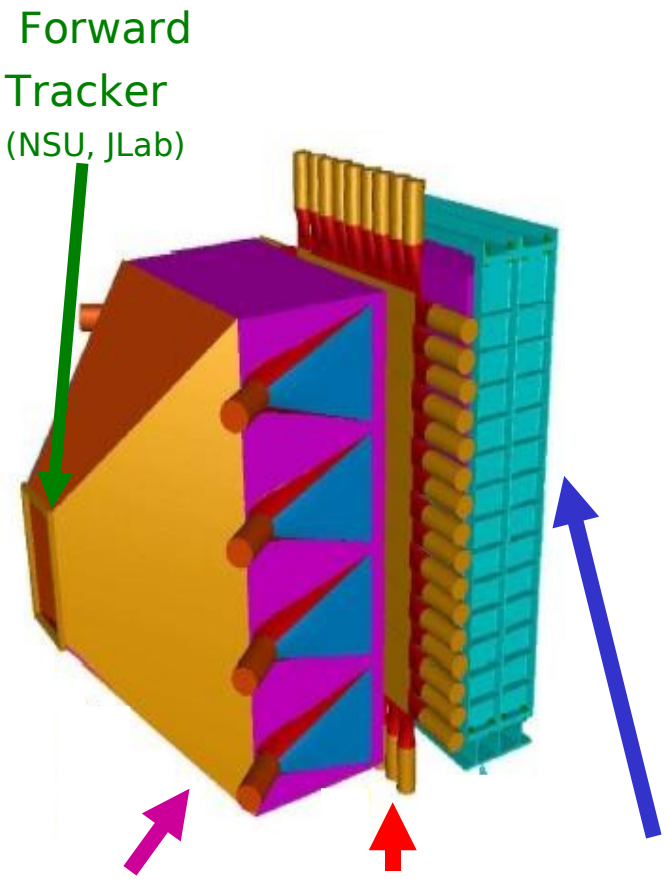
SANE expected results





- Constrain x=1 extrapolations of A_1^p +/- 0.1
- Use A2 to improve worlds A1
- High precision d_2 over broad Q^2 range

Big Electron Telescope Array

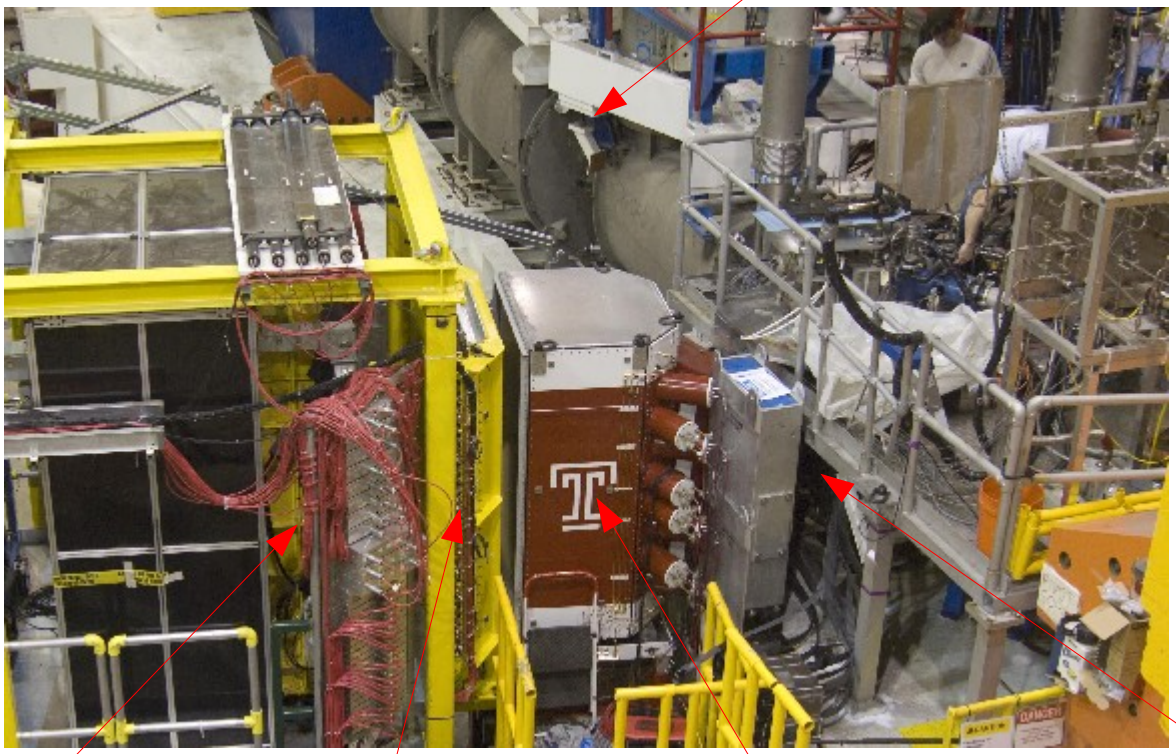


- BigCal 1744 lead glass blocks, 120x240cm x40cm

  Used recently as electron detector for high Q^2 G_{ep}
- Forward Tracker: Scintillator bars with fiber readout
- Gas Cherenkov: Pion rejection
- Lucite Bars

  Target magnetic field with positions from tracker, lucite and BigCal allow rejection of low momentum positron backgrounds

Busy Picture



Future Hall C spin structure

- Hall C 12 GeV experiments. 5-10 years.

  Polarized ^{3}He target.

  HMS - High Momentum Spectrometer

  SHMS (NEW) Super High Momentum Spectrometer

  - Neutron *A1* $3 < Q^2 < 10$ GeV^2
  - Neutron g_2, d_2 : $0.3 < x < 1$, $2.5 < Q^2 < 6.6$ GeV^2, ties onto Hall A data expected early 2009