The Resonance Spin Structure Measurement at Hall-C and the Future JLab Physics Program

Shigeyuki Tajima

University of Virginia

Topics:

1. Resonance Spin Structure Measurement
2. Spin Asymmetries on the Nucleon Experiment

Resonance Spin Structure

Jefferson Lab RSS Collaboration

Spokespersons: Oscar Rondon (U. of Virginia)
and Mark Jones (Jefferson Lab)

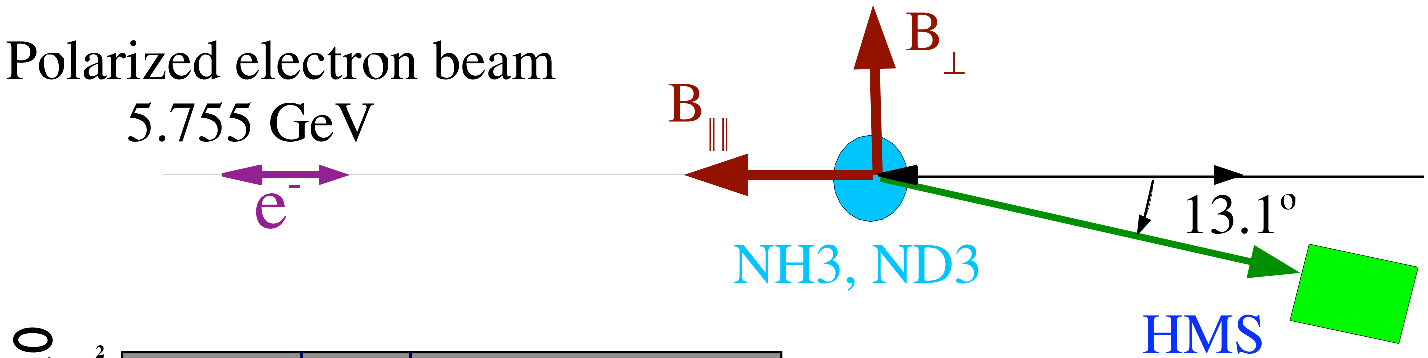
U. Basel, Florida International U., Hampton U., U. Massachusetts, U. Maryland, Mississippi S. U., North Carolina A&T U., U. of N. C. at Wilmington, Norfolk S. U., Old Dominion U., S.U. New Orleans, U. of Tel-Aviv, TJNAF, U. of Virginia, Virginia P. I. & S.U., Yerevan Physics I.

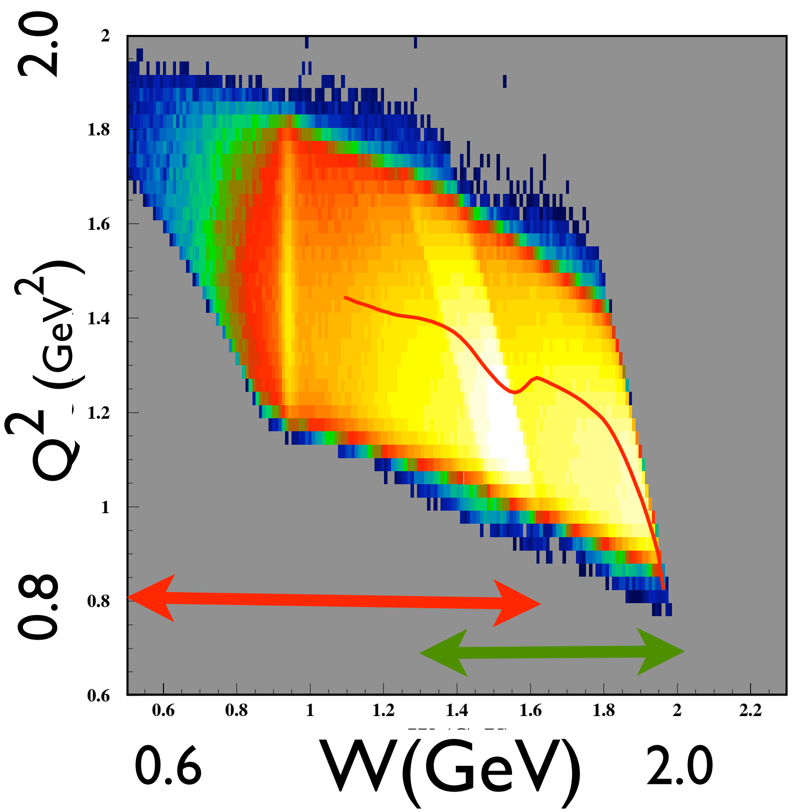
Analysis: Paul Mckee, Karl Slifer, S. Tajima, Frank Wesselmann, Junho Yun, Hongguo Zhu, (Peter Bosted, Eric Christy)

The physics goals

- Measure proton and deuteron $A_1(W,Q^2)$ and $A_2(W,Q^2)$ in the nucleon resonance region $(0.8 < W < 2.0)$ at $Q^2 \sim 1.3\,GeV^2$
- Extract polarized structure functions g_1 and g_2 and study
  i. W-dependence
  ii. Onset of polarized local duality
  iii. Twist-3 effects in d_2 matrix element

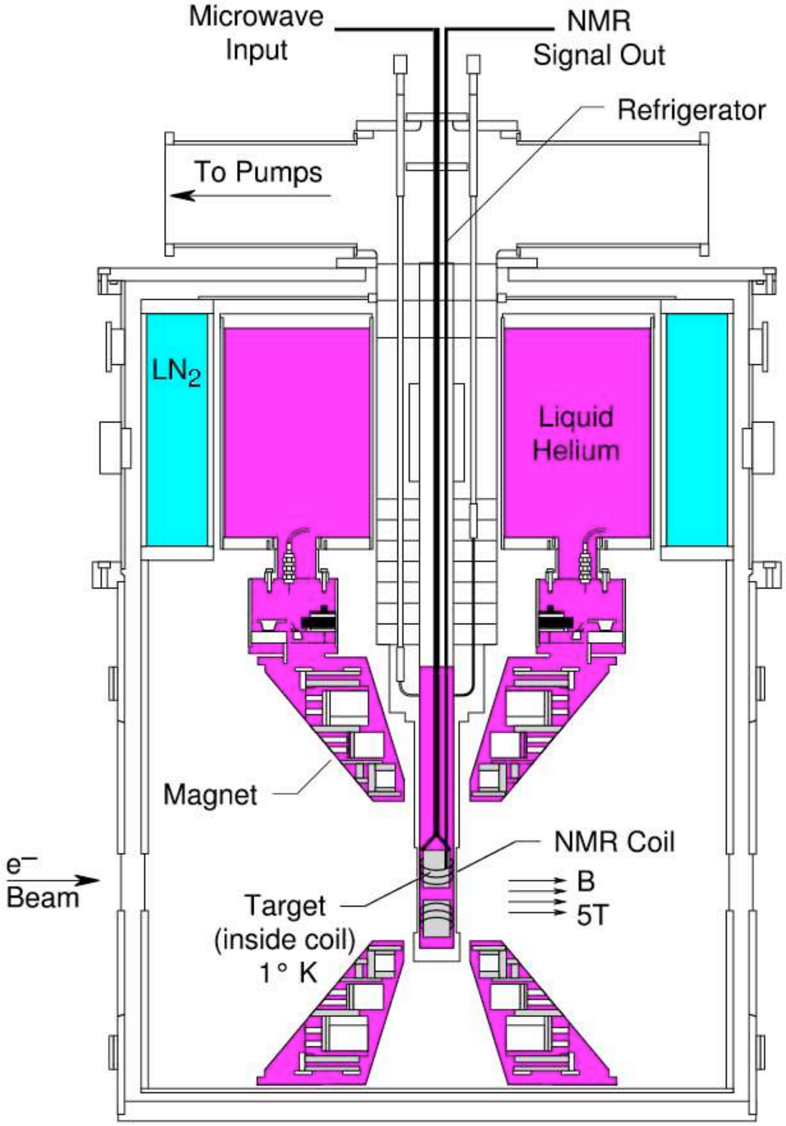
RSS Experiment in Hall C at JLab





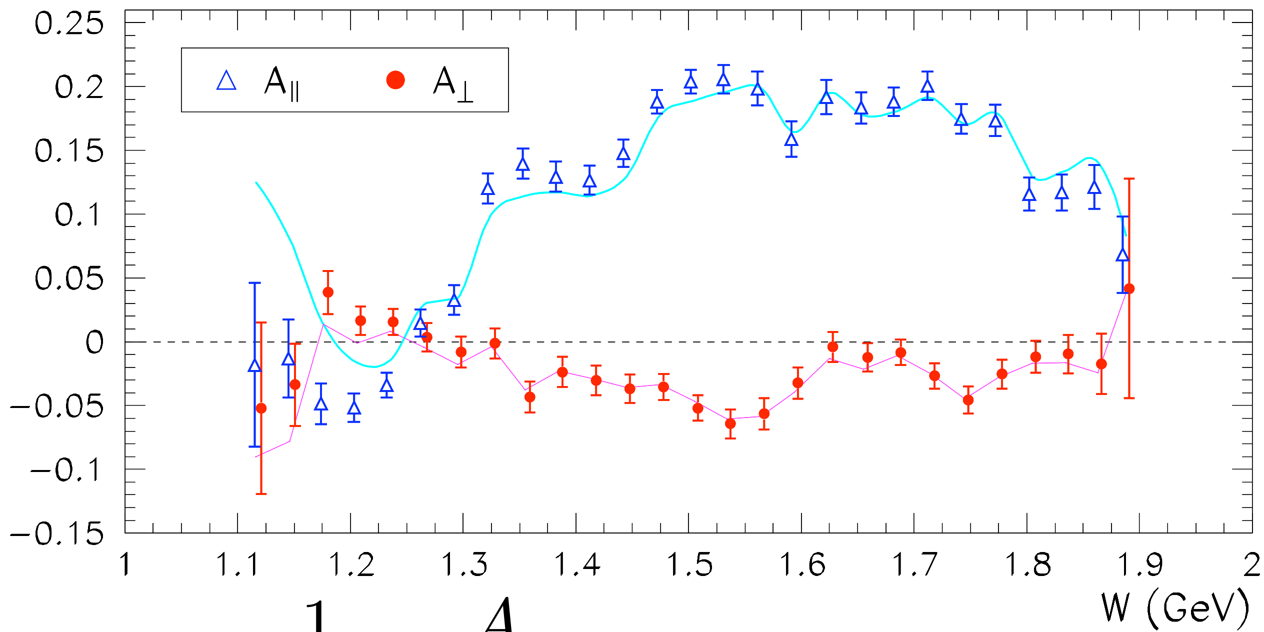
- HMS detects scattered electrons. Momentum settings: 4.7 , 4.1 GeV/c
- $\langle Q^2 \rangle = 1.3\ GeV^2$, $0.8 < W < 2.0$ GeV
- I ~ 100nA for NH_3 and ND_3
- Beam Polarization (P_B) by Moller:
  - $P_B = 65.5 \pm 2.6$ (%) for $B_{||}$
  - $P_B = 70.9 \pm 1.7$ (%) for $B_{\perp}$
- Beam charge asym. < 0.1%

Polarized Targets ($^{15}NH_3$ and $^{15}ND_3$)



- Dynamic Nuclear polarized ammonia
- Target ladder contained carbon disc (7mm thick) and two NH_3 (or ND_3) cups
- 5T Field on target. Magnetic field was either parallel or perpendicular to beam direction.
- Polarization can be flipped by 180°. Ran ± for equal times
- Average target polarization
  P_T =68 % (NH_3); 18 % (ND_3)
- Relative systematic error ~2.9%

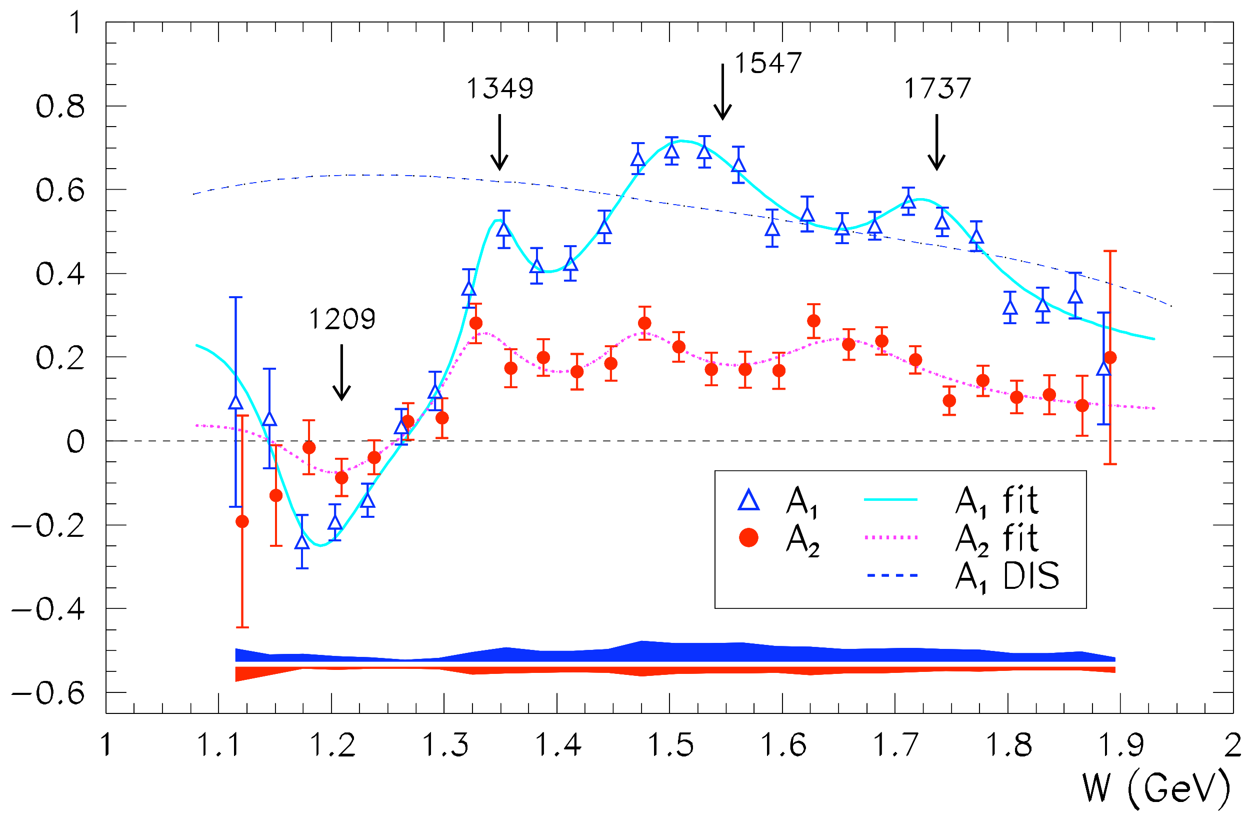
Proton $A_\parallel$ and $A_\perp$ versus W



$$A_{\parallel,\perp} = \frac{1}{C_N f_{rc}} \cdot \frac{A_{raw}}{f P_B P_T} + A_{rc}$$

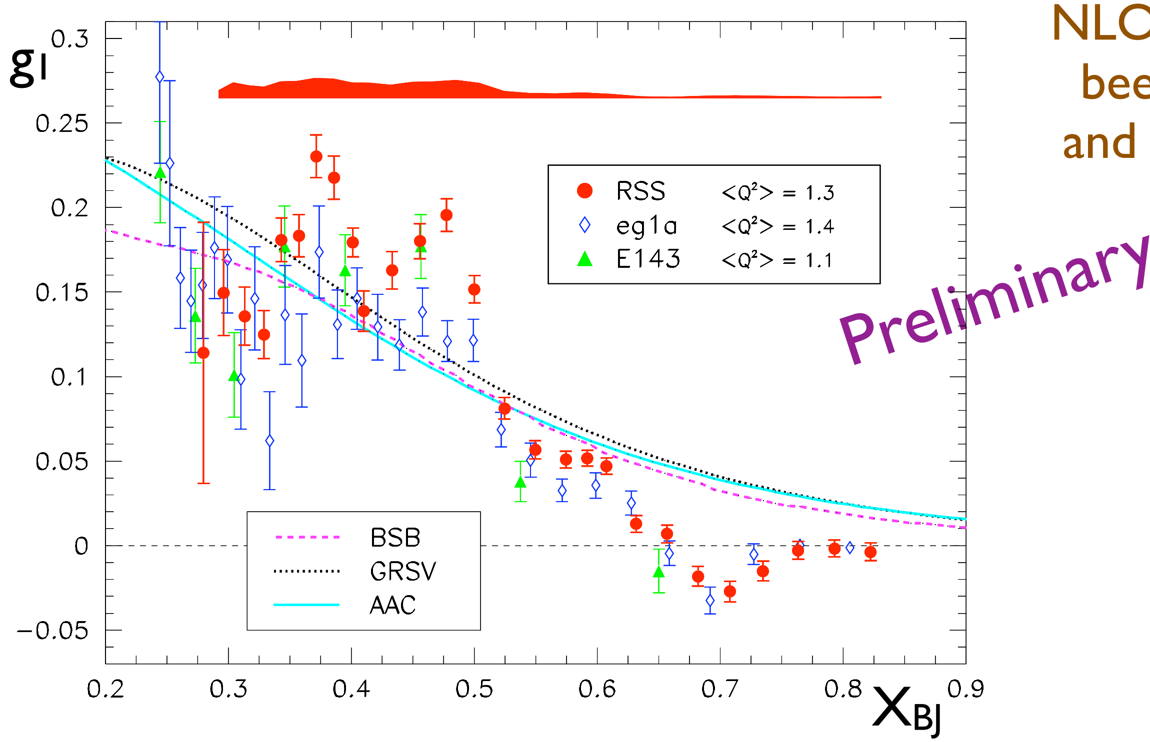
- A_{raw}= raw asym (counts are normalized by the charge and deadtime)
- f = dilution factor; P_B, P_T = beam and target polarizations
- C_N = corrections for ^{15}N asymmetry
- f_{rc} , A_{rc} = radiative corrections.
  POLRAD (Akusevich et al.) modified to include a fit to our data.

Proton A_1 and A_2 versus W



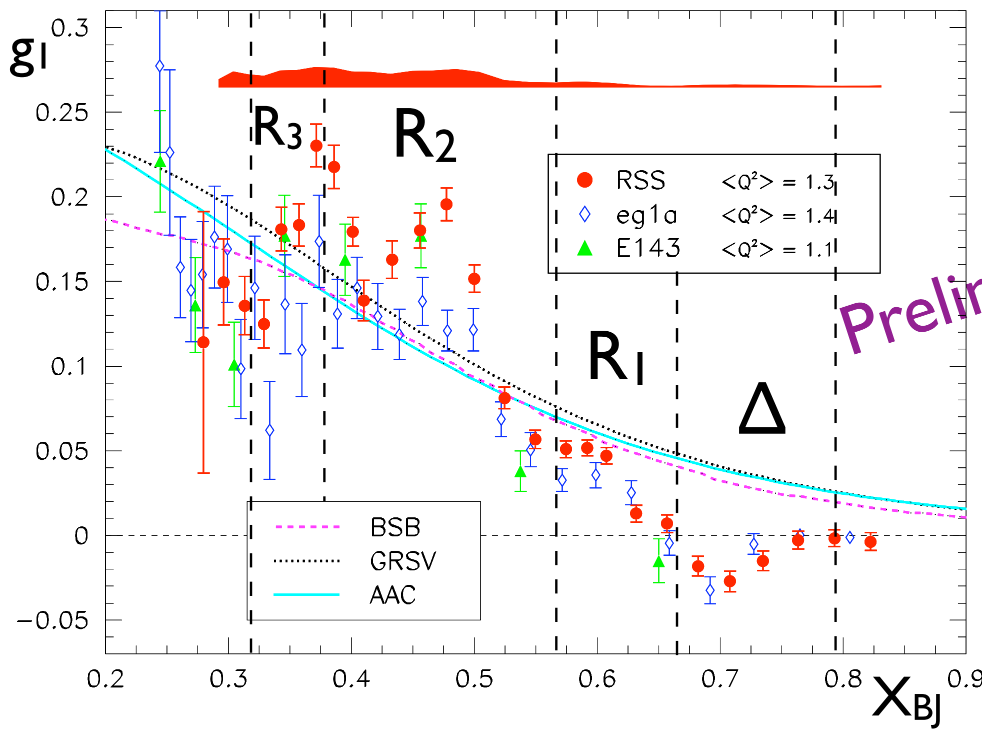
- A_1 and A_2 are extracted from $A_{||}$ and $A_{\perp}$ using Hall C F_2 and R fits by E. Christy

Proton g_1 and Study of Polarized Duality



NLO PDFs (BSB, GRSV, AAC) have been evolved to $Q^2 = 1.3\ GeV^2$, and have target mass corrections.

Proton g_1 and Study of Polarized Duality

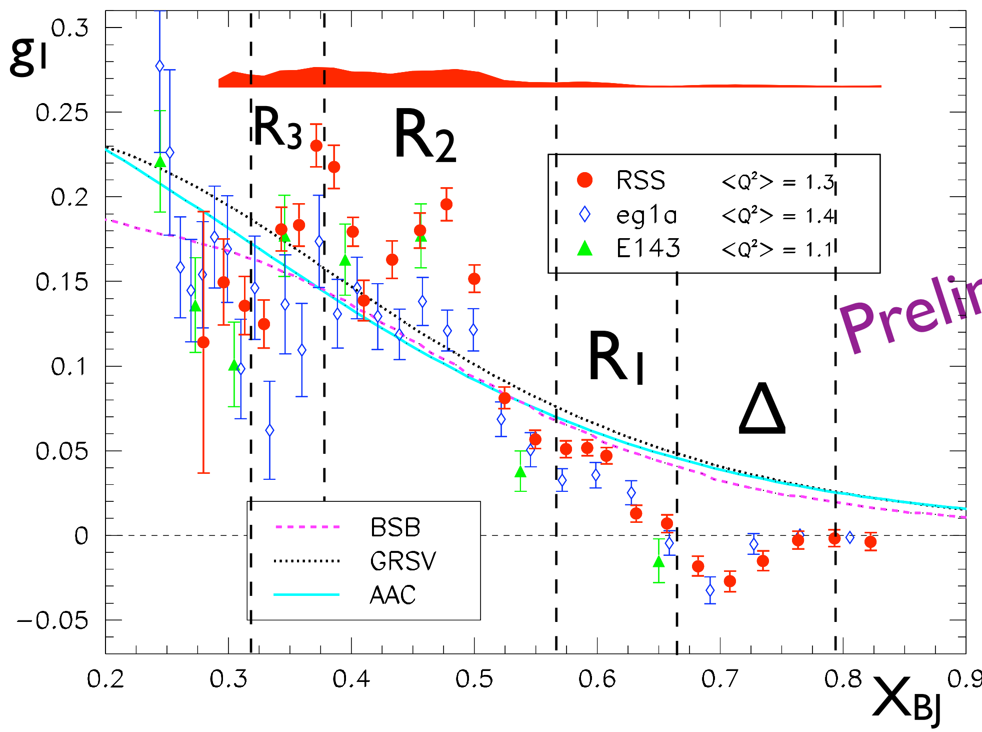


NLO PDFs (BSB, GRSV, AAC) have been evolved to $Q^2 = 1.3$ GeV^2, and have target mass corrections.

	W range	Ratio of Integrals (PDF and data fit)
Delta	1.12--1.30	4.80 ± 0.68
R1	1.30--1.40	1.34 ± 0.07
R2	1.40--1.69	0.78 ± 0.04
R3	1.69--1.81	0.84 ± 0.04
Global	1.08--1.91	1.17 ± 0.06

- Quoted errors are for the data only. Phenomenology systematics for the PDFs (±0.06 for the global ratio) needs to be added.

Proton g_1 and Study of Polarized Duality



NLO PDFs (BSB, GRSV, AAC) have been evolved to $Q^2 = 1.3$ GeV^2, and have target mass corrections.

Preliminary

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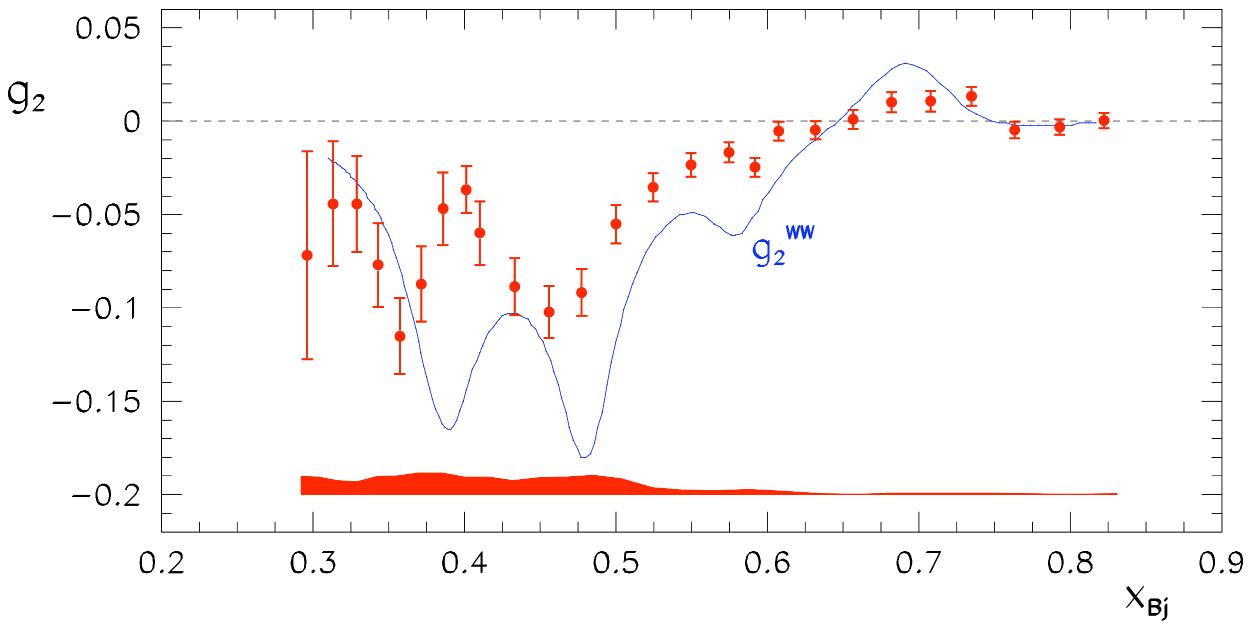
- Quoted errors are for the data only. Phenomenology systematics for the PDFs (±0.06 for the global ratio) needs to be added.
- Local duality is not observed in proton g_1 at $Q^2 = 1.3$ GeV^2
- The global ratio becomes 1.42 ±0.07 if large-x resummations for the PDFs (Bianchi et al, PRD 69, 014505 (2004)) are included.

Proton g_2 and Higher Twist

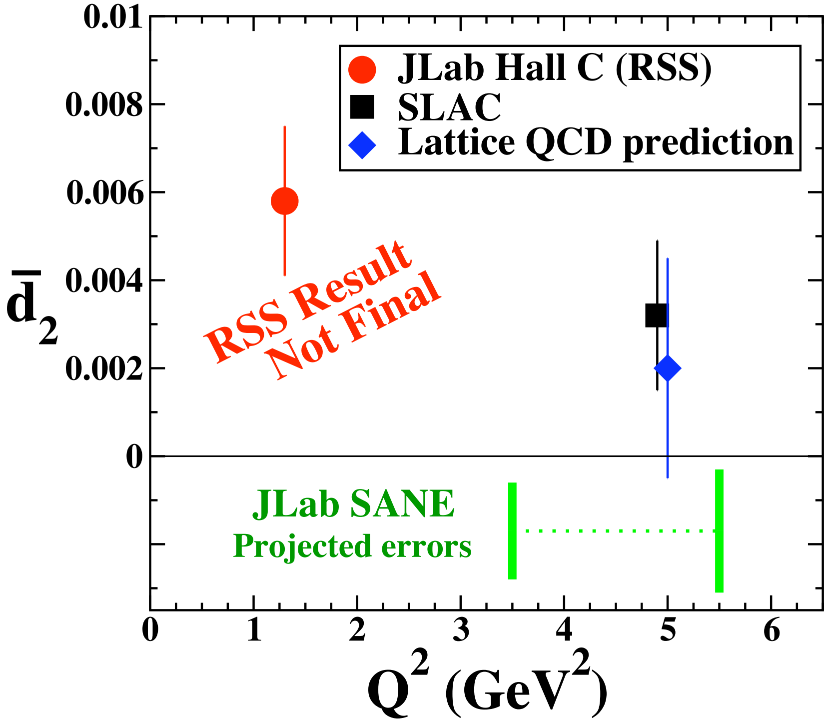


$$g_2 = g_2^{WW} + \bar{g}_2; \quad \text{Twist 2}: g_2^{WW}(x, Q^2) = -g_1(x, Q^2) + \int_x^1 \frac{dy}{y} g_1(y, Q^2)$$

- Use measured g_1 to calculate g_2^{WW}

Twist-3 Matrix Element d_2

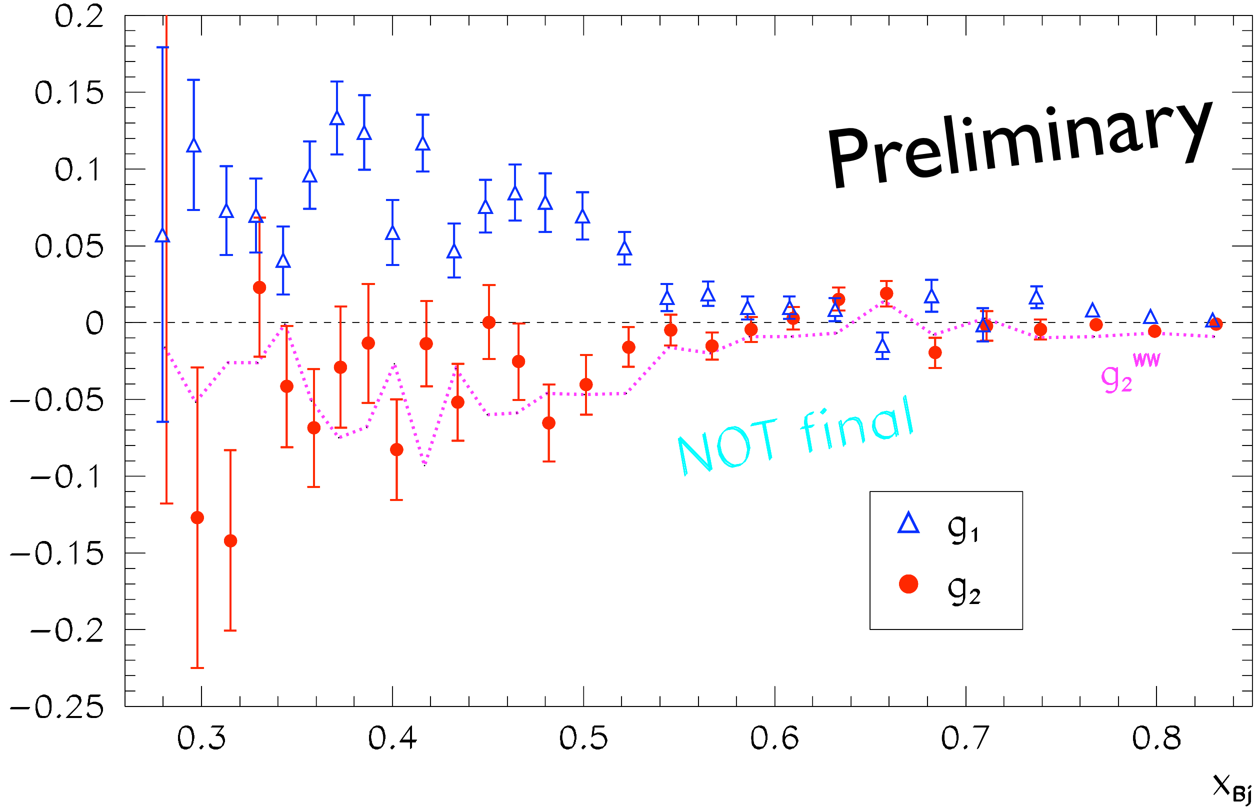
$$d_2 = \int_0^1 2x^2(g_1 + \frac{3}{2}g_2)dx$$



Experiment	Q^2	Note
JLab RSS	1.3	0.29< x <0.84
SLAC E-155	5.0	
LQCD Calc.	5.0	Göckeler et al, PRD72, 054507 (2005)
JLab SANE	3, 4, 5, 6	Data taking in 2008 Expected error is better than ±0.0012

Elastic contribution is large at Q^2 =1.3 (d_2_elas=0.03) but it's small at Q^2 =5.0 (d_2_elas=0.00013).

Deuteron g_1 and g_2 versus x



- All corrections are applied except for the radiative corrections.

Spin Asymmetries on the Nucleon Experiment

Jefferson Lab SANE Collaboration

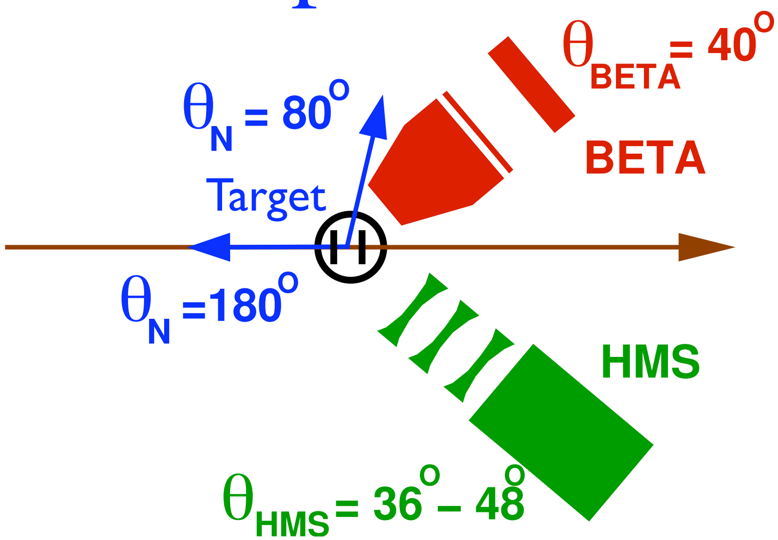
(Spokespersons: Oscar Rondon (U. of Virginia),
Zein-Eddine Meziani (Temple), Seonho Choi (Seoul))

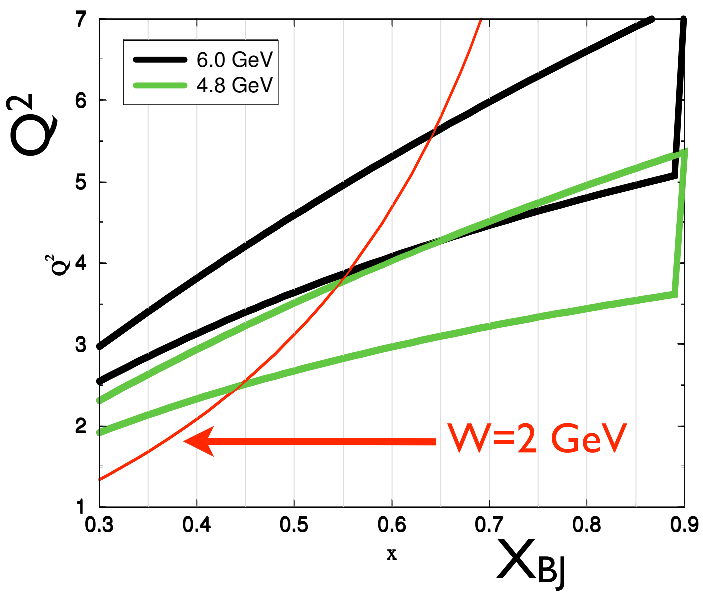
Basel, F.I.U, Hampton, IHEP Protvino, Kent State, Norfolk State,
N.C. A&T, Renesselaer Polytechnic, St. Norbert, Temple, TJNAF,
University of Virginia, William&Mary, Yerevan

- Measure proton A_1 and g_2 with large acceptance detector (BETA) in range $2.5 < Q^2 < 6.5$ and $0.3 < x < 0.8$
- Study x and Q^2 dependence, Twist-3 effect, moments of g_2 and g_1, Test polarized local duality for $W > 1.4$
- Will take data in Hall C at JLab in 2008

Experimental Setup

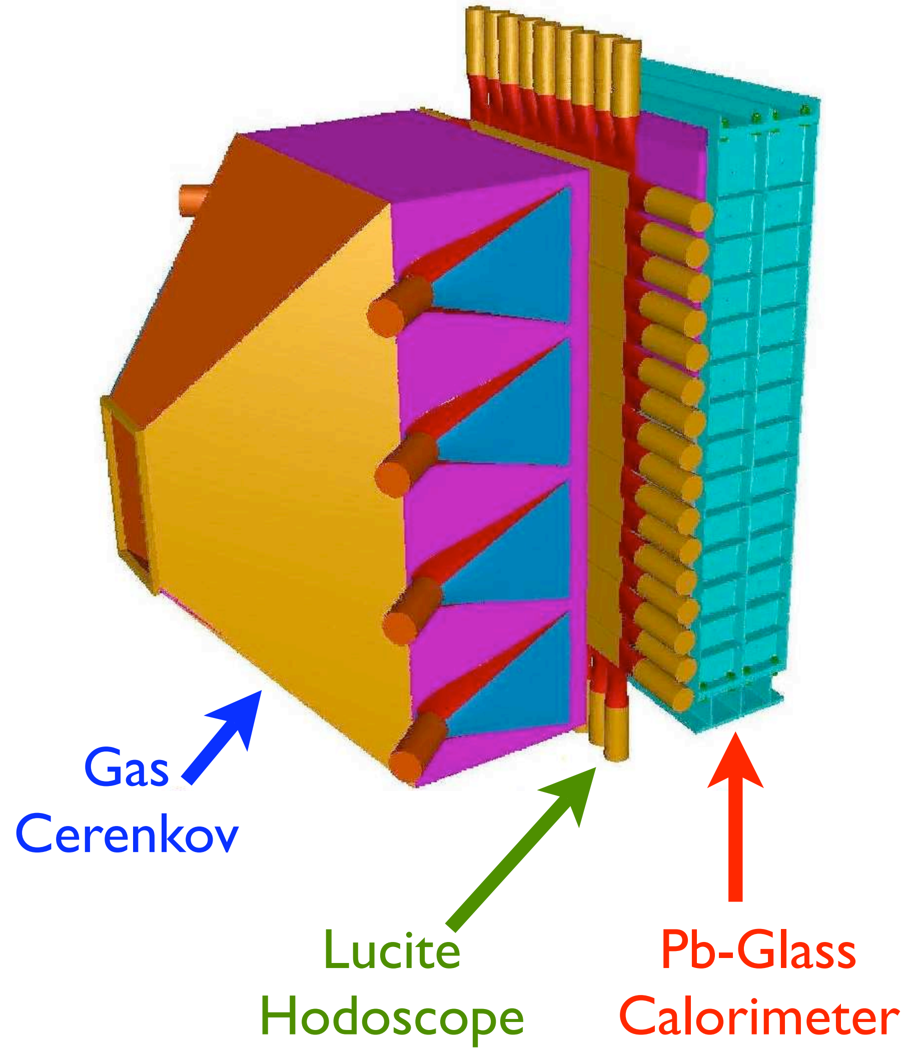
- Polarized Electron Beam
  - P_{Beam} = 75%
  - E_{Beam} = 4.8, 6.0 GeV
- UVa Polarized Target (NH3)
  - P_T = 75%
  - Target polarization parallel (180°) or perpendicular (80°)
- Electron Detector (BETA) @ 40°
  - Large Acceptance (194mSr)
- Electron Spectrometer (HMS)
  - Background Studies
  - BETA Calibration (ep elastic)



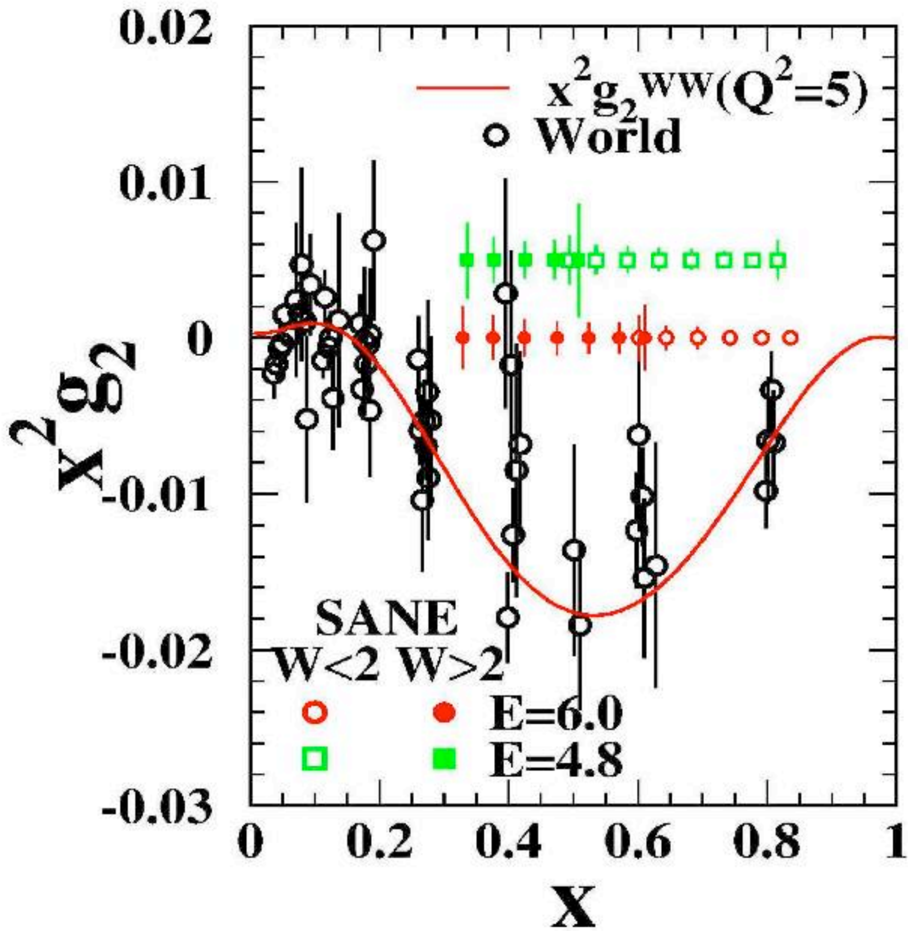


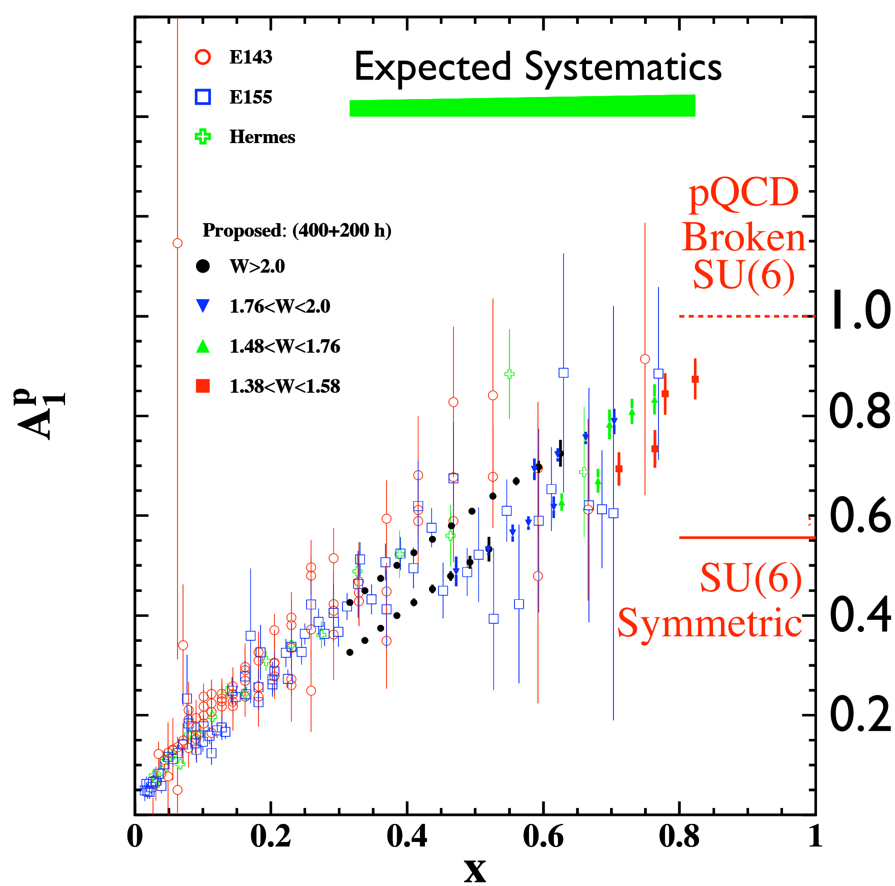
Big Electron Telescope Array (BETA)

- Lead Glass Calorimeter
  - $\Delta E / E = 5\,\% / \sqrt{E}$
  - Large Solid Angle (194mSr)
  - Highly segmented 1744 blocks (4x4x40cm)
- Gas Cerenkov
  - π/e separation
    1000:1 rejection factor
- Lucite Hodoscope Array
  - Redundant PID, Tracking info when combined with Calorimeter

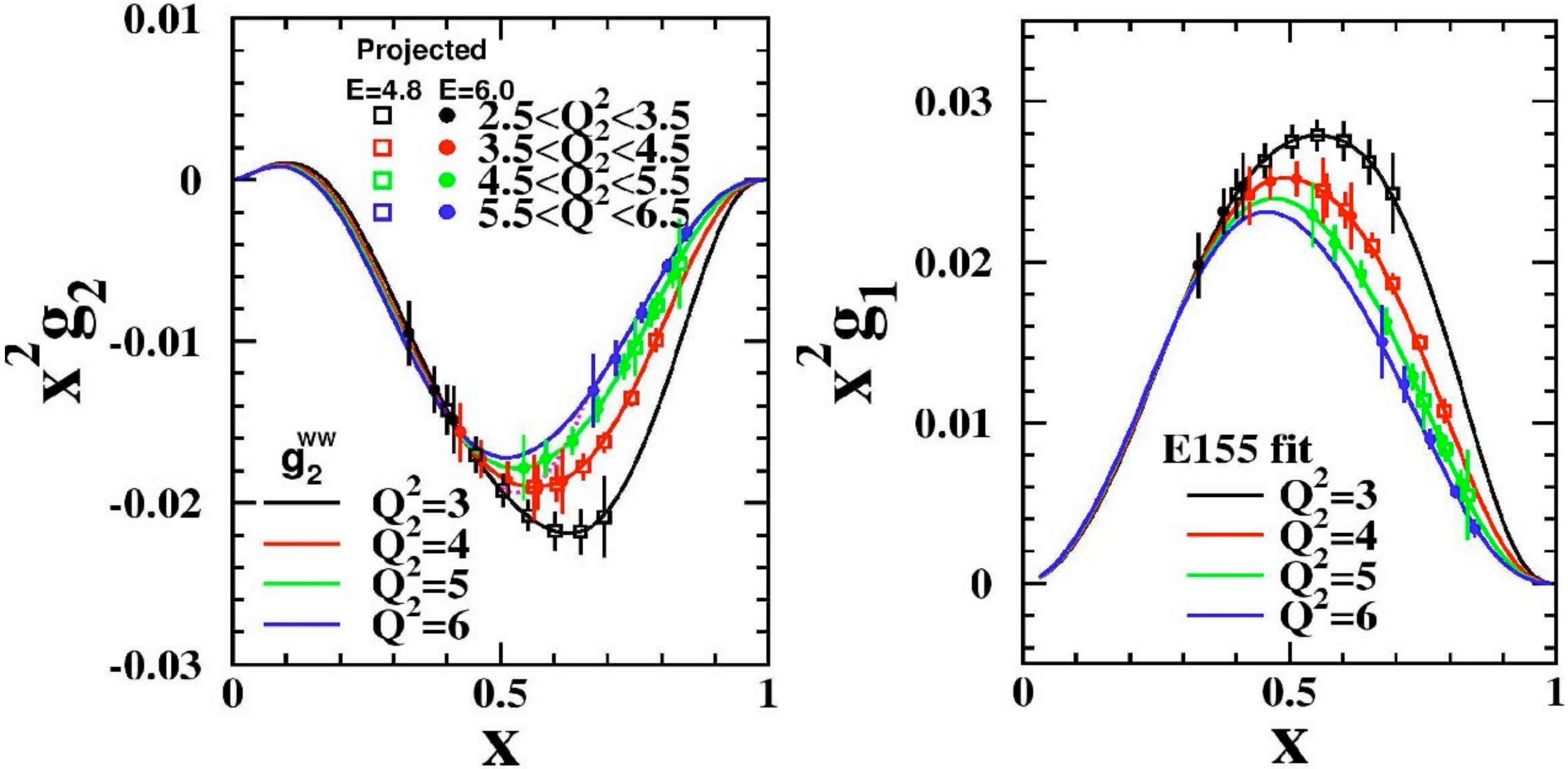


Expected Results for Proton g_2 and A_1





Expected Results (**x** and **Q²** dependence)



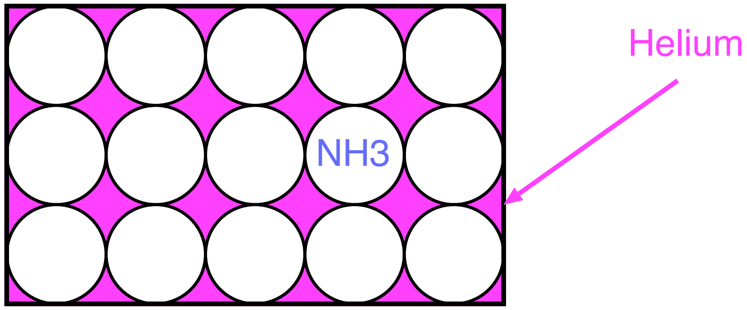
✓ d_2 will be measured at Q^2 =3.5 and 5.5 GeV^2 with high precision.

Summary of RSS and SANE experiments

- RSS (Proton data analysis nearly done)
  - Extracted proton spin asymmetries A_1, A_2 and structure functions g_1, g_2 in the resonance region.
  - Studied polarized duality in the resonance region, twist-3 effect, and d_2 matrix element
  - Deuteron and Neutron SSFs to be extracted.
  - A PRL (for the proton results) to be submitted soon
- SANE (Future experiment)
  - Will measure proton A_1 and g_2 with large acceptance detector (BETA) in range $2.5 < Q^2 < 6.5$ and $0.3 < x < 0.8$
  - Study x and Q^2 dependence, twist-3 effect, moments of g_2 and g_1, test polarized local duality for $W > 1.4$
  - Will take data in Hall C at JLab in 2008

Packing Fraction and Dilution Factor

Packing Fraction (PF) is the ratio of NH_3 to (NH_3 +He)



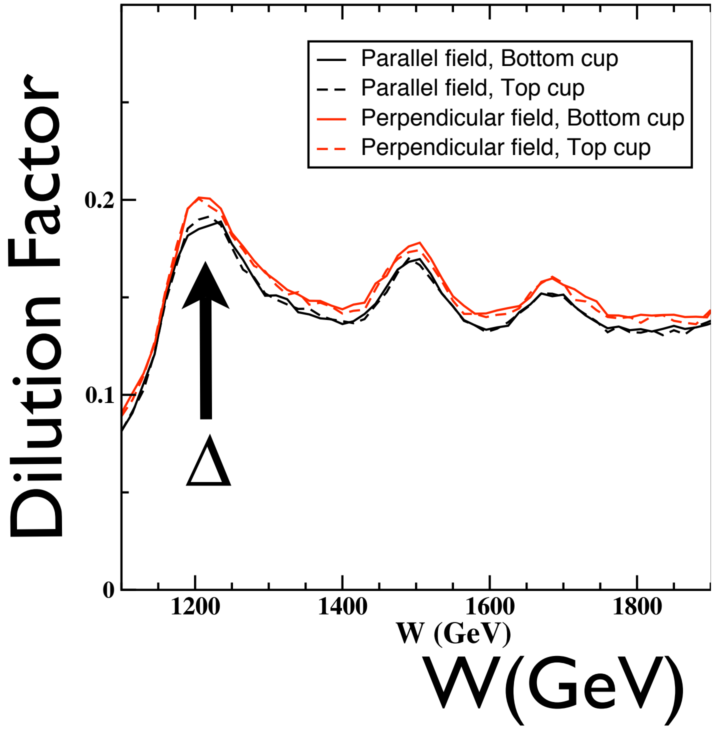
- PF for each target cell was determined by comparing the simulated W spectrum with data.
- Measured NH_3 PFs: 52-61%, Systematic error in PFs: <2%

Dilution Factor: f(W)

f(W)= #Events(free proton) / #Events(total)

Hall C fits for F_2 and R (M.E. Christy)

QFS for A>2



How to get A_1, A_2, g_1, and g_2

- Full expression for *RSS* analysis

$$A_1 = \frac{Q^2}{D'} \frac{(\nu \cot(\theta/2) + E' \sin\theta)\cos\phi\ A_{||} + E'(1+\cos\theta)A_\perp}{E'\sin\theta\cos\phi\ (Q^2 + 2E(E + E'\cos\theta))}$$

$$A_2 = \frac{\sqrt{Q^2}}{D'} \frac{(Q^2\cot(\theta/2) - \nu E'\sin\theta)\cos\phi\ A_{||} + (Q^2 + \nu(E + E'\cos\theta))A_\perp}{E'\sin\theta\cos\phi\ (Q^2 + 2E(E + E'\cos\theta))}$$

  - ***D'***(*E, E', θ, R*) = depolarization factor

- Have both SA's and SF's calculated using above.

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

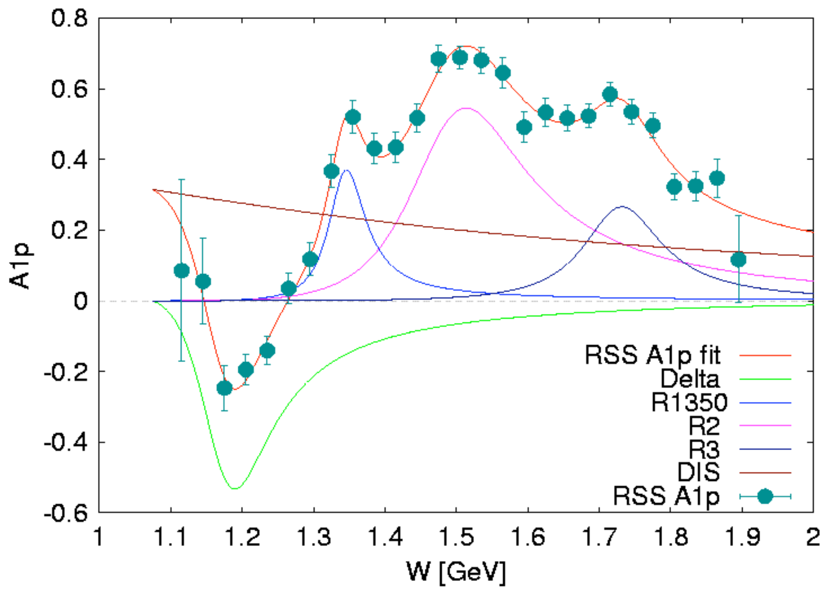
$$g_2 = \frac{F_1}{1+\gamma^2}(A_2/\gamma - A_1)$$

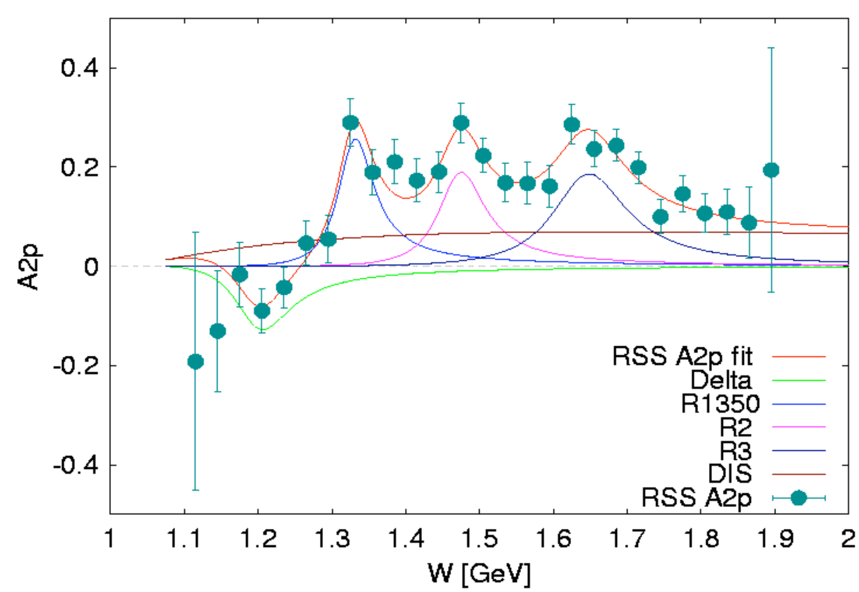
$$\gamma = \sqrt{\frac{Q^2}{\nu^2}}$$

$F_1 = F_2(1+\gamma^2)/2x/(1+R)$

Recent Fits to F2 and R data in the resonance region were used to obtain F1

Fit to the Proton SA's

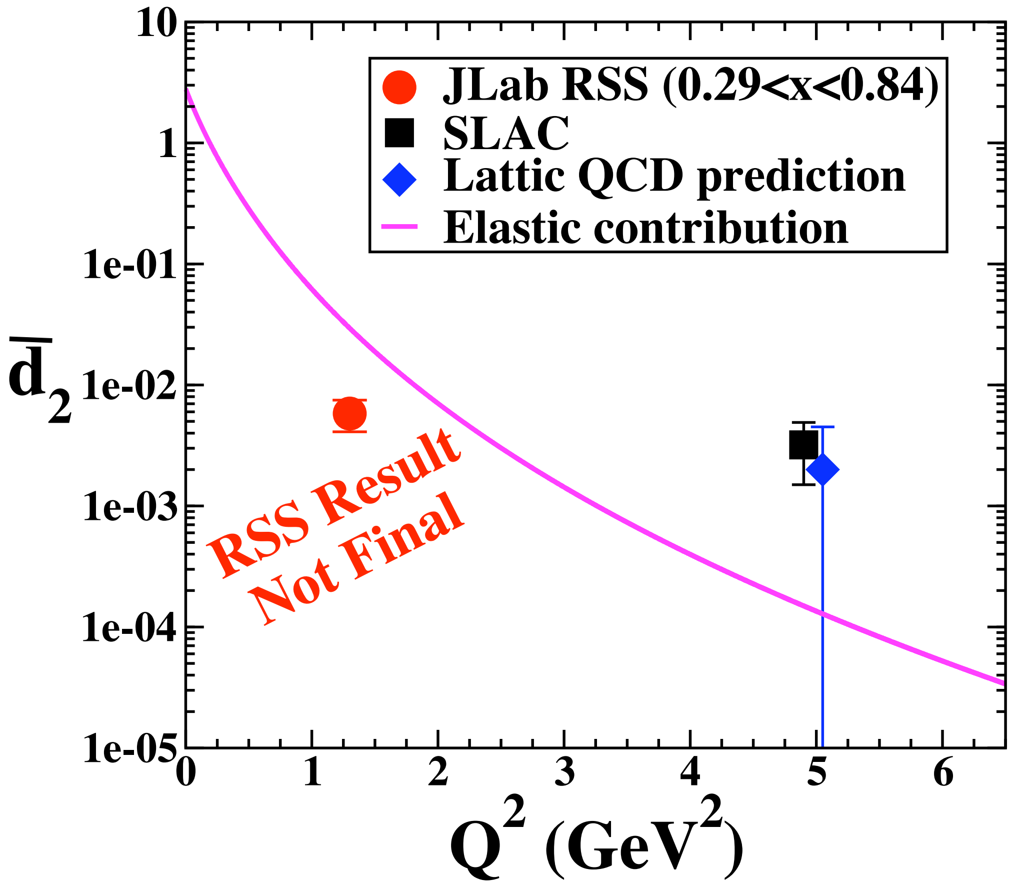




- Four Breit-Wigner resonance shapes plus DIS background
- Fit A_1 and A_2 independently
- Reduced $\chi^2 \sim 1.3 - 1.5$ for 12 d.o.f.

Elastic contribution to d_2

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



A large elastic contribution to d_2 at $Q^2 = 1.3$ GeV^2

Next: Neutron Spin Structure

- Extract neutron from *p* and *d*
- Bodek-Ritchie version of Atwood-West smearing
  - generate smeared proton $\mathbf{A}_{\parallel}$, $\mathbf{A}_{\perp}$ from $\boldsymbol{g}_1$, $\boldsymbol{g}_2$
  - subtract from deuteron $\mathbf{A}_{\parallel}$, $\mathbf{A}_{\perp}$ to form smeared neutron quantities
  - unsmear neutron using iterated fit to model