Nucleon Resonances Spin Structure -*RSS*: Experiment 01-006 at Jefferson Lab

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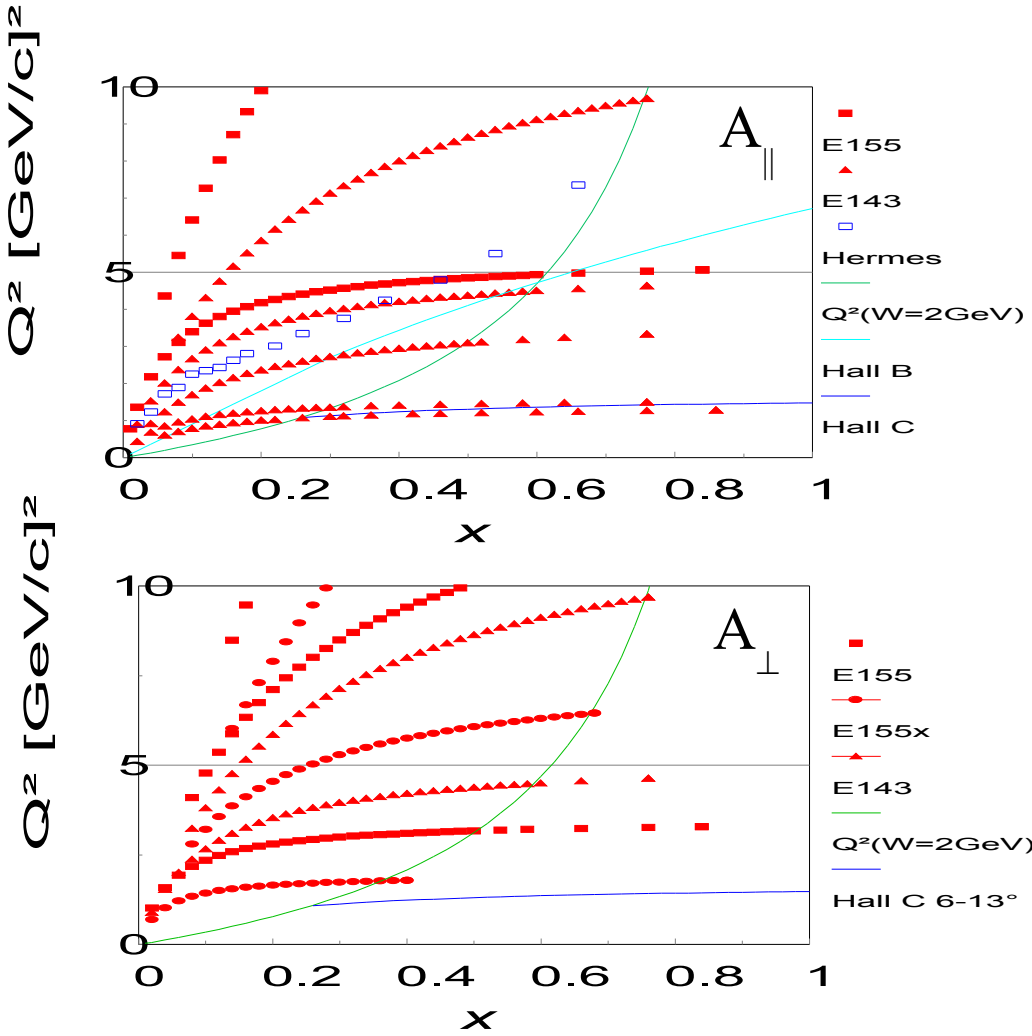
$A_{\parallel}$ and $A_{\perp}$ data on protons and deuterons

- Spin Structure g_1 and g_2 obtained from $A_{\parallel}$ and $A_{\perp}$

$$A_{\parallel} = \frac{\sigma^{(\uparrow\downarrow)} - \sigma^{(\downarrow\downarrow)}}{\sigma^{(\uparrow\downarrow)} + \sigma^{(\downarrow\downarrow)}}, \quad A_{\perp} = \frac{\sigma^{(\uparrow\rightarrow)} - \sigma^{(\downarrow\leftarrow)}}{\sigma^{(\uparrow\rightarrow)} + \sigma^{(\downarrow\leftarrow)}}$$

- Few $A_{\perp}$ data for W<2 GeV
- JLab E01-006 (*RSS*) first complete measurement on *protons* and *deuterons* in the resonances



Central kinematics of world's *p*, *d* data
($Q^2 < 10$ GeV^2; upper Q^2 limit for Hall B)

JLab E01-006: *R*esonances *S*pin *S*tructure

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

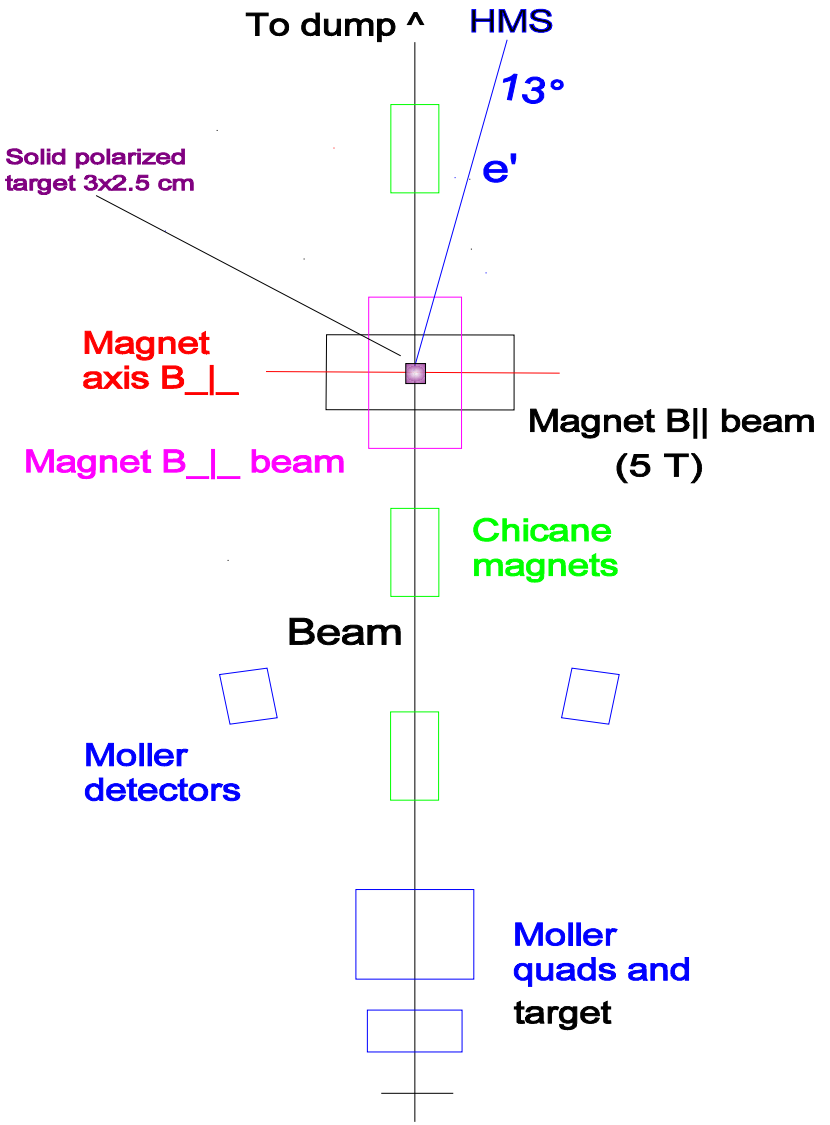
U. Basel, Florida International U., Hampton U., U. Massachusetts, U. Maryland, Mississippi S. U., North Carolina A&T U., U. of N. C. at Wilmington, Norfolk S. U., Old Dominion U., S.U. New Orleans, U. of Tel-Aviv, TJNAF, U. of Virginia, Virginia P. I. & S.U., Yerevan Physics I.

Spokesmen: Oscar A. Rondon (U. of Virginia) and Mark K. Jones (Jefferson Lab)

- Measure *proton* and *deuteron* spin asymmetries $\mathbf{A_1}(W, Q^2)$ and $\mathbf{A_2}(W, Q^2)$ at four-momentum transfer $Q^2 \approx 1.3$ GeV^2 and invariant mass $0.8 \leq W \leq 2$ GeV
- Study W dependence, onset of polarized local duality, twist-3 effects, using inclusive polarized scattering

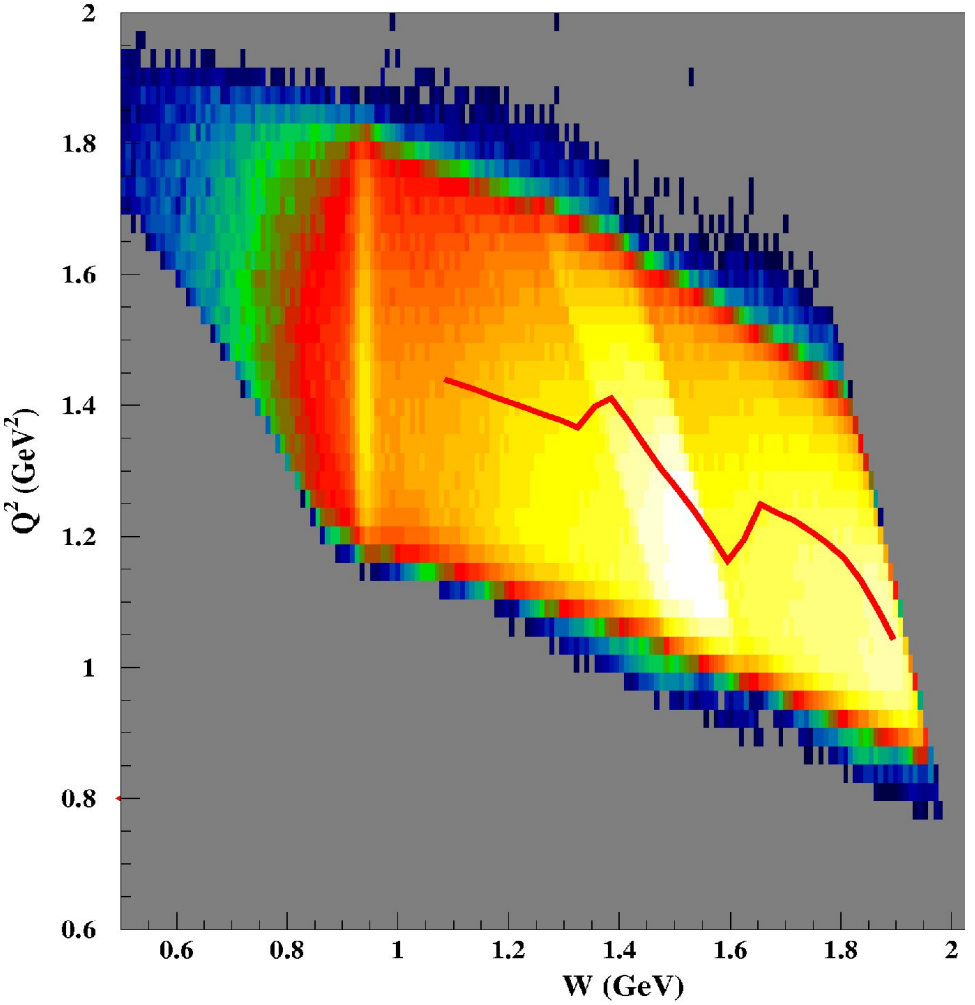
RSS technique

- Equipment: TJNAF Hall C
  - CEBAF polarized electron beam
    - 2 cm diameter raster at target
    - I = 85-150 nA
  - Target: polarized ammonia NH_3, ND_3.
    - Luminosity ~10^{35} $s^{-1}cm^{-2}$
  - HMS electron detector
- Data run: Jan.-Feb. 2002
    - 160 M proton,
    - 350 M deuteron triggers



RSS kinematics

- Beam energy 5.755 GeV
- HMS angle 13.15°
- HMS central momenta:
  - 4.71 GeV/c
  - 4.08 GeV/c
- Final state mass range:
  - 0.8 GeV ≤ W ≤2.0 GeV
- $\langle Q^2 \rangle = 1.3$ [GeV/c]^2



Measured asymmetries $A_{\parallel}$, $A_{\perp}$

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

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

- N^-, N^+ = charge normalized, dead time and pion corrected yields for +/- beam helicities
- P_b, P_t = beam, target polarizations
- f = dilution factor
- C_N, C_D = corrections for ^{15,14}N proton $C_D = 0$, deuteron $C_N \simeq 1$
- f_{rc}, A_{rc} = radiative corrections

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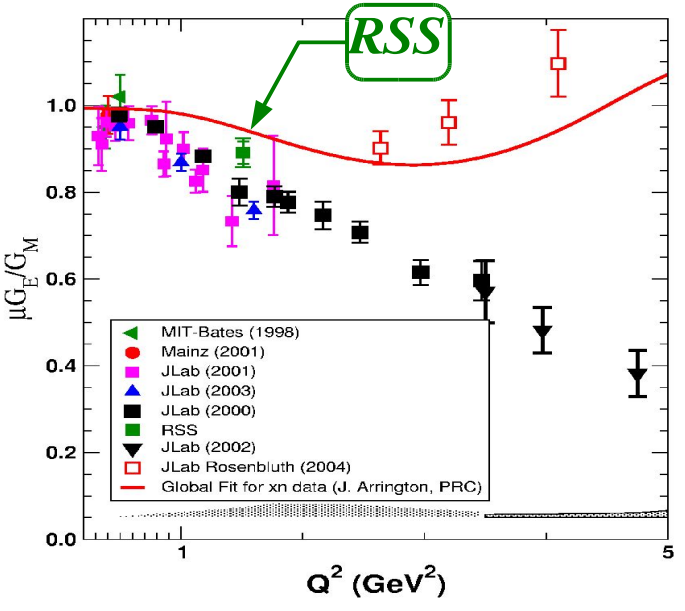
Method - Material	***Polarization* [%]**	
	$A_{\parallel}$	$A_{\perp}$
Moller - Beam	71	66
NMR - NH_3	70 ± 1.7	
NMR - ND_3	$20 \pm 2.$	

Proton Elastic	***G_E/G_M Sensitivity***	***Use***
$A_{\parallel}$	Low	$P_b P_t$
$A_{\perp}$	High	G_E/G_M



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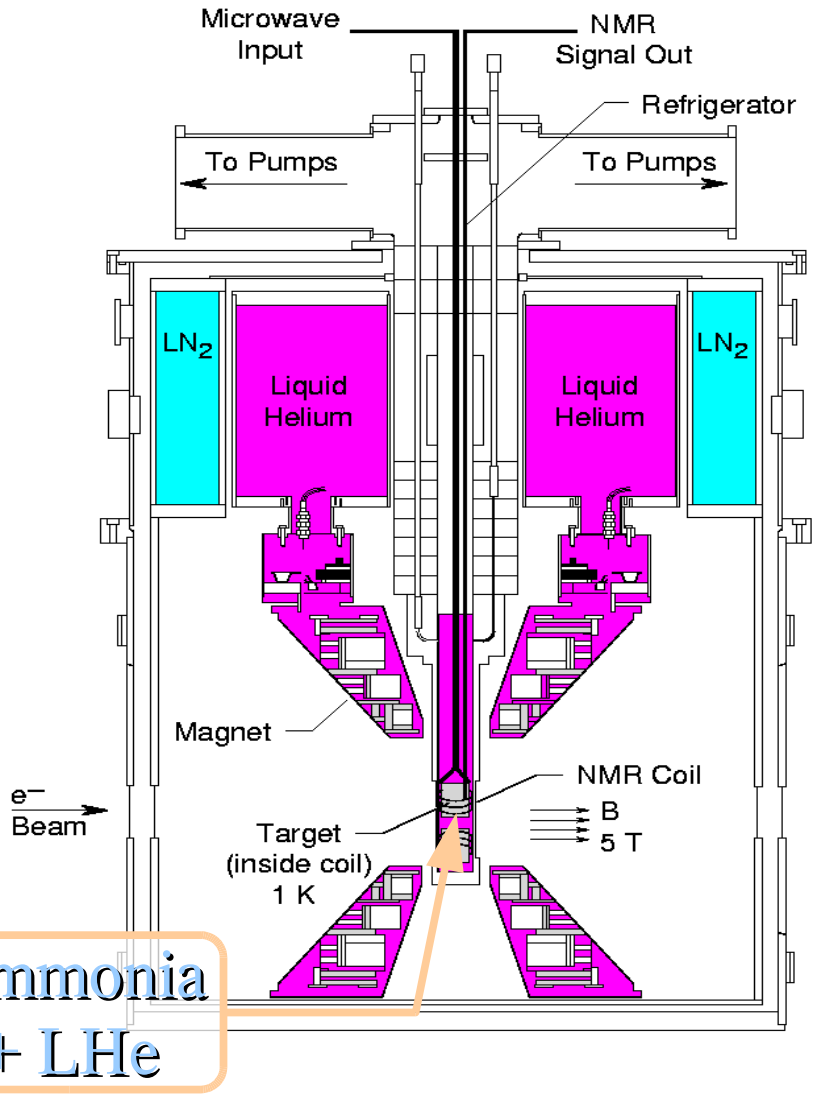
- P_b, P_t = beam, target polarizations
- f = dilution from N, He and others
- C_N, C_D = corrections for ^{15,14}N proton $C_D = 0$, deuteron $C_N \simeq 1$
- A_{rc} = radiative correction



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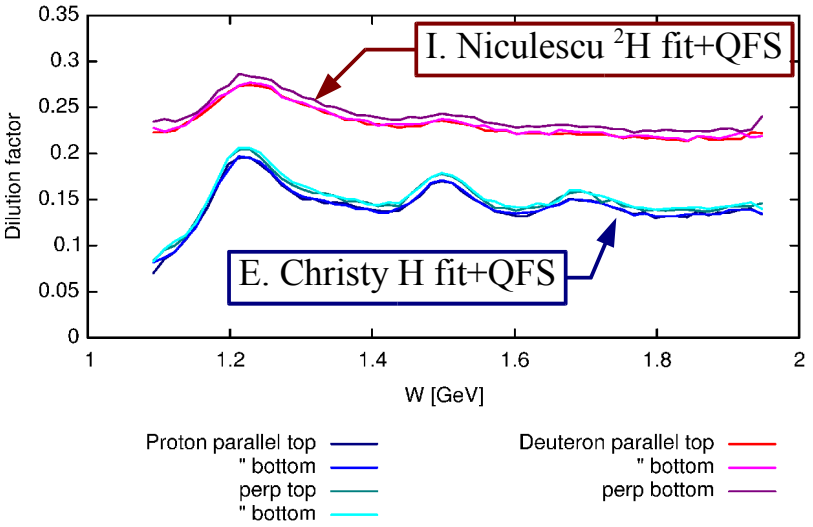
- f = fraction of rate from polarized H, ^{2}H
  - Monte Carlo radiated rates
- Effective ammonia thickness (packing fraction) is cell specific - 8 cells total
  - obtained from data-MC comparison
  - packing fraction range: 0.52 - 0.61



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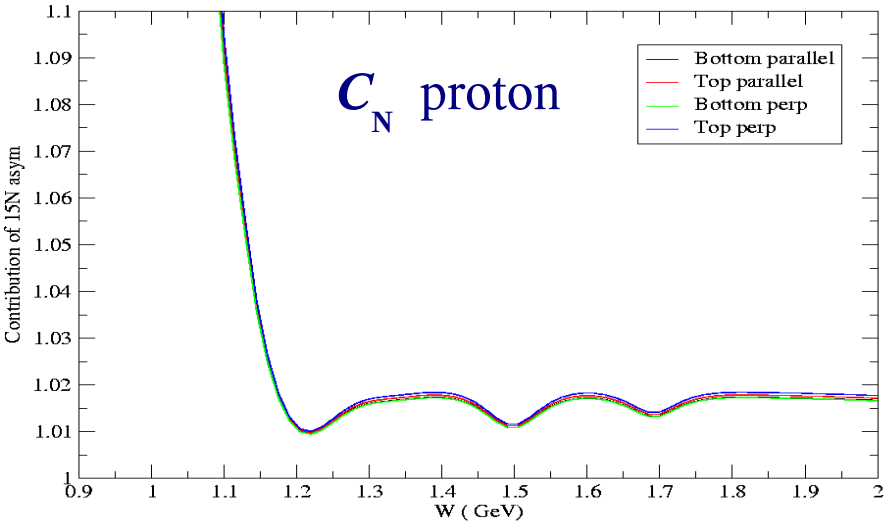

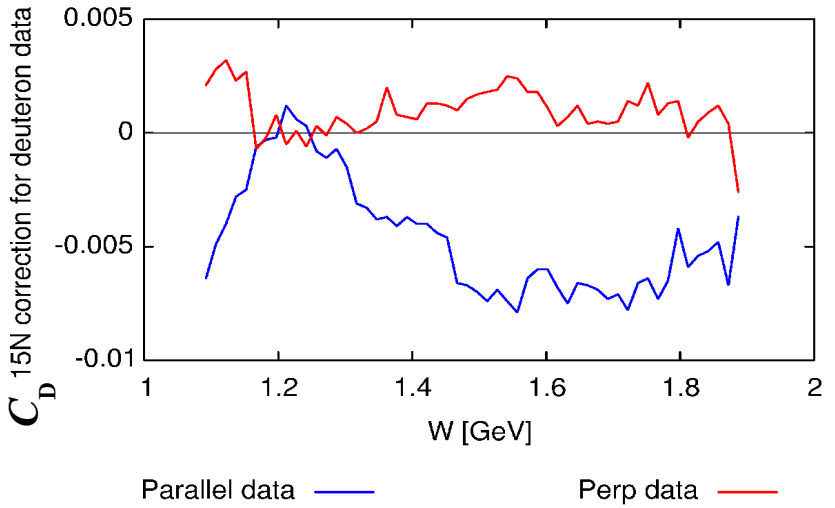

Measured asymmetries $A_{\parallel}$, $A_{\perp}$

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

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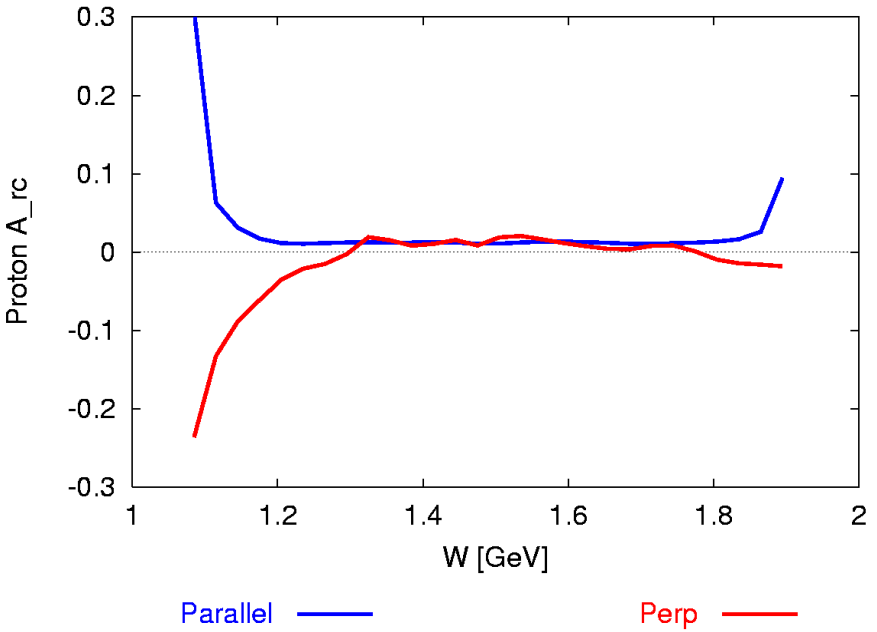
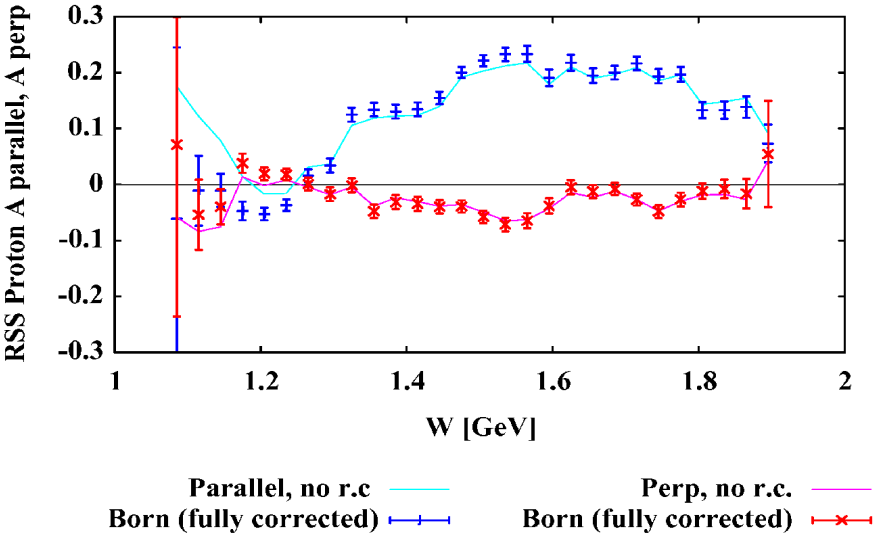


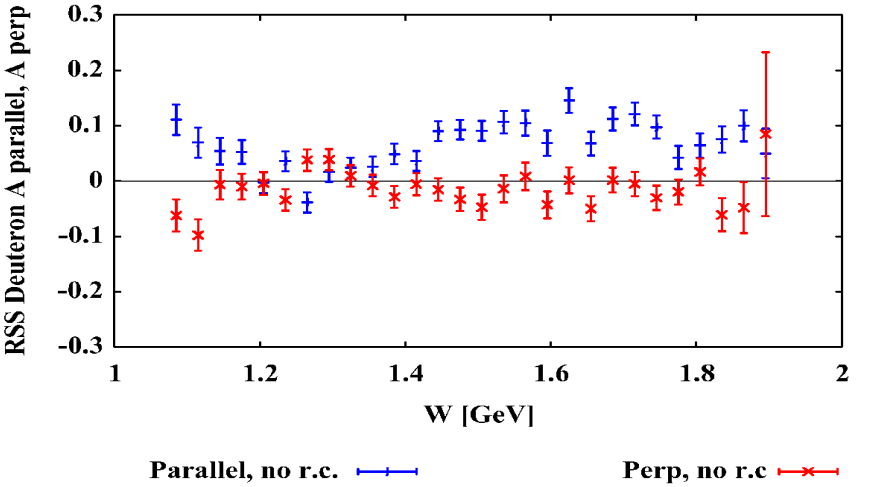
Measured asymmetries $A_{\parallel}$, $A_{\perp}$

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

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

- N^-, N^+ = charge normalized, dead time and pion corrected yields for +/- beam helicities
- P_b, P_t = beam, target polarizations
- f = dilution factor
- C_N, C_D = corrections for ^{15,14}N proton $C_D = 0$, deuteron $C_N \simeq 1$
- A_{rc} = radiative correction (p only)





How to get A_1, A_2

- Combine $\mathbf{A_{\parallel}}$, $\mathbf{A_{\perp}}$ to get $\mathbf{A_1}$, $\mathbf{A_2}$:

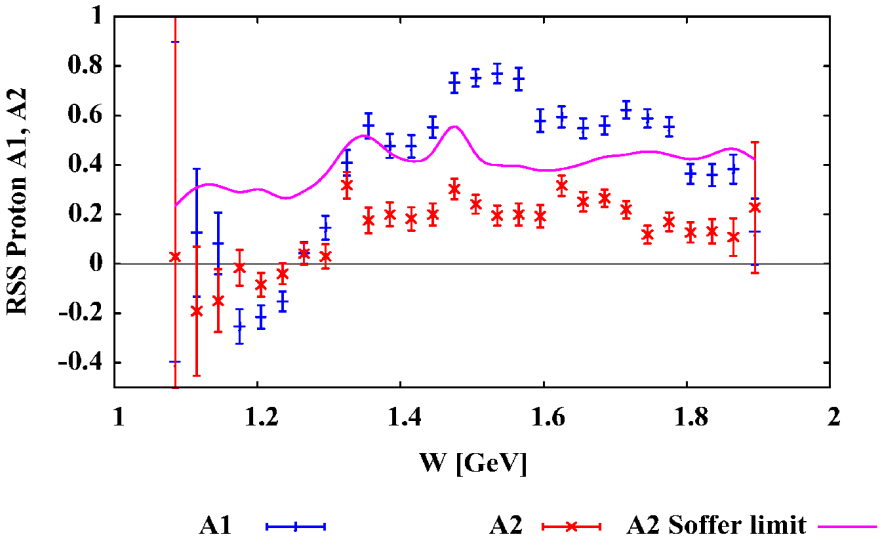
$$A_1 = \frac{1}{(E+E')D'}\left((E - E'\cos\theta)A_{\parallel} - \frac{E'\sin\theta}{\cos\phi}A_{\perp}\right)$$

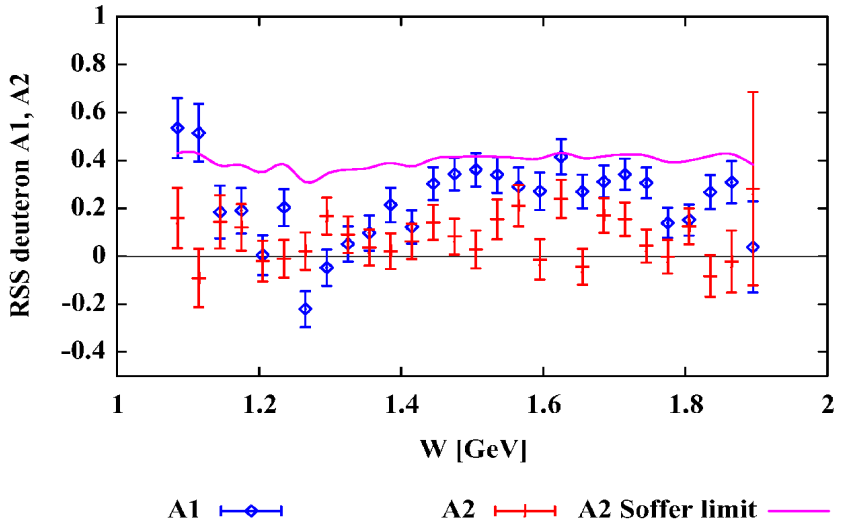
$$A_2 = \frac{\sqrt{Q^2}}{2ED'}\left(A_{\parallel} + \frac{E - E'\cos\theta}{E'\sin\theta\cos\phi}A_{\perp}\right)$$

- $\boldsymbol{D'}(E,E',\theta,R)$ is function of kinematics and $\boldsymbol{R} = \sigma_L/\sigma_T$
- Proton $\boldsymbol{R}$, $\boldsymbol{F}_2$ unpolarized S.F.s from E. Christy's fit to JLab Hall C *e-p* data

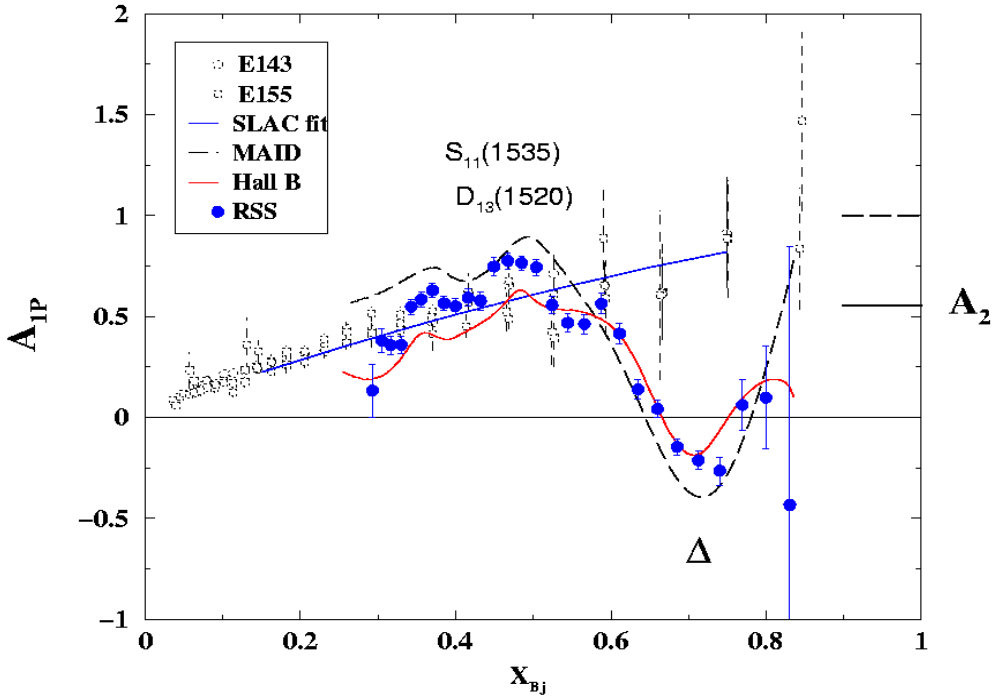
Spin Asymmetry results

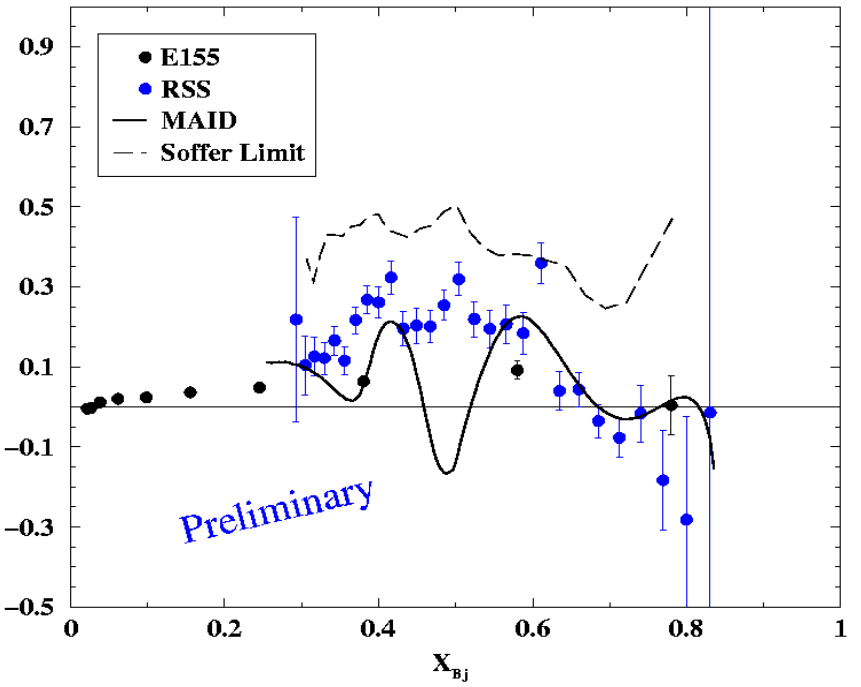
- A_1, A_2 for proton, deuteron in resonances are unique:
  - *RSS* is only experiment that can separate A_1, A_2
- Proton (near) final results
- Deuteron radiative corrections not applied yet





RSS Proton SA's in context





- A_1: clear resonance structure
  - will use updated fit to R, F_2 for final shape, minor changes
- A_2: first measurement on proton

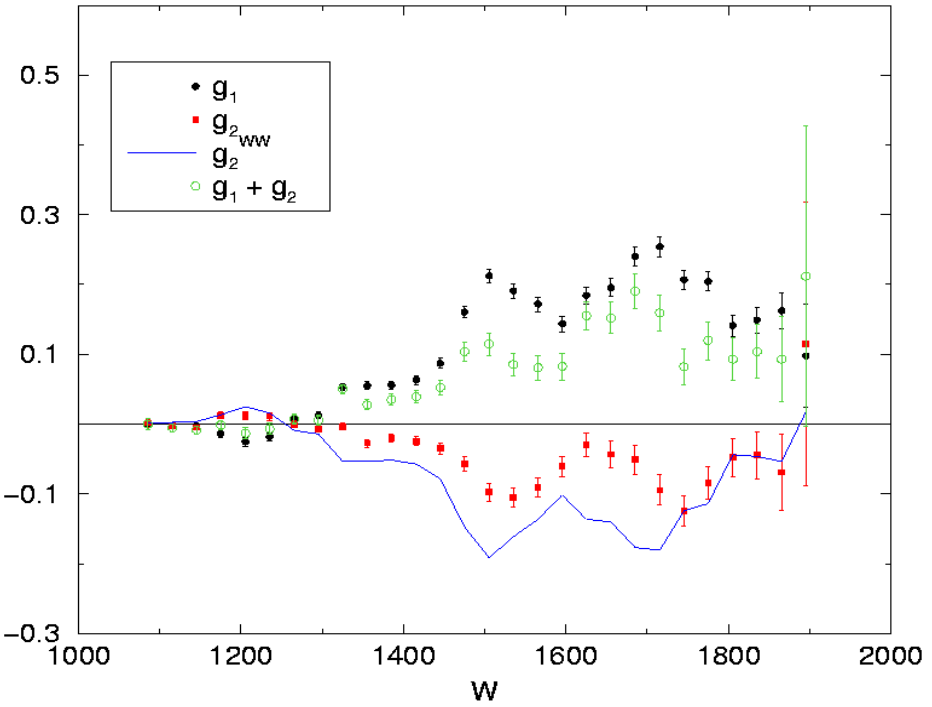
Spin Structure Functions

- Use unpolarized F_1

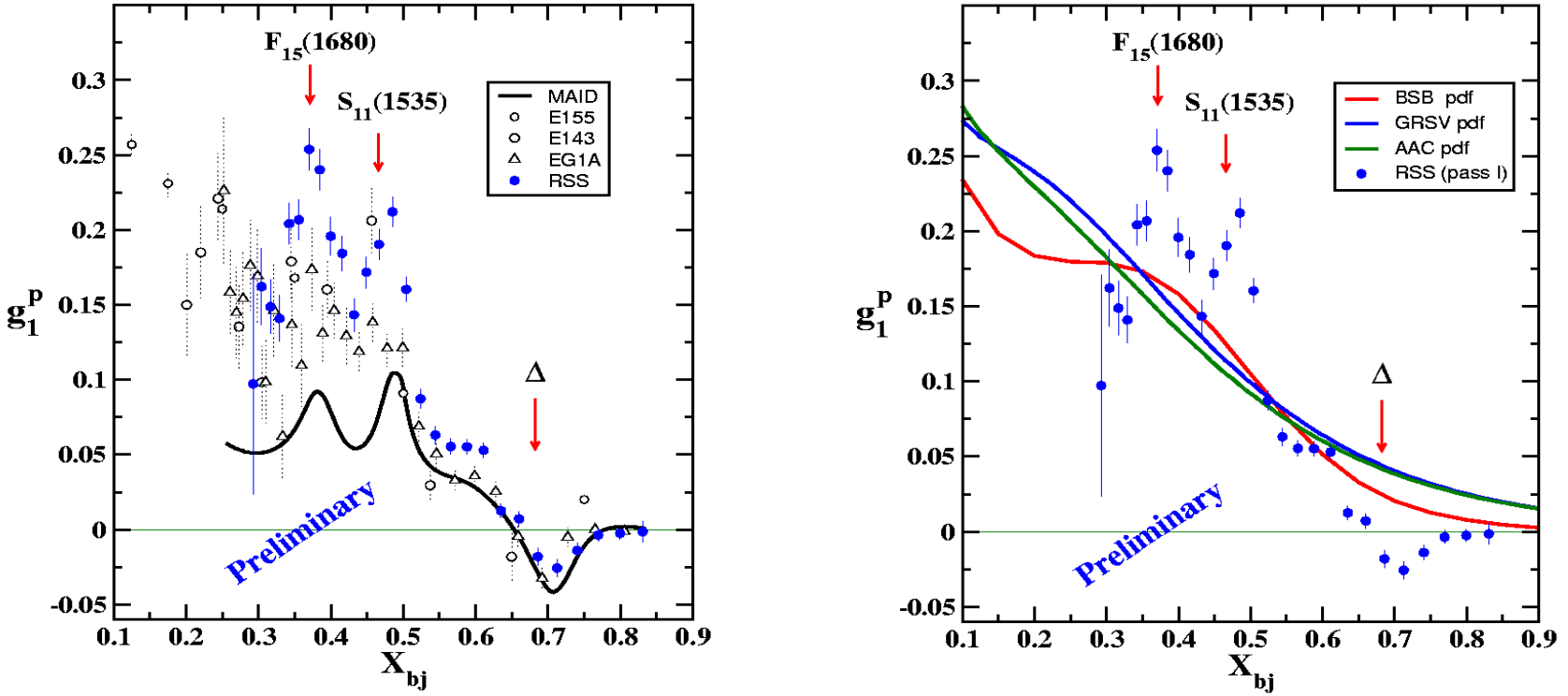
$$g_1 = \frac{F_1}{1+\gamma^2}(A_1 + \gamma A_2)$$

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

- High precision, high resolution measurement
- First world data for g_2^p in the resonances
- Clear high twist in g_2^p



RSS Proton g_1 results in context



- Local (Bloom-Gilman) duality in g_1^p:
  - compare integrals over resonances and extrapolated DIS for each resonance

High twist in g_2^p

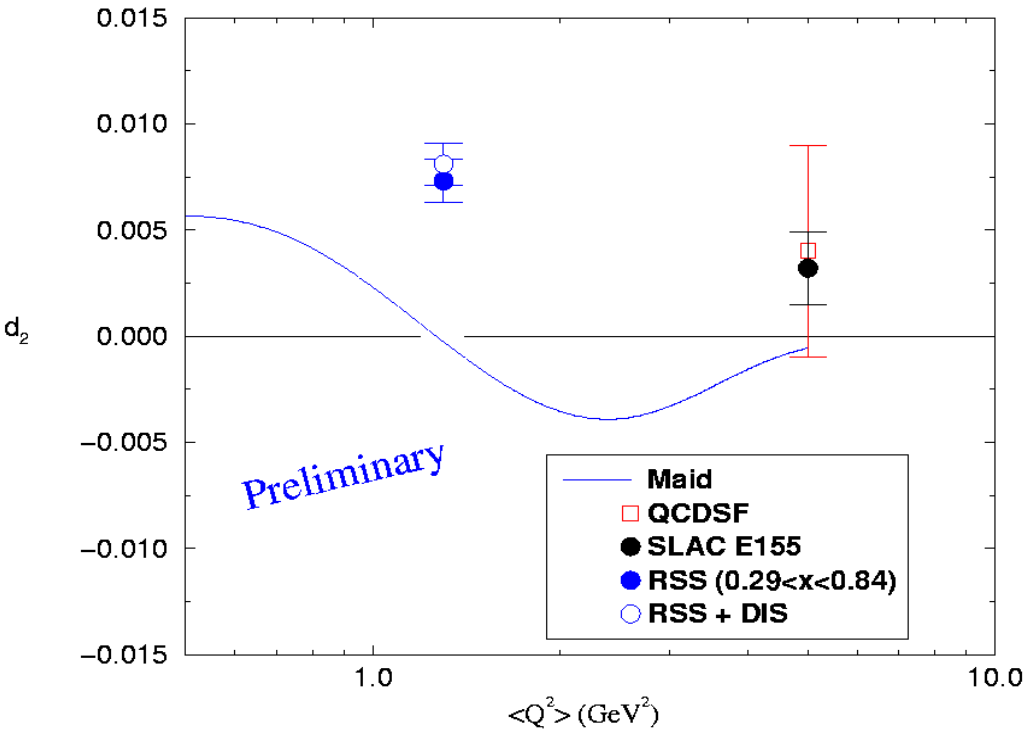
- g_2: combination of twist-2 (*q-q)* and twist-3 (*q-g*)

$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) + \overline{g_2}(x,Q^2)$$

- OPE matrix elements d_N measure twist-3
  - calculable in the lattice:

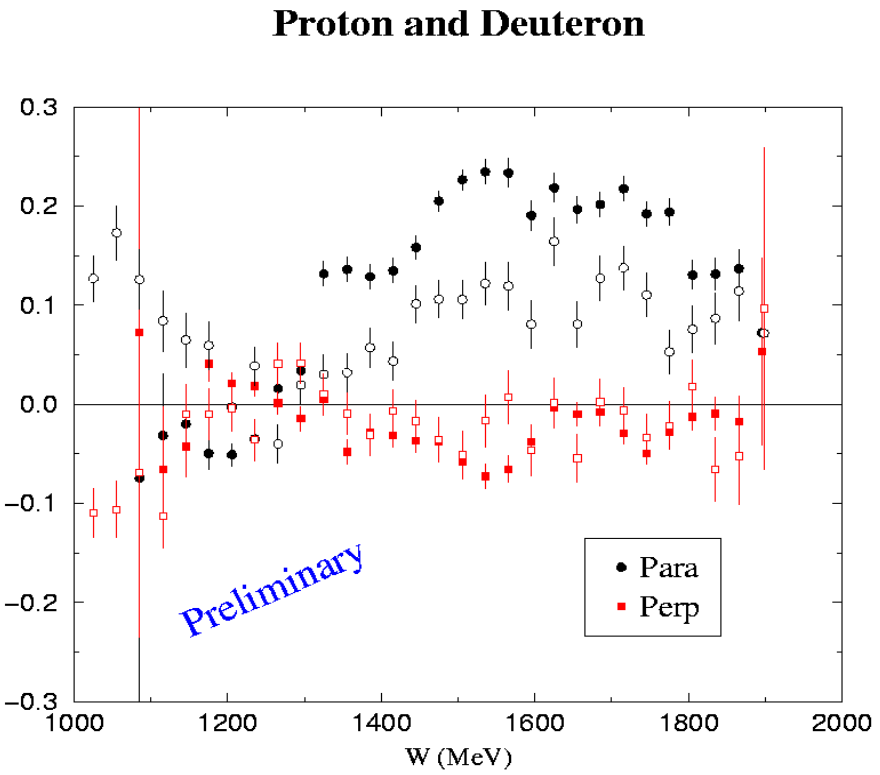
$$d_2(Q^2) = 3\int_0^1 x^2 \overline{g_2}(x,Q^2)\,dx$$

- Measured d_2:
  - elastic not included



Next: Neutron Spin Structure

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



Credits

Analysis Team

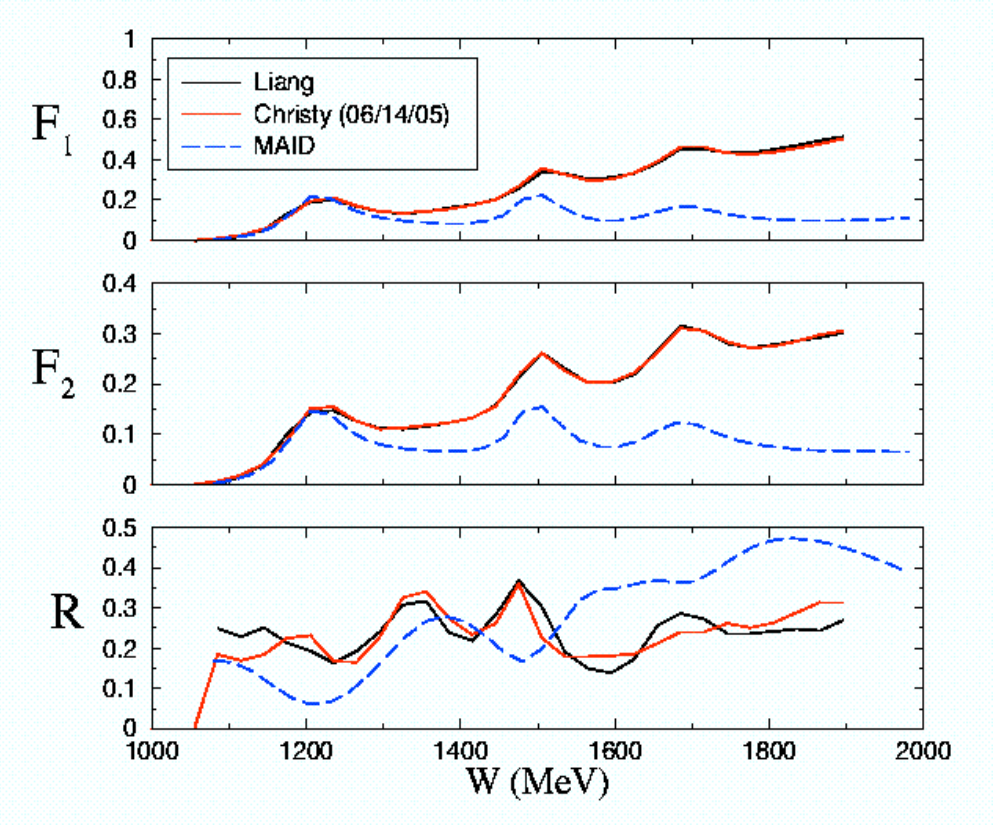
- Mark Jones
- Karl Slifer
- Shigeyuki Tajima
- Frank Wesselmann
- Eric Christy
- Paul McKee
- Hamlet Mkrtchyan
- Junho Yun
- Hongguo Zhu
- Oscar Rondon

Special Thanks

- Peter Bosted
- Don Crabb
- Donal Day
- Mahbub Khandaker
- JLab Hall C
- JLab Target group

Proton Unpolarized SF's

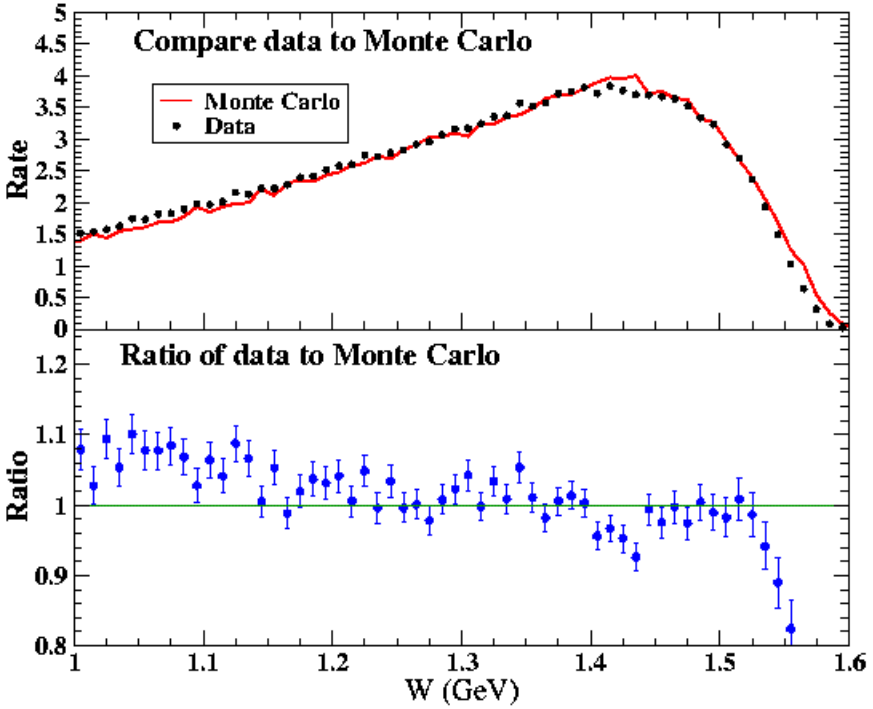
- Used E. Christy's fit to JLab Hall C *e-p* inelastic data to get
  - unpolarized H cross section in MonteCarlo for dilution factor
  - unpolarized proton F_1, F_2 and R.



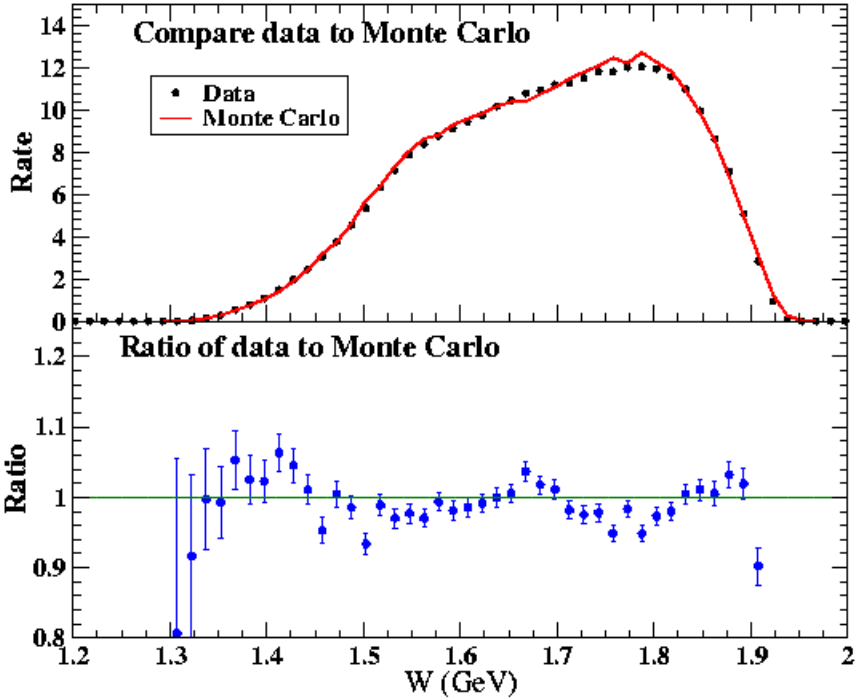
MC-data Comparison

Carbon data used to fit QFS model.

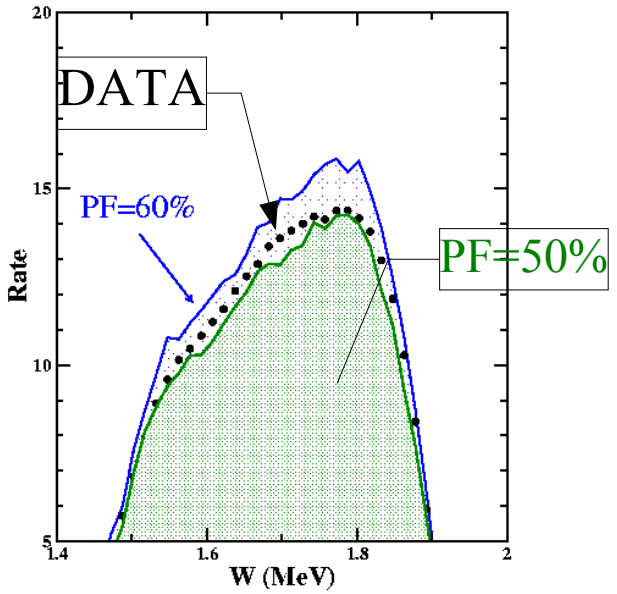
P_0 = 4.7 GeV/c

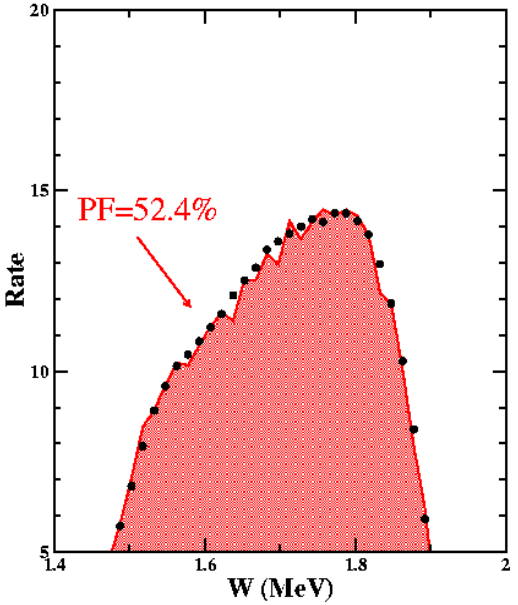


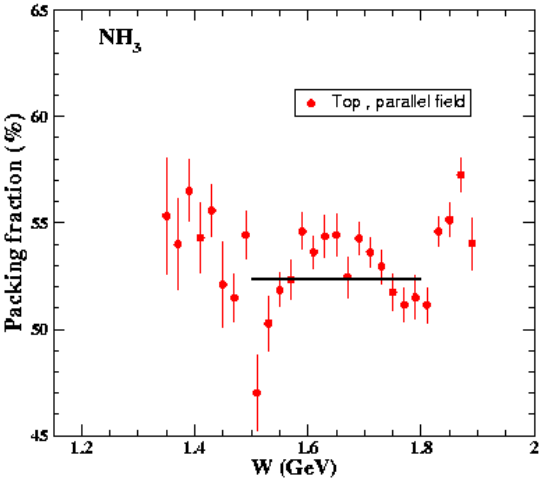
P_0 = 4.1 GeV/c



Packing Fraction







- Compare data spectra to MonteCarlo simulation for two (or more) values of packing fraction
- Interpolate to match data