Resonant Spin Structure

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Hall C Workshop, Jan. 2006

Resonant Spin Structure (RSS)
of the Proton and Deuteron

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Analysis

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E01-006 Collaboration

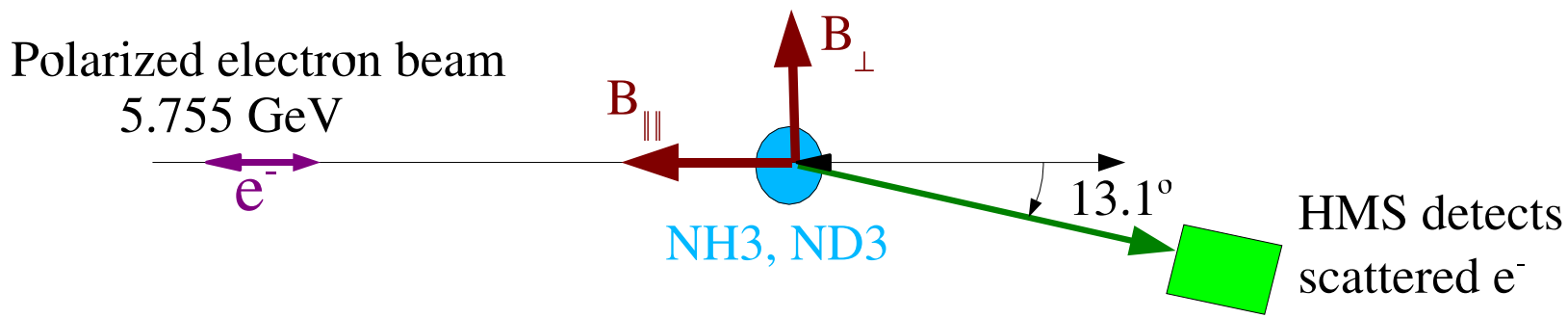
Univ. Basel, Florida International Univ., Hampton Univ., Univ. of Massachusetts, Univ. of Maryland,
Mississippi State Univ.,North Carolina A&T Univ., Univ. of N. C. at Wilmington,
Norfolk State Univ.,Old Dominion Univ.,S.U. at New Orleans, Univ. of Tel-Aviv,
Jefferson Lab, Univ. of Virginia, Virginia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

Overview

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

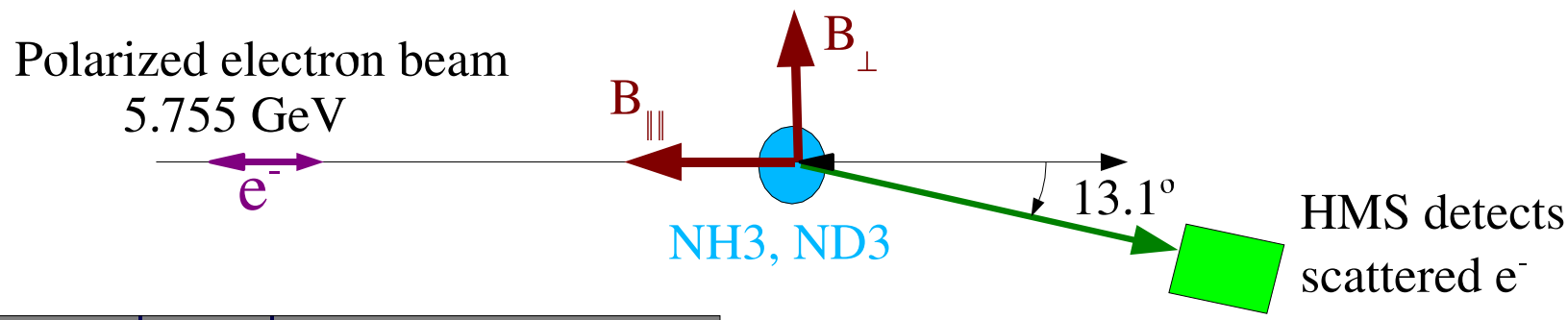
- Measure $A_1(W, Q^2)$ and $A_2(W, Q^2)$
- Extract g_1 and g_2 structure functions
- Add to world data on $A_\perp$
- W–dependence
- Onset of polarized local duality
- Twist-3 effects in d_2 matrix element

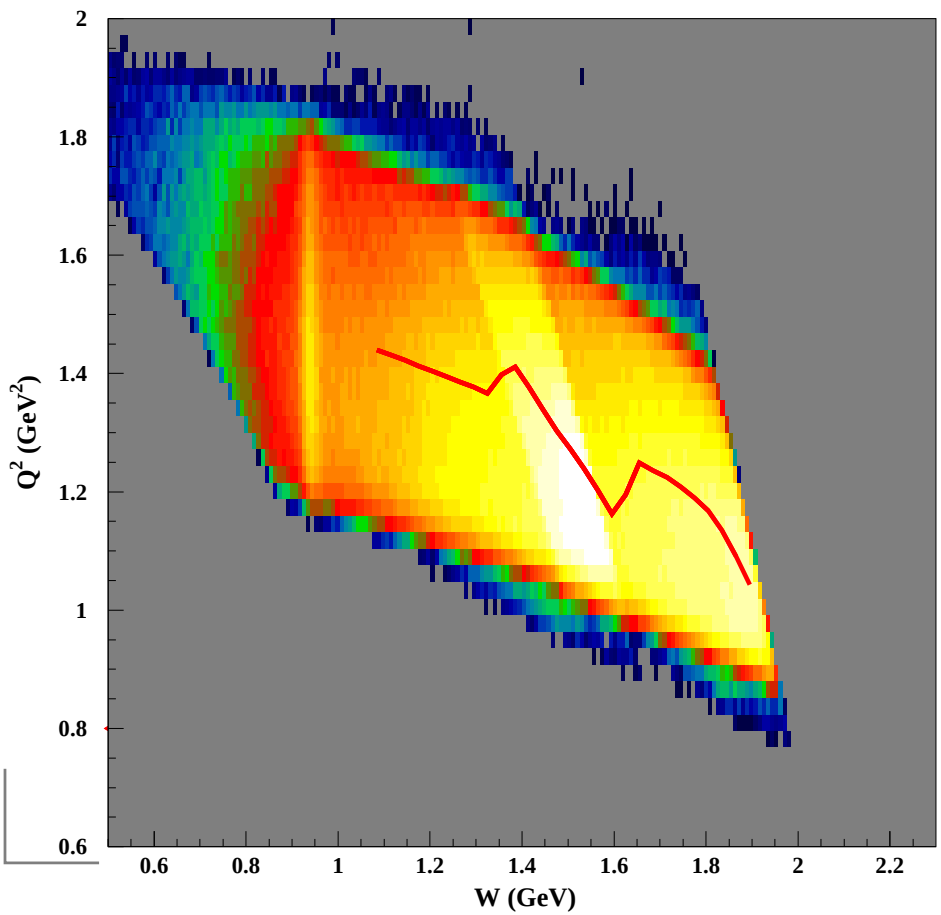
Experimental set-up in Hall C



P_0 = 4.7, 4.1 GeV/c

Experimental set-up in Hall C





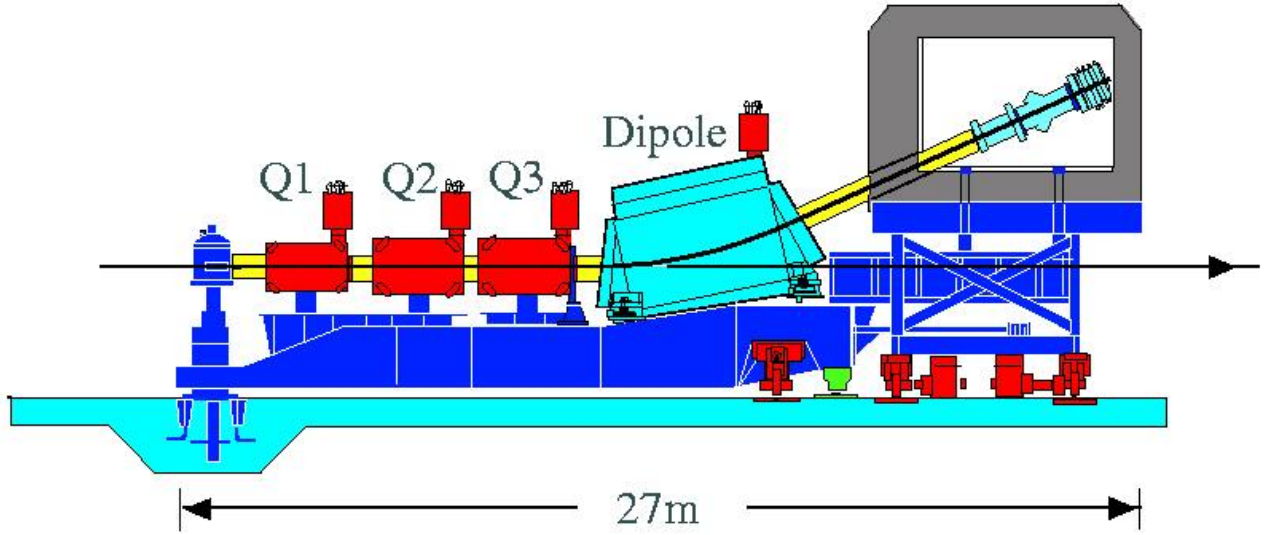
P_0 = 4.7, 4.1 GeV/c

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

P_b = 65.6 $\pm$ 2.6 for B$_{||}$
P_b = 70.9 $\pm$ 1.7 for B$_{\perp}$

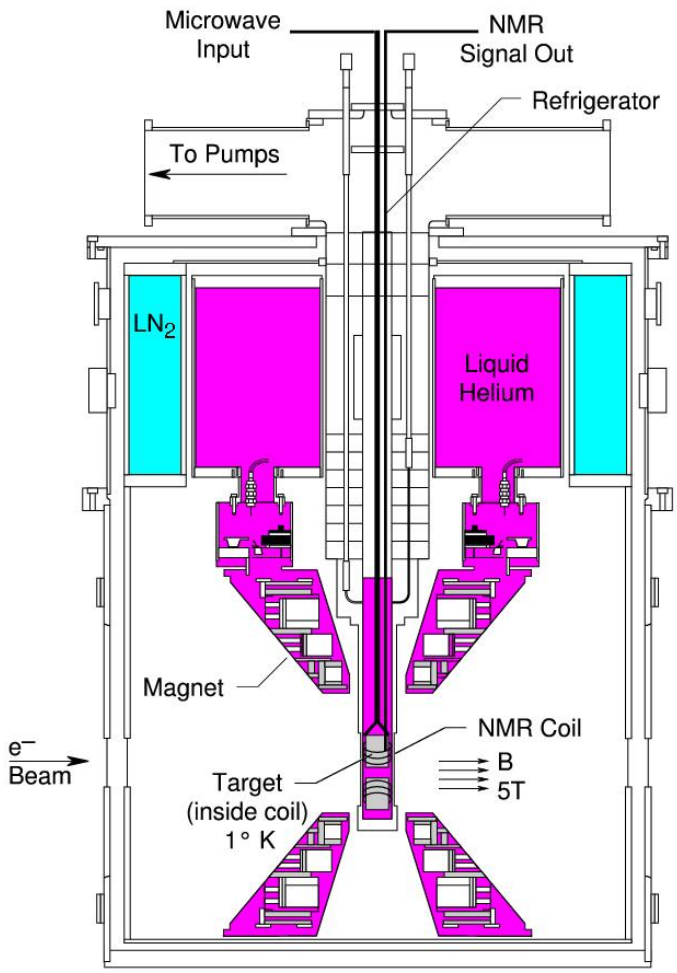
$I \approx$ 100nA
Beam charge asym. < 0.1%

High Momentum Spectrometer



- $12.5° < \Theta < 90°$
- 1 dipole, 3 quadrupoles
- $\pm 9\%$ acceptance
- Shielded detector package
  - Scintillator hodoscopes, wire drift chambers
  - Gas cherenkov, segmented Pb glass calorimeter

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.

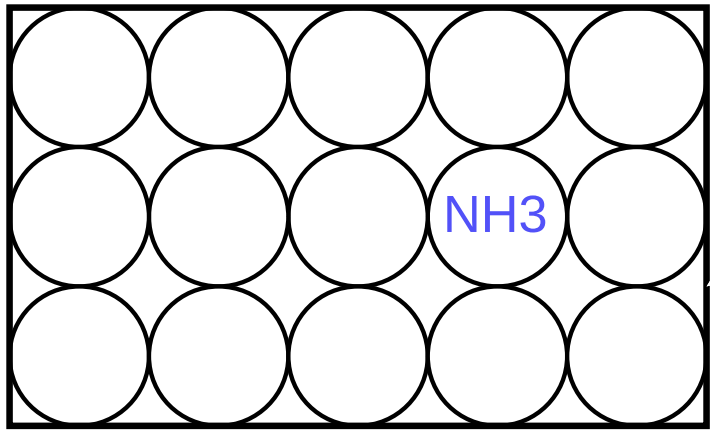
Target Polarization

NH_3 : $P_t \approx 0.68 \pm 0.017$

ND_3 : $P_t \approx 0.18 \pm 0.007$

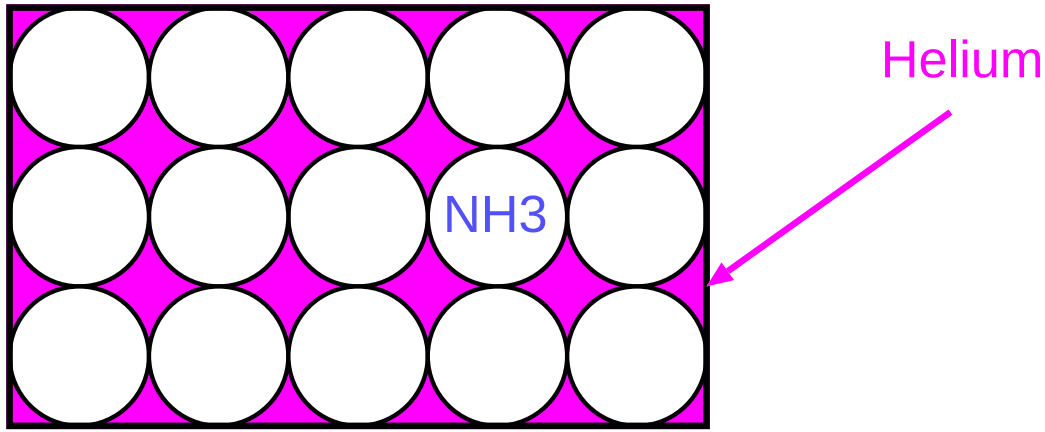
Packing fractions

Packing fraction is ratio of NH_3



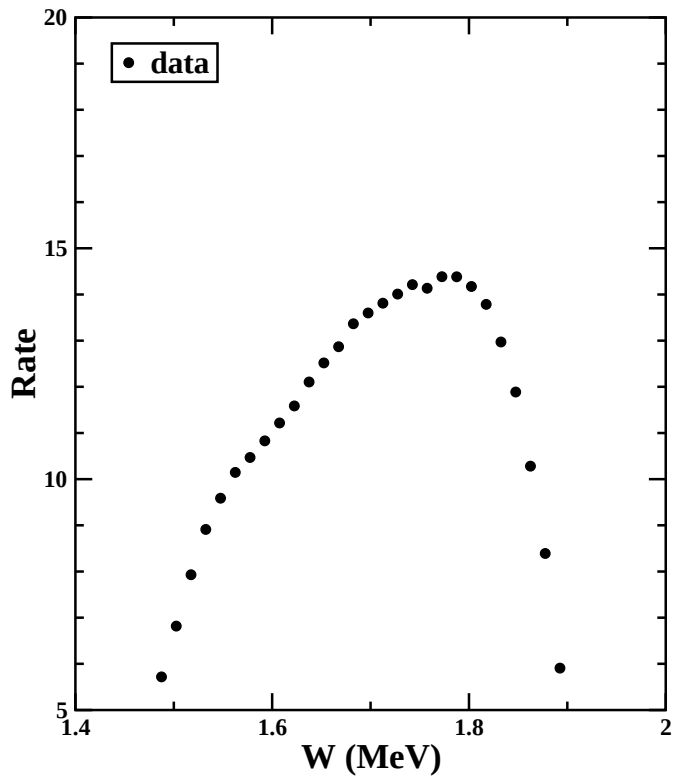
Packing fractions

Packing fraction is ratio of NH_3 to (NH_3 + He).



Packing fractions

Work of S. Tajima



Packing fractions

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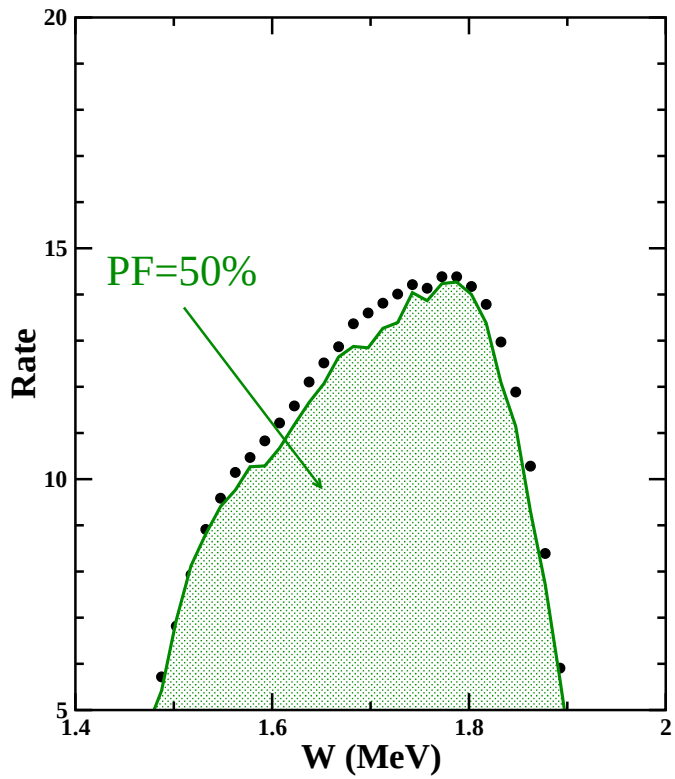

Packing fractions

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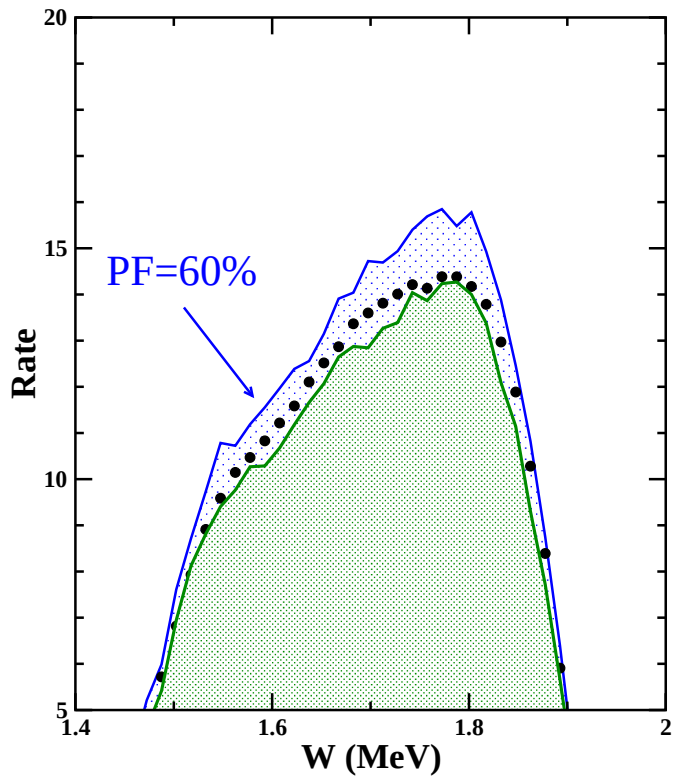
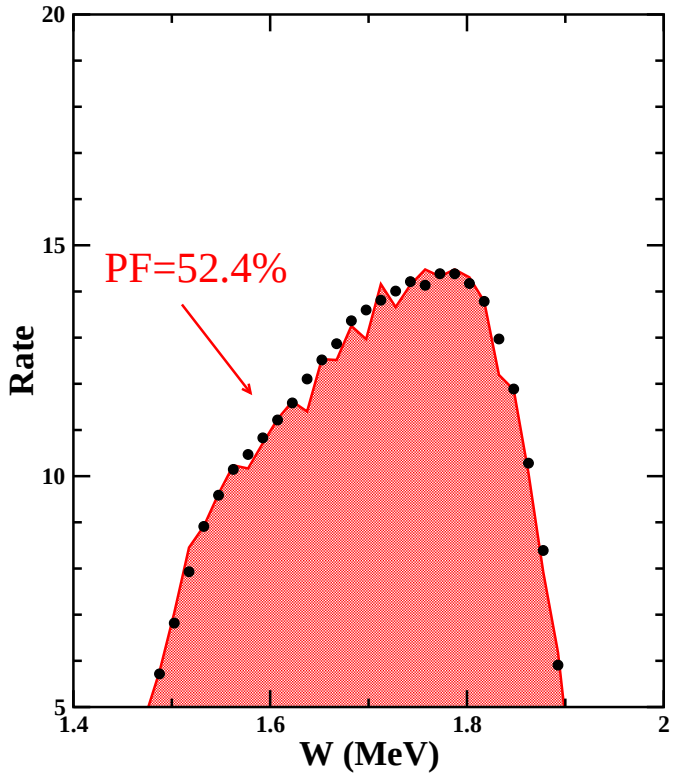
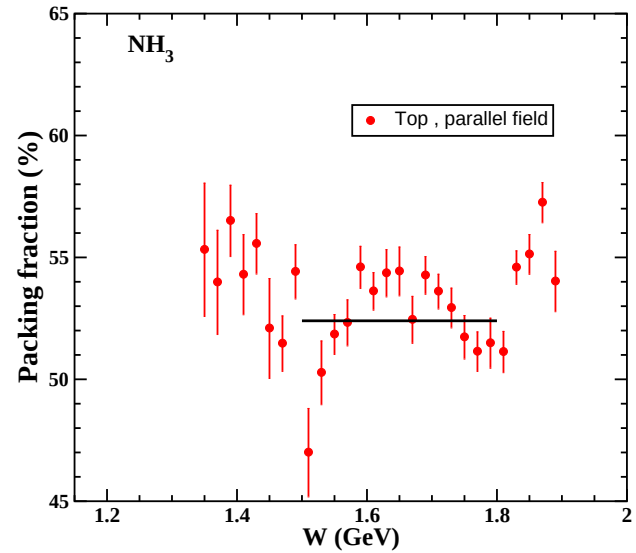


Packing fractions

Work of S. Tajima



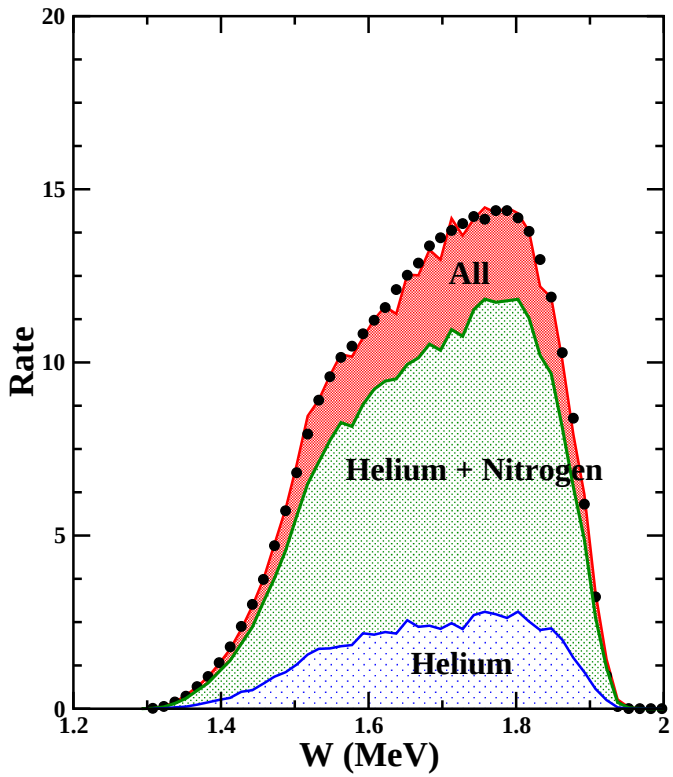


Packing Fractions

	NH_3		ND_3	
	$B_{\parallel}$	$B_{\perp}$	$B_{\parallel}$	$B_{\perp}$
Top	52.4%	58.9	55.2	–
Bottom	53.2	60.7	56.0	62.1

Dilution factors

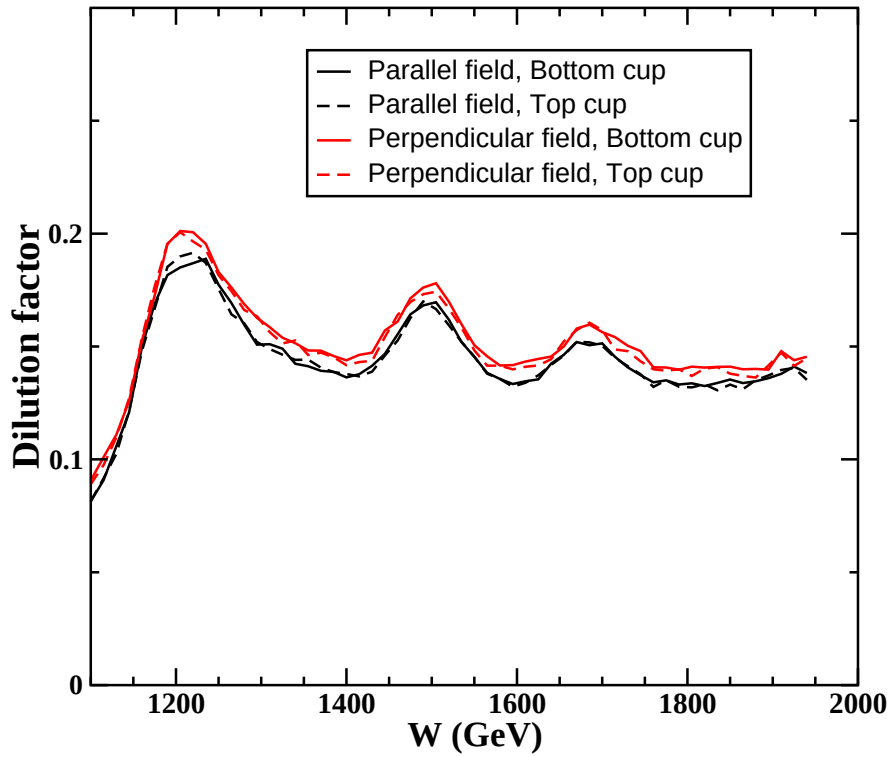
$$f = \frac{\dot{N}_{\text{Pol}}}{\dot{N}_{\text{Tot}}}$$



NH_3

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

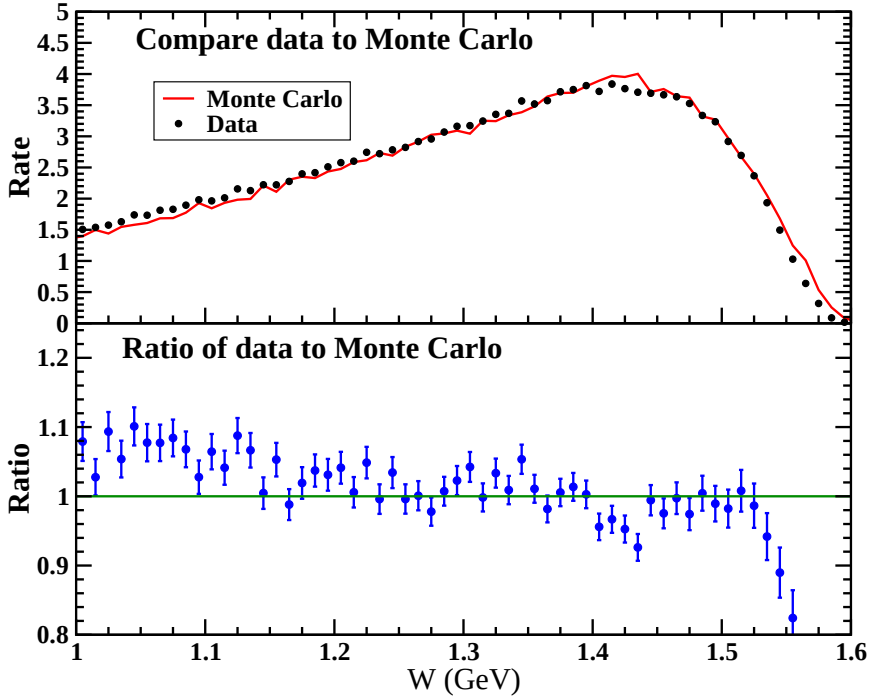
QFS for A $>$ 2



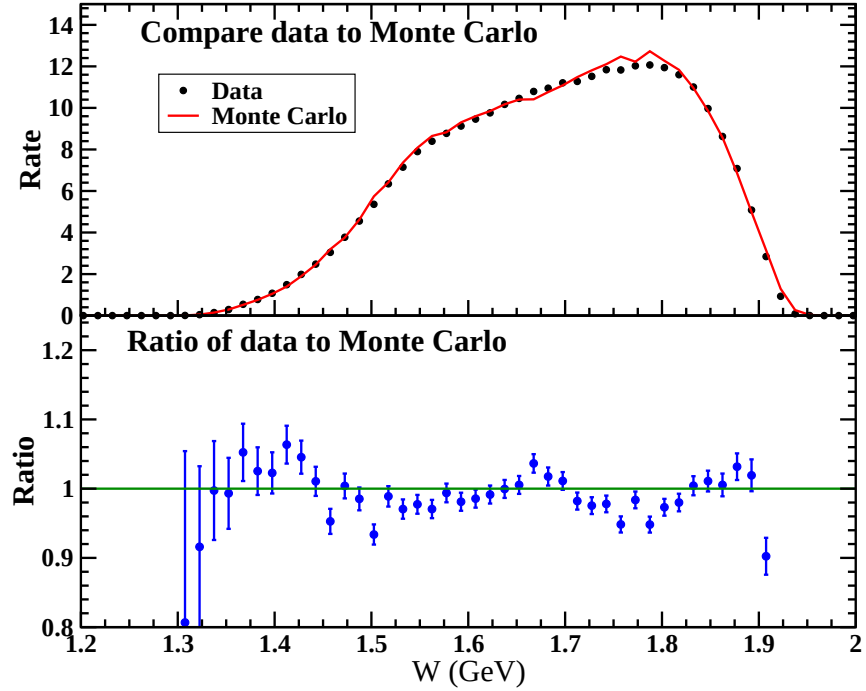
Comparisons to carbon data

Carbon data used to fit QFS model.

P_0 = 4.7 GeV/c



P_0 = 4.1 GeV/c



Extracting Asymmetry

- Raw Asymmetries

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

N^+, N^- : Helicity gated counts, normalized by the charge and deadtime

Extracting Asymmetry

- Raw Asymmetries

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

- Physics Asymmetries

$$A_{\parallel,\perp} = \frac{1}{C f_{rc}} \frac{1}{f P_b P_t} A_{raw} + A_{rc}$$

f : ratio of rates from polarized nucleons to all nucleons.

P_b, P_t : beam and target polarizations.

C : corrections for ^{15}N asymmetry

f_{rc}, A_{rc} : radiative corrections

POLRAD (Akusevich *et al.*)

Inelastic Asymmetries

^{15}N asymmetry correction (≈ 1.02) applied to data.

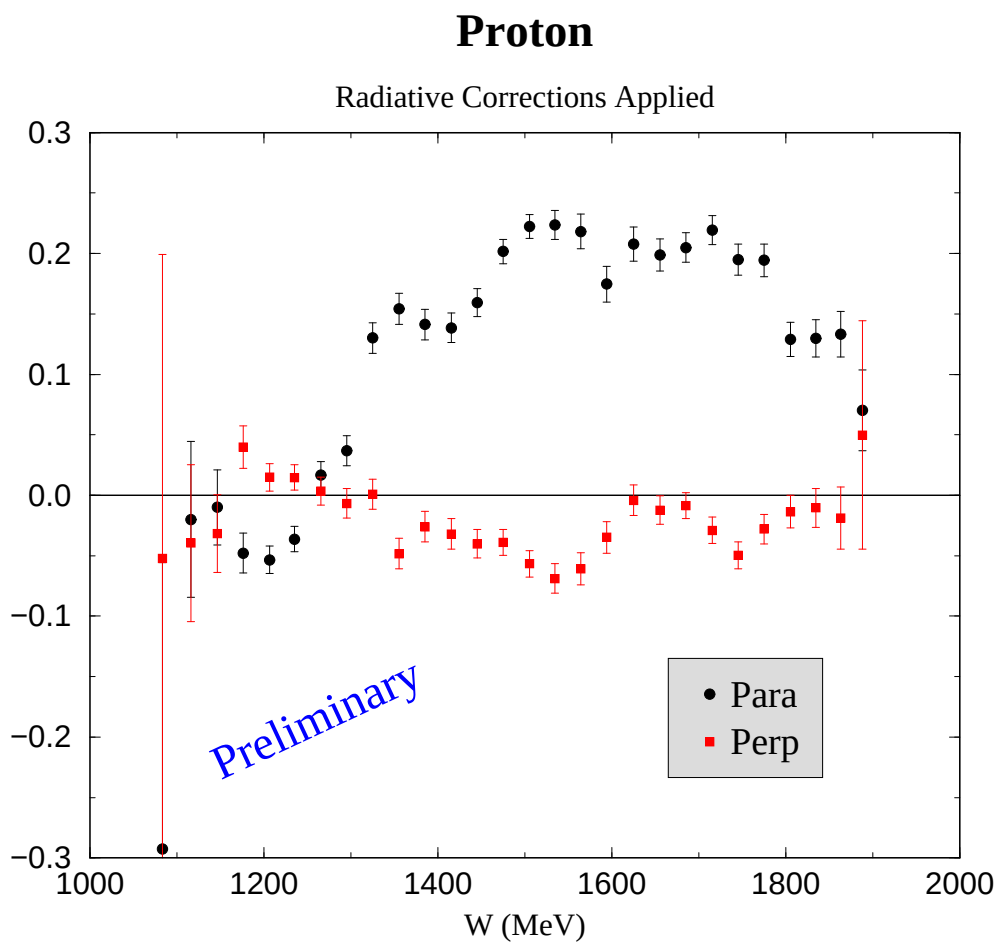
Radiative corrections have been applied to proton data.
(deuteron in progress.)

Expected Systematic Errors:

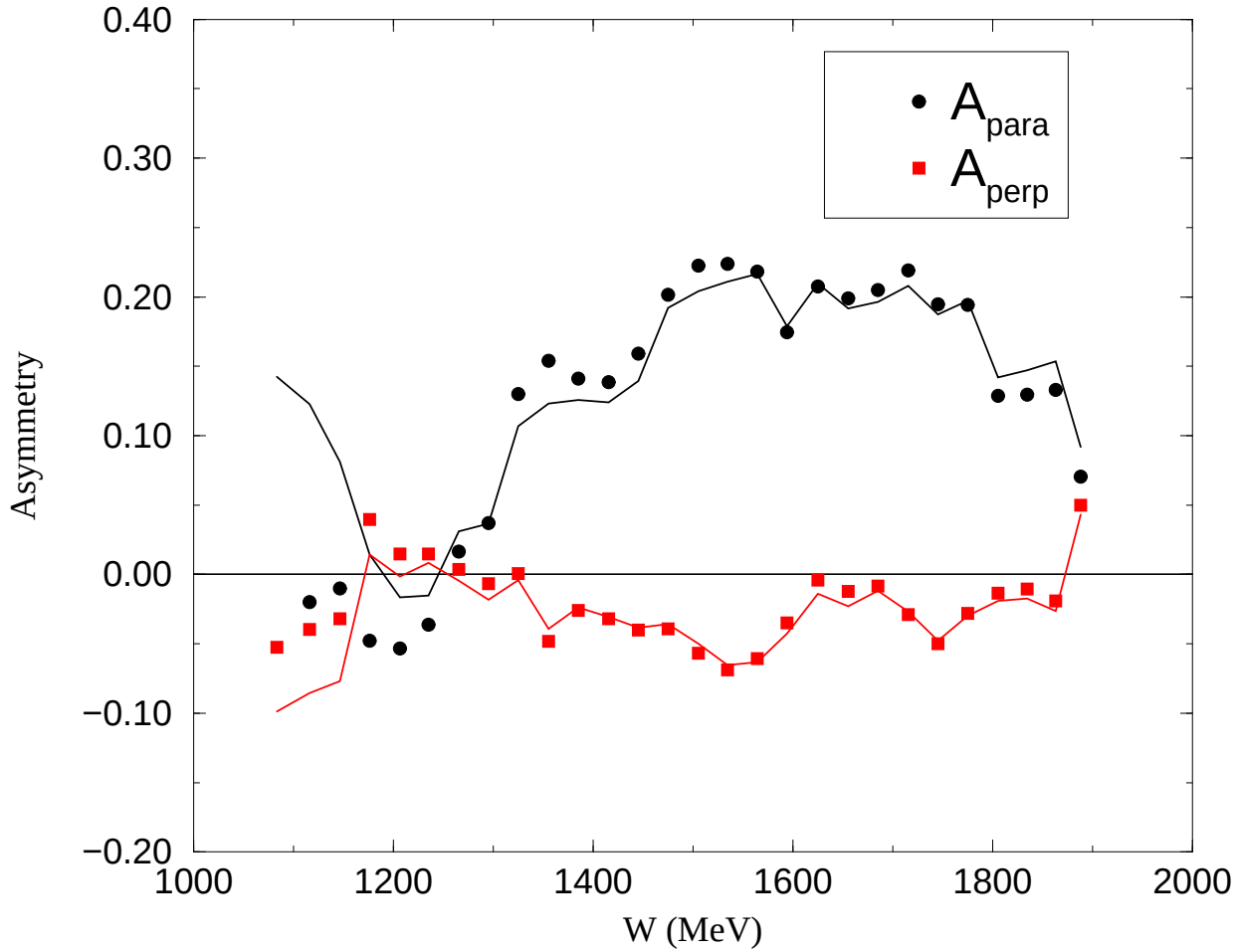
- NH_3 : 6% (relative)
- ND_3 : 8% (relative)

$A_{\parallel}$ and $A_{\perp}$ transformed to A_1 and A_2 using Hall C R fit (M. E. Christy)

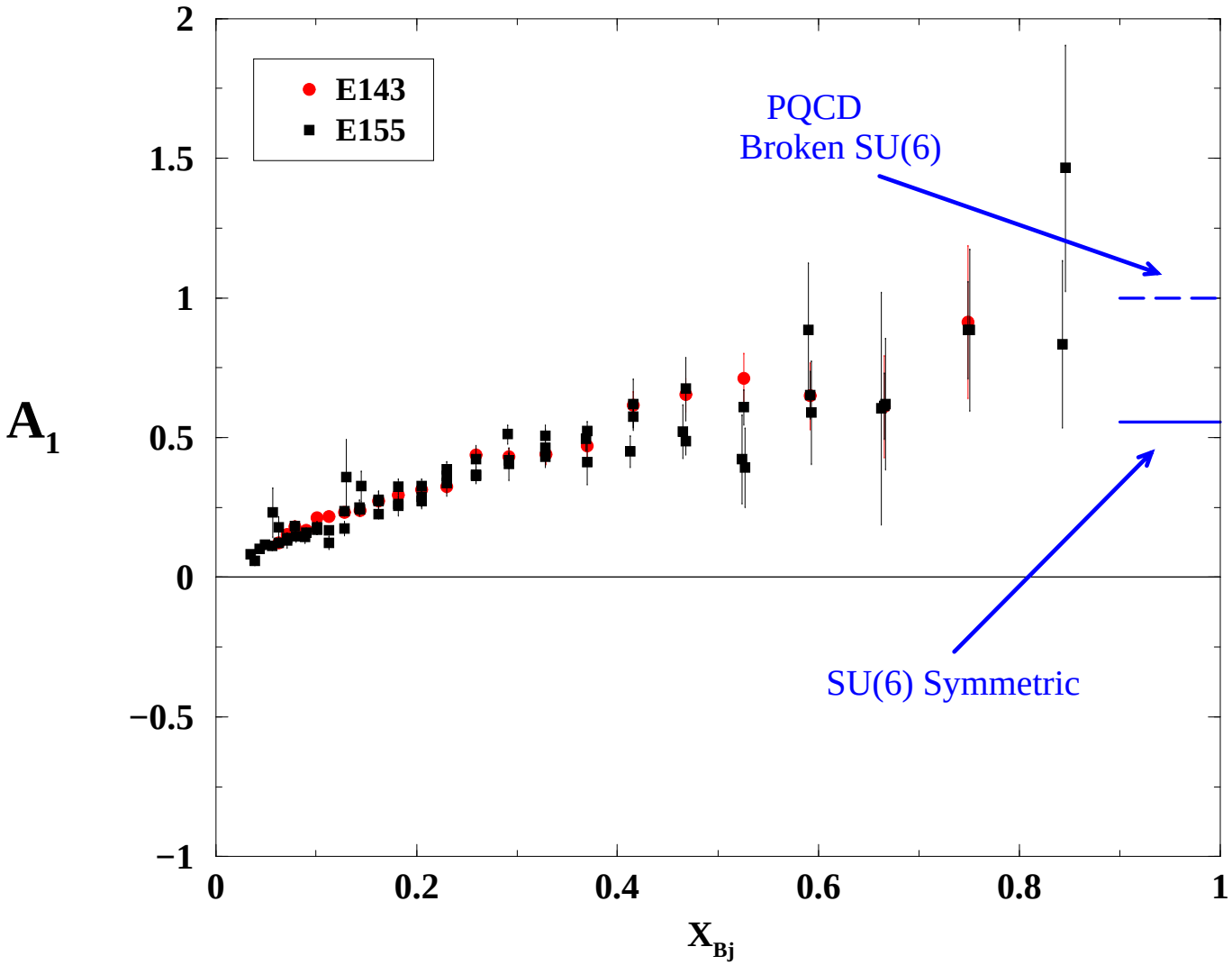
Asymmetries



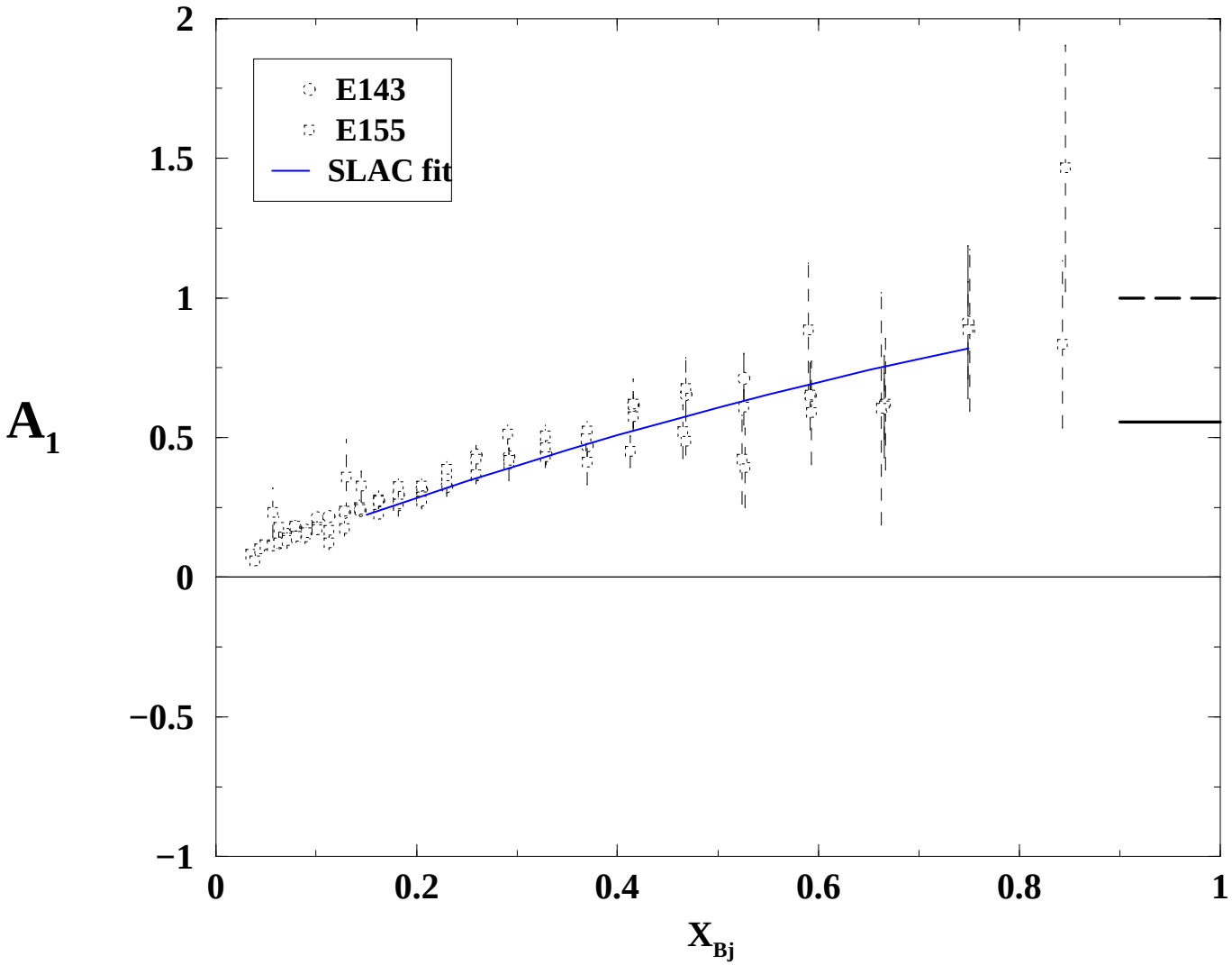
Radiative Corrections



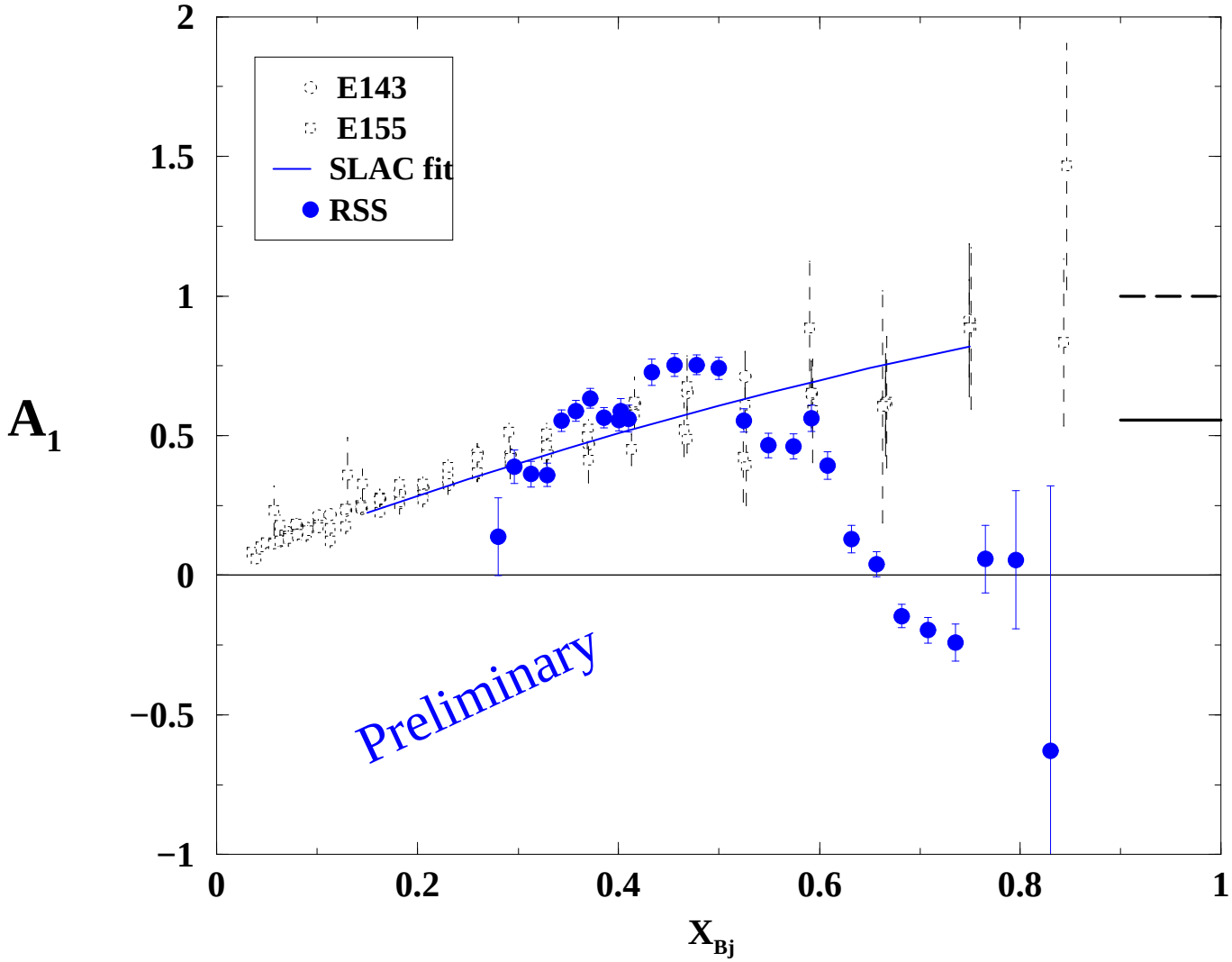
Proton A_1


E143
E155
PQCD
Broken SU(6)
SU(6) Symmetric
A1
XBj
2
1.5
1
0.5
0
−0.5
−1
0
0.2
0.4
0.6
0.8
1

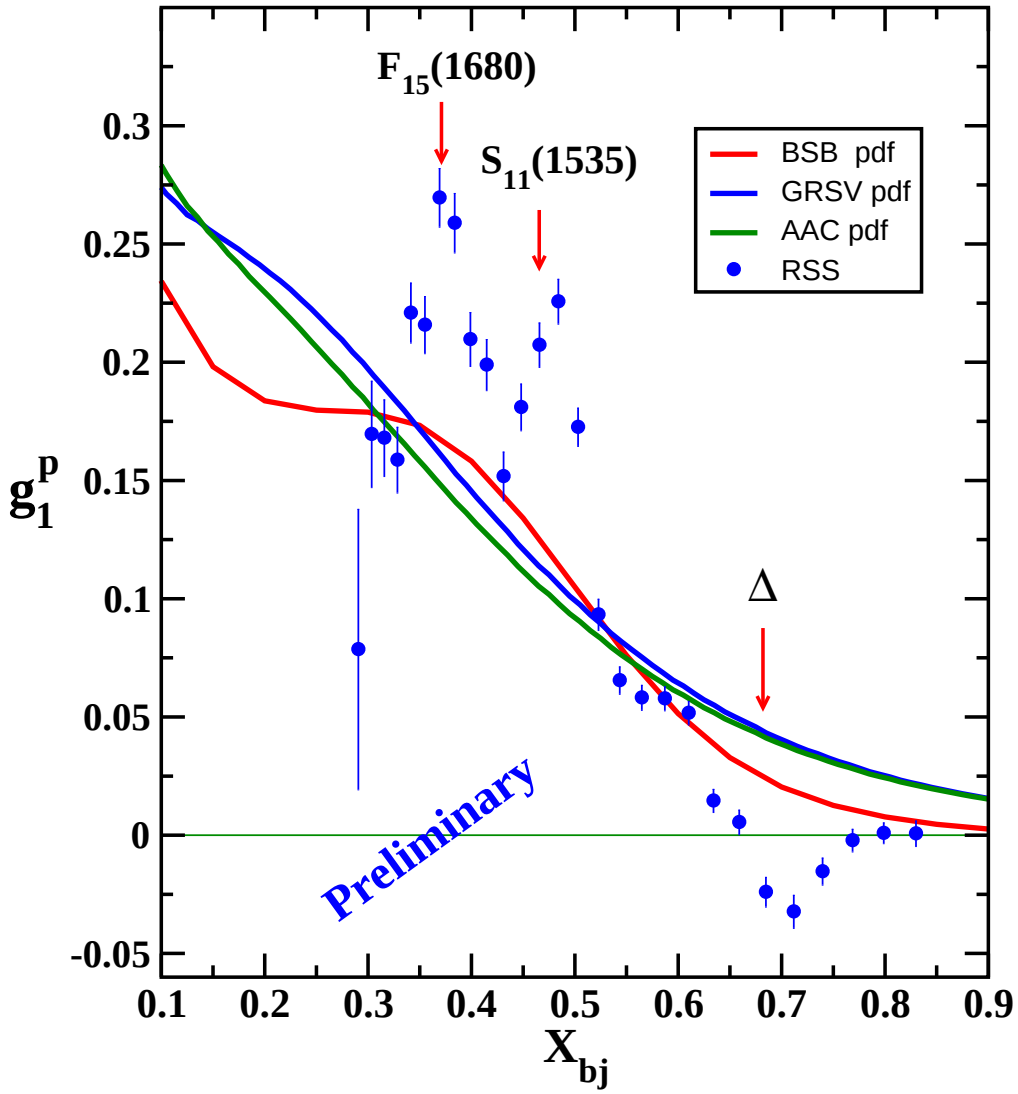
Proton A_1



Proton A_1


E143
E155
SLAC fit
RSS
Preliminary
A_1
X_{Bj}
2
1.5
1
0.5
0
−0.5
−1
0
0.2
0.4
0.6
0.8
1

Proton g_1



All pdfs evolved to Q^2 = 1.3

GRSV has target mass correction applied.

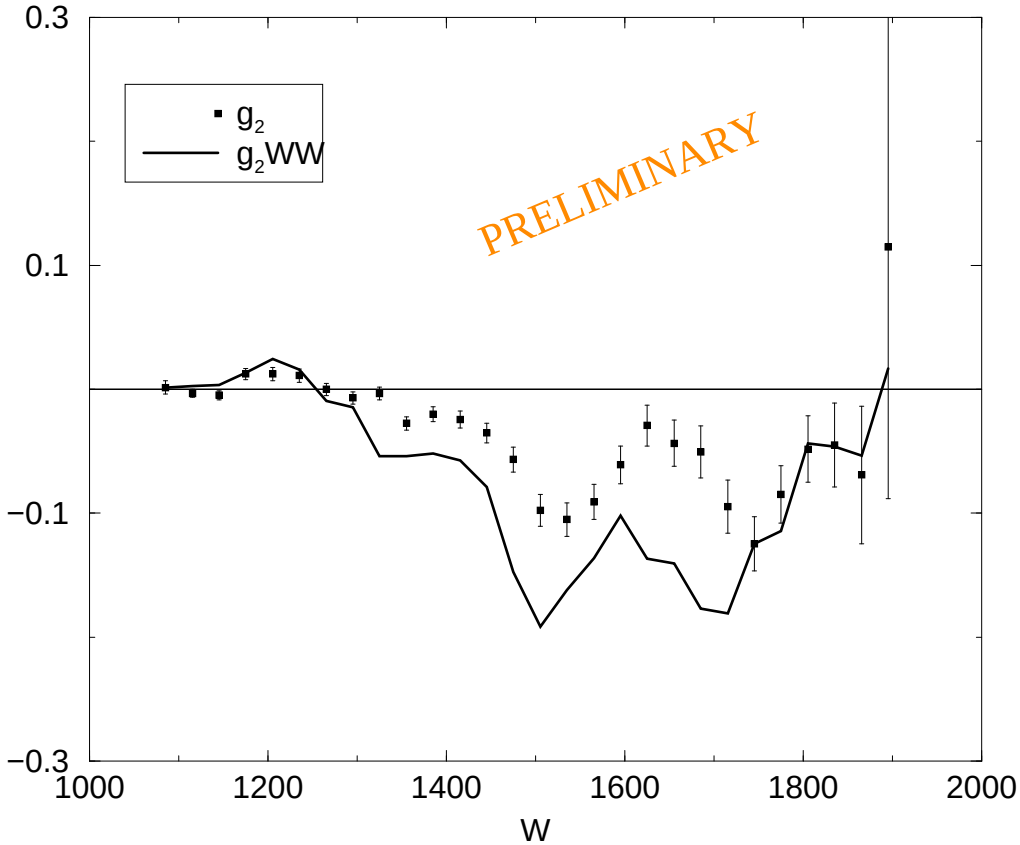
Integral Ratios

$$\text{Ratio} = \frac{\Gamma_1^{DIS}}{\Gamma_1^{Res}}$$

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

W	Stat PDF	GRSV	+ tm	AAC 1	Ave
1.08-1.91	1.03	1.11	1.12	1.03	1.05 ± 0.03
1.21	1.97	3.57	3.56	3.39	3.07 ± 0.6
1.35	1.08	1.24	1.25	1.16	1.16 ± 0.06
1.55	0.78	0.72	0.73	0.67	0.71 ± 0.03
1.74	0.83	0.80	0.80	0.73	0.77 ± 0.03

Higher twist in g_2



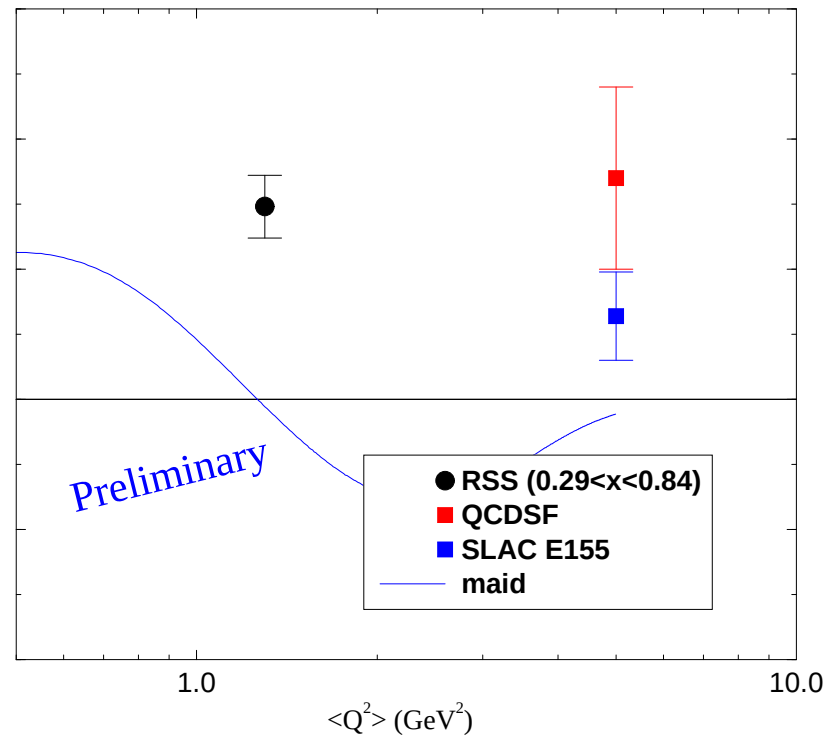
$$g_2 = g_2^{\mathrm{WW}} + \overline{g}_2$$

Twist-2 : $$g_2^{\mathrm{WW}} = -g_1 + \int_x^1 \frac{g_1}{y} dy$$

Twist-3 : $\overline{d_2}$

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

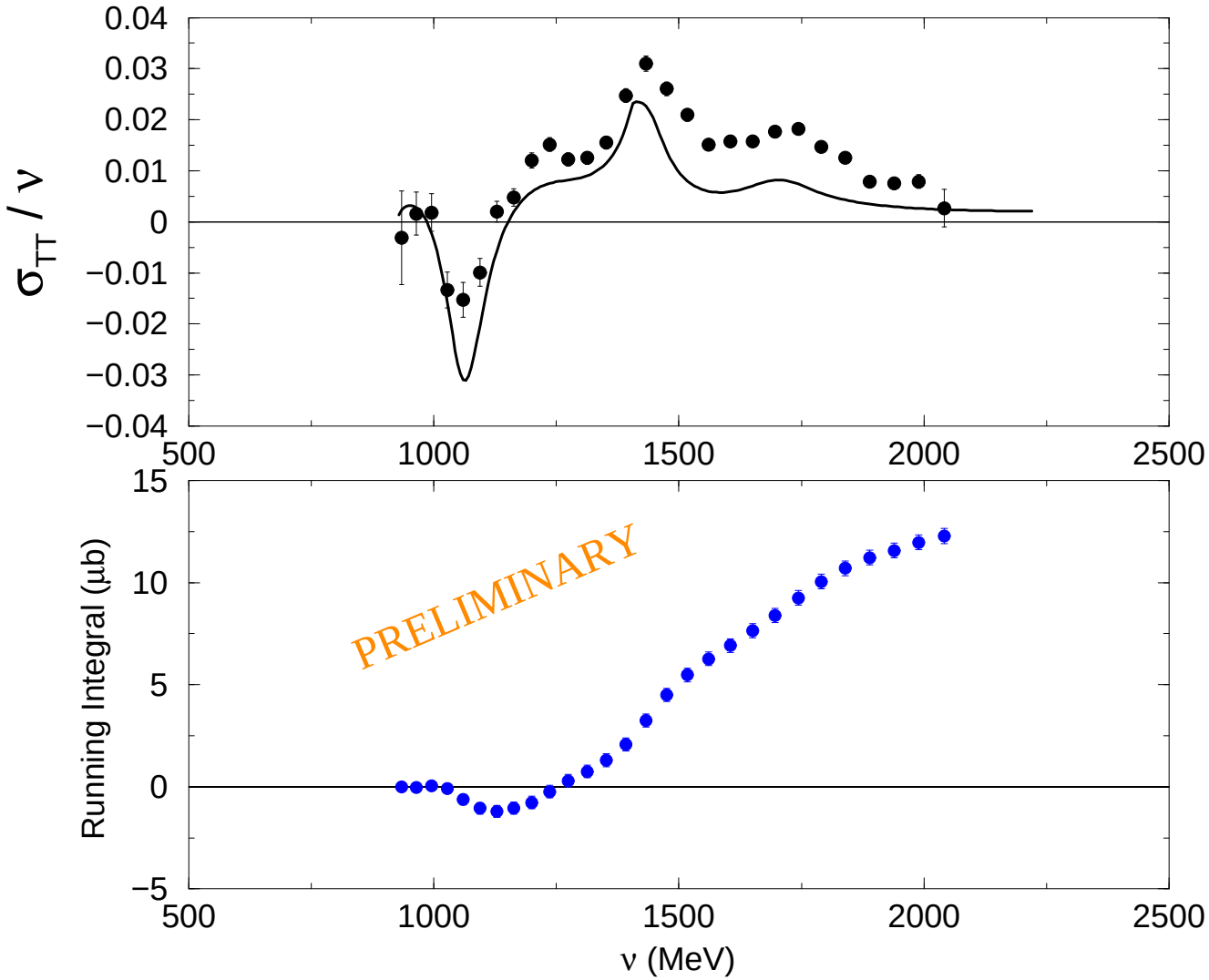
$\overline{d_2}$ = 0.0074 $\pm$ 0.0012
(0.29 $< x_{bj} <$ 0.84)



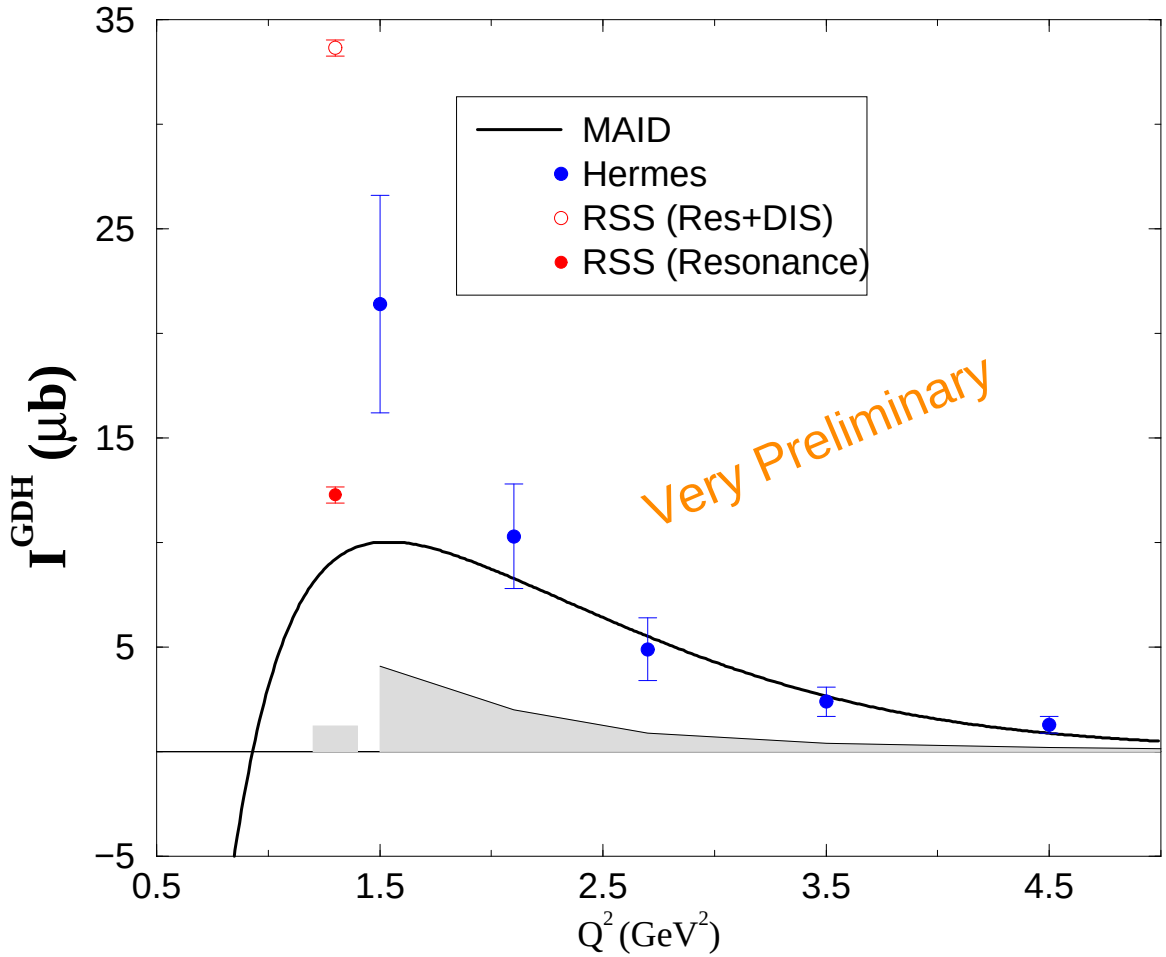
Lattice QCD at $Q^2 = 5$
d_2 = 0.0085 $\pm$ 0.0035
QCDSF group , hep-lat/0011091

SLAC E155 at $< Q^2 >= 5$
$\overline{d_2}$ = 0.0032 $\pm$ 0.0017

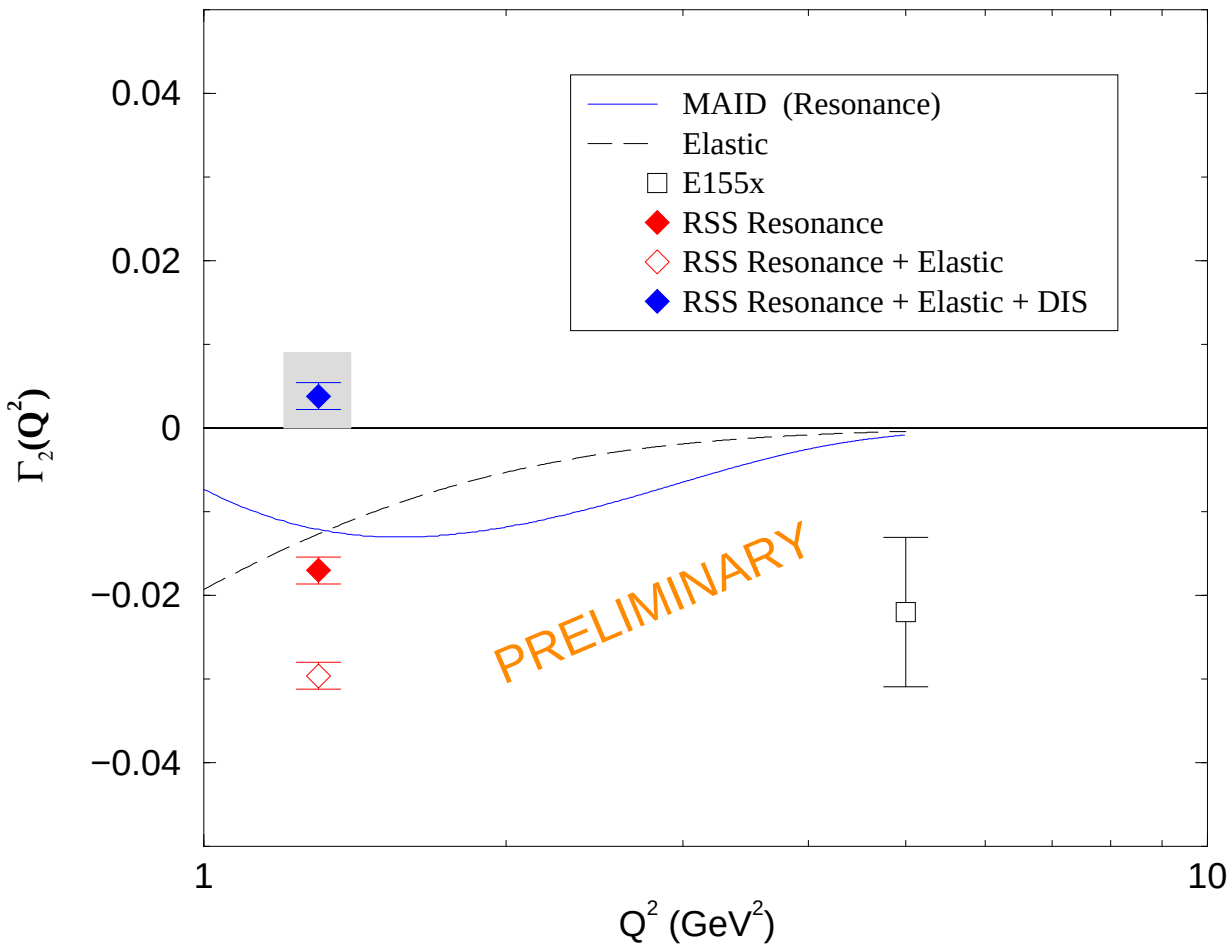
σ'_{TT}


0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
σTT / ν
500
1000
1500
2000
2500
15
10
5
0
−5
Running Integral (μb)
PRELIMINARY
ν (MeV)

Extended GDH Sum



Burkhart-Cottingham Sum Rule



RSS Summary

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

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

Extracted A_1 & A_2, g_1 & g_2

Compared to DIS data

Preliminary comparison of g_1 to PDFs

Positive d_2 measured with 15% error

Preliminary SF Moments

To Do

1st draft of publication out for review

Finalizing last pass through proton data

Deuteron analysis

Neutron SSF's from smeared proton and measured deuteron.