E01-012: Spin Duality

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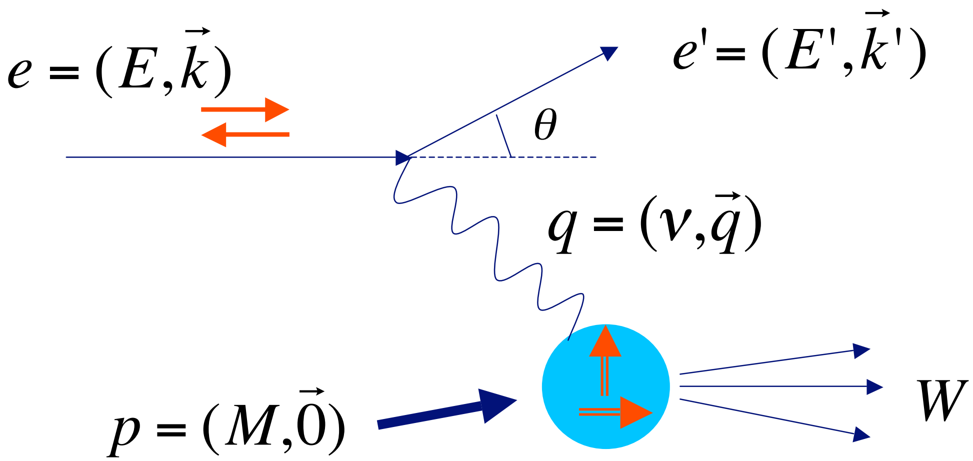
Temple University

Hall A Collaboration Meeting
Jefferson Lab
June 22, 2006

Inclusive Electron Scattering



4-momentum transfer squared

$$Q^2 = -q^2 = 4EE'\sin^2\tfrac{\theta}{2}$$

Invariant mass squared

$$W^2 = M^2 + 2M\nu - Q^2$$

Bjorken variable

$$x = \frac{Q^2}{2M\nu}$$

Unpolarized case

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

Polarized case

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

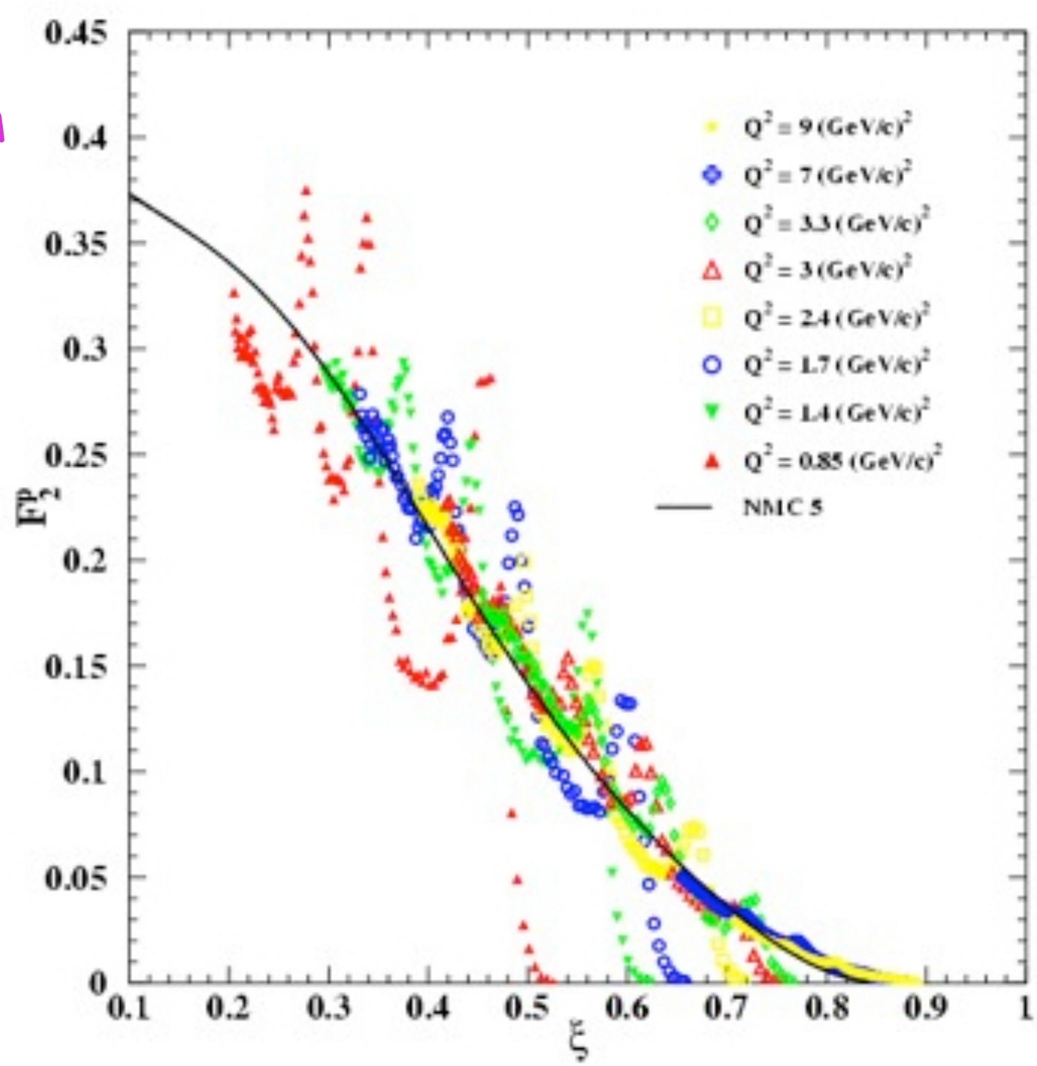
$$\frac{d^2\sigma^{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Rightarrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\sin\theta\left[g_1(x,Q^2) + \frac{2ME}{\nu}g_2(x,Q^2)\right]$$

Quark-hadron duality

- First observed by Bloom and Gilman in the 1970's on F_2

- Scaling curve seen at high Q^2 is an accurate average over the resonance region at lower Q^2

- Global and Local duality are observed for F_2

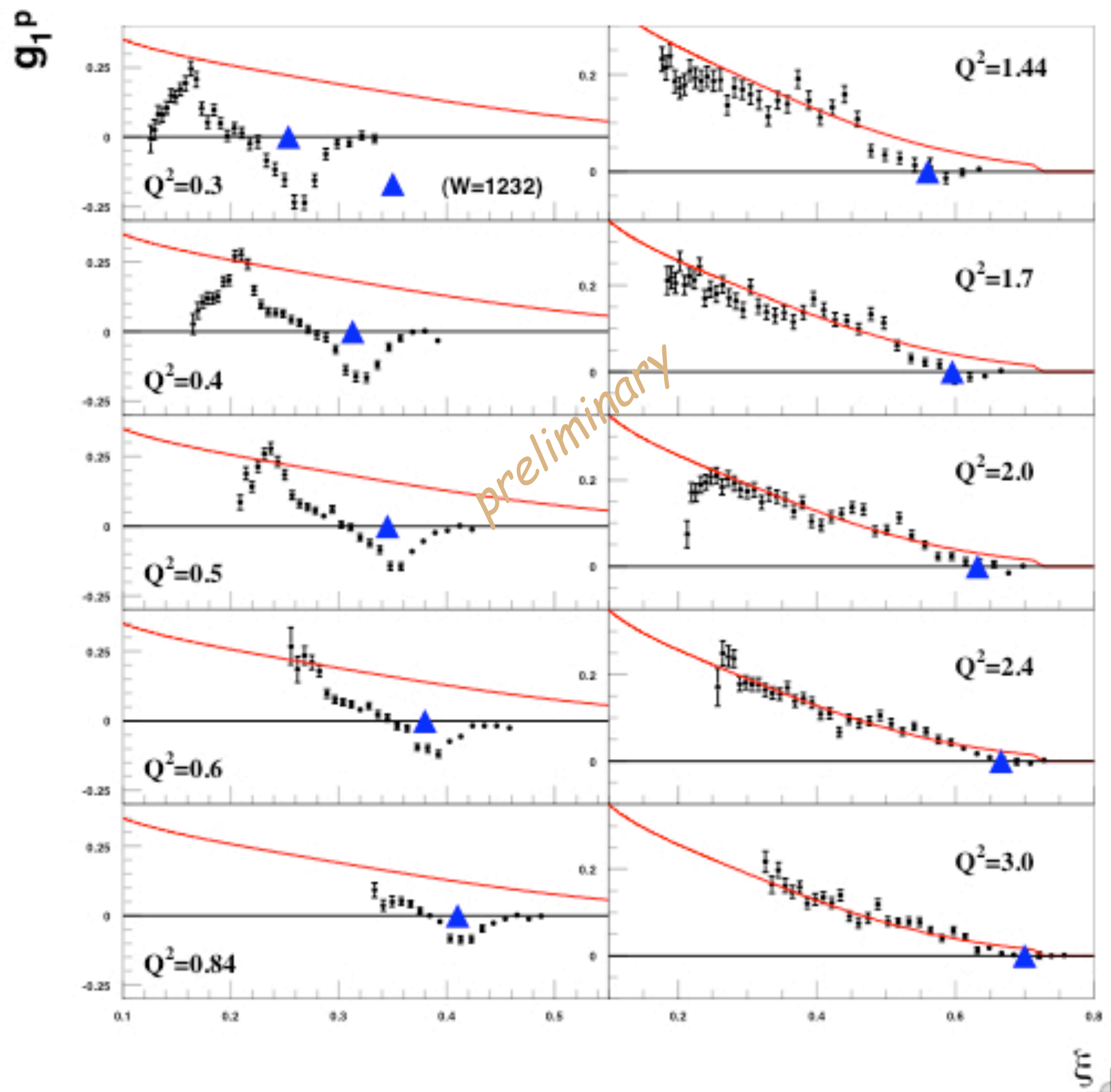


I. Niculescu et al., PRL 85 (2000) 1182

World data

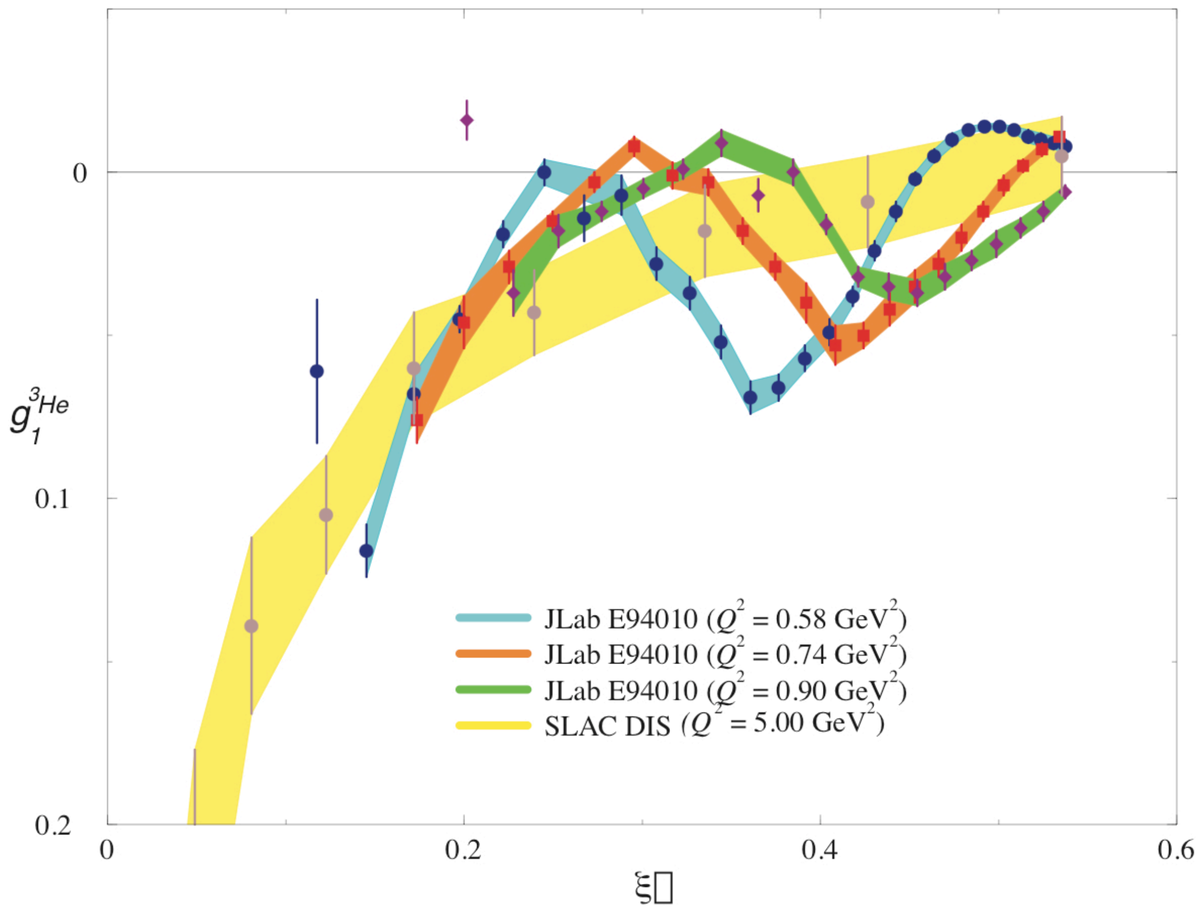
Jlab Hall B for g_1^p

From DIS 2005 proceedings



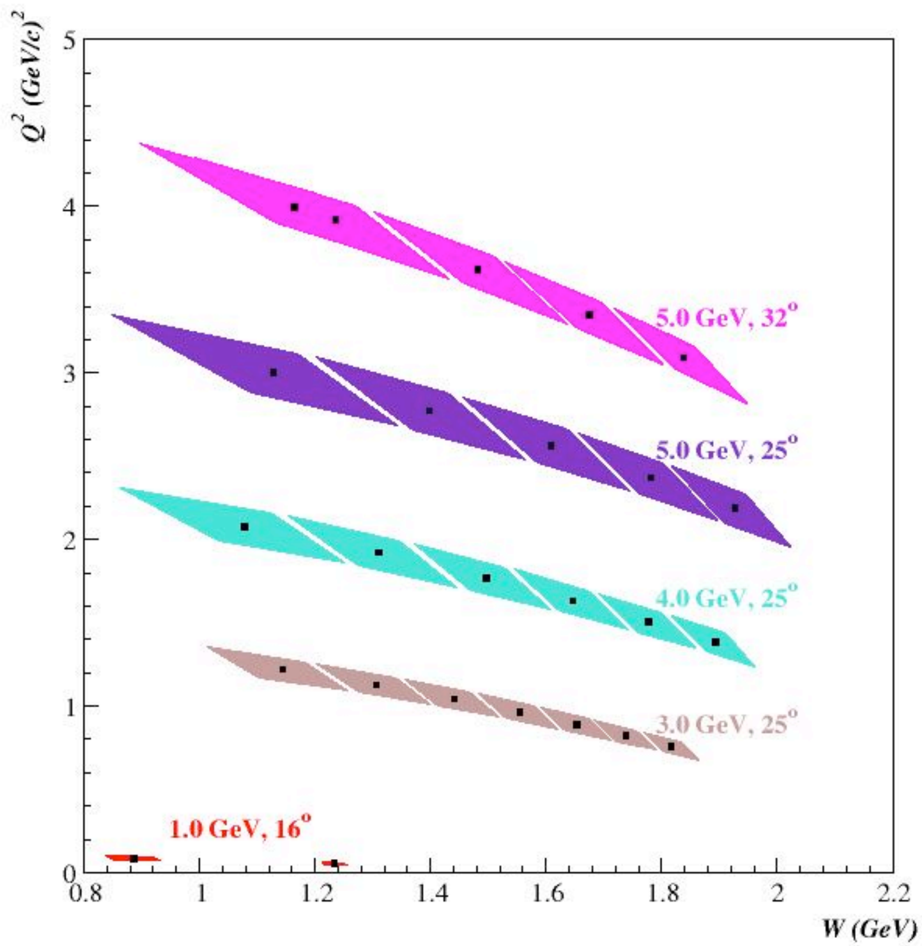
World data

Indication of duality from Jlab Hall A for g_1^{3He}



The experiment E01-012

- Ran in Jan.-Feb. 2003
- Inclusive experiment: $^3\vec{He}(\vec{e},e')X$
  - Polarized electron beam:
    $70 < P_{beam} < 85\%$
  - Hall A in standard equipment:
    - ↪ HRS in symmetric configuration
    - ↪ PID performance $\pi/e < 10^{-4}$
  - Pol. ^3He target (para and perp):
    $\langle P_{targ} \rangle = 37\%$
- Measured polarized cross section differences
- Form g_1 and g_2 for ^3He



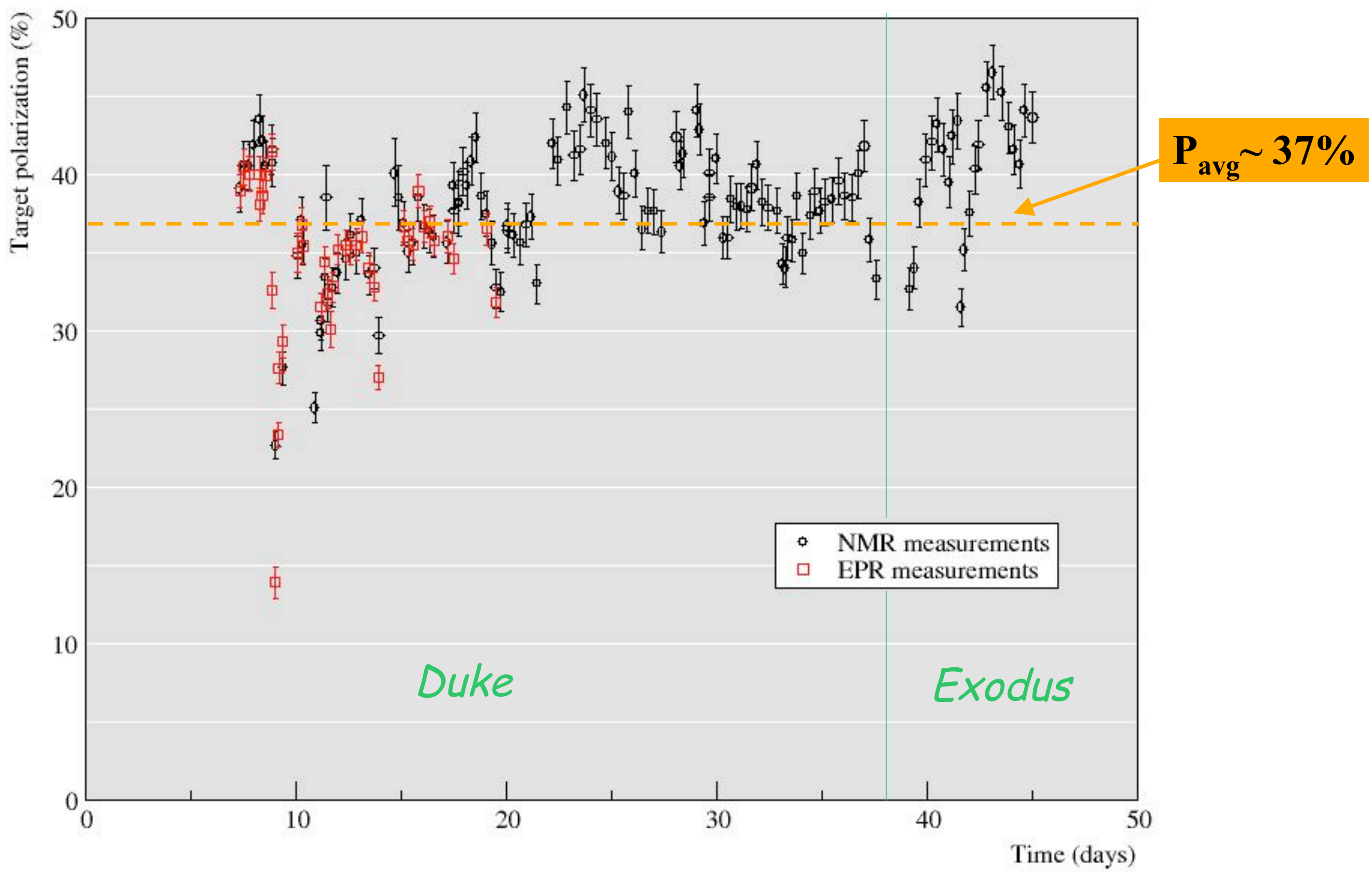
↪ **Test of spin duality on the neutron (^{3}He)**

The E01-012 Collaboration

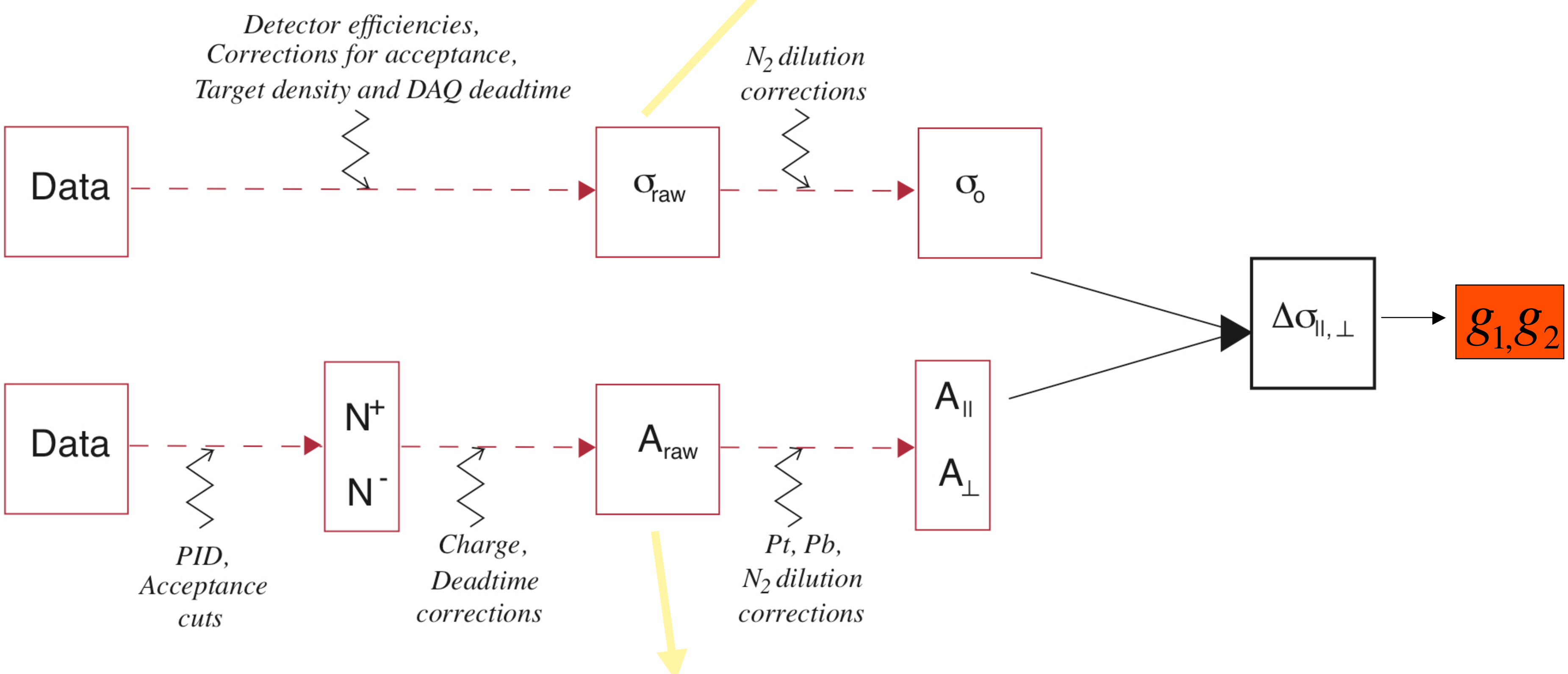
K. Aniol, T. Averett, W. Boeglin, A. Camsonne, G.D. Cates, G. Chang, J.-P. Chen, Seonho Choi, E. Chudakov, B. Craver, F. Cusanno, A. Deur, D. Dutta, R. Ent, R. Feuerbach, S. Frullani, H. Gao, F. Garibaldi, R. Gilman, C. Glashausser, O. Hansen, D. Higinbotham, H. Ibrahim, X. Jiang, M. Jones, A. Kelleher, J. Kelly, C. Keppel, W. Kim, W. Korsch,K. Kramer, G. Kumbartzki, J. LeRose, R. Lindgren, N. Liyanage, B. Ma, D. Margaziotis, P. Markowitz, K. McCormick, Z.-E. Meziani, R. Michaels, B. Moffit, P. Monaghan, C. Munoz Camacho, K. Paschke, B. Reitz, A. Saha, R. Sheyor, J. Singh, K. Slifer, P. Solvignon, V. Sulkosky, A. Tobias, G. Urciuoli, K. Wang, K. Wijesooriya, B. Wojtsekhowski, S. Woo, J.-C. Yang, X. Zheng, L. Zhu

and the Jefferson Lab Hall A Collaboration

Target performance



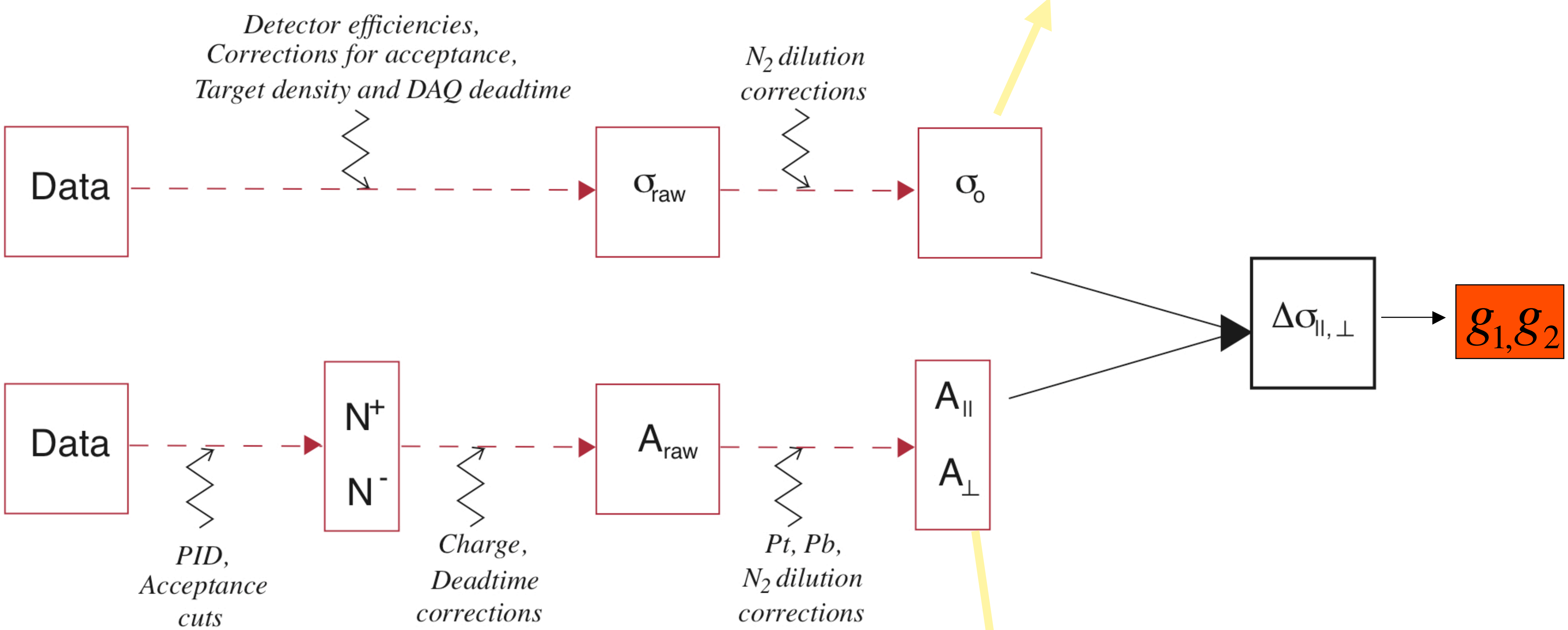
Analysis scheme



$$\sigma_0 = \frac{N_{cuts}}{N_{inc.}\rho\varepsilon_{\det}LT} * Acc.$$

$$A_{\parallel,\perp} = \frac{\frac{N^+}{Q^+LT^+} - \frac{N^-}{Q^-LT^-}}{\frac{N^+}{Q^+LT^+} + \frac{N^-}{Q^-LT^-}}$$

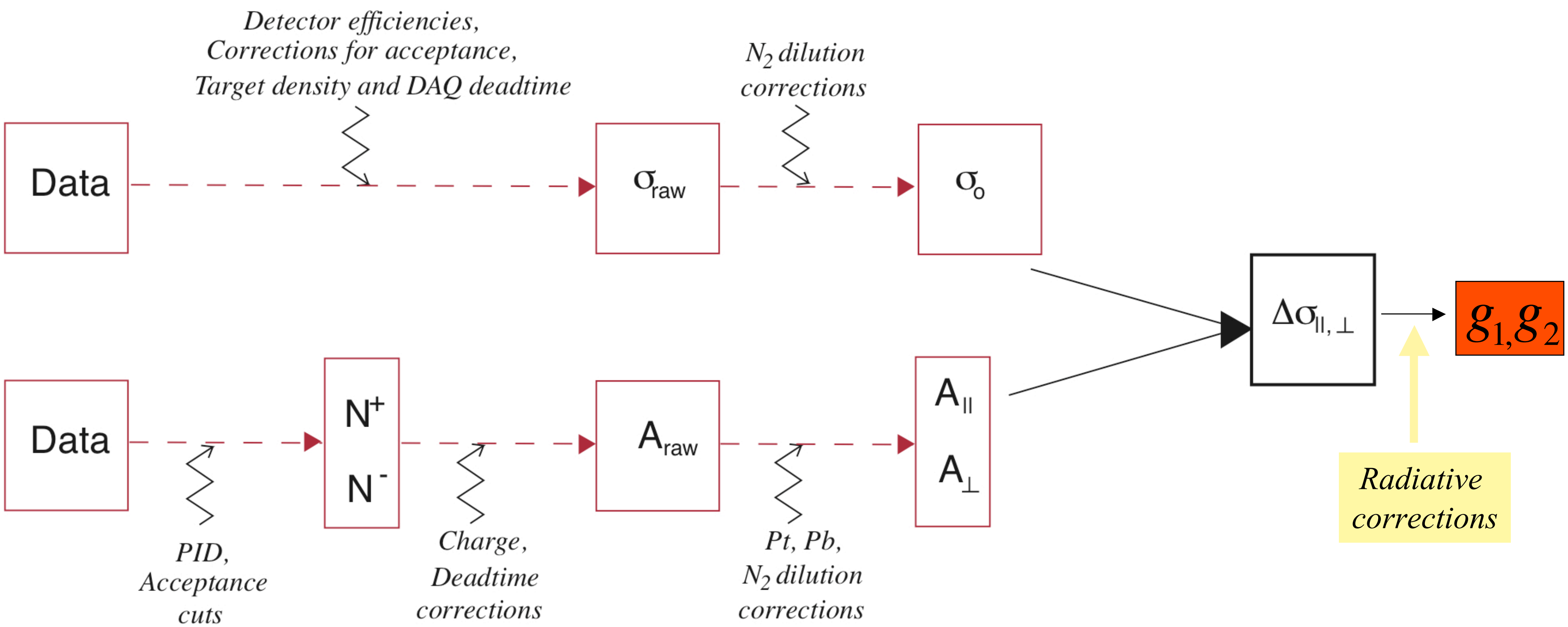
Analysis scheme



$$\sigma_0 = \sigma_{raw} - \frac{\rho_N}{\rho + \rho_N}\sigma_N$$

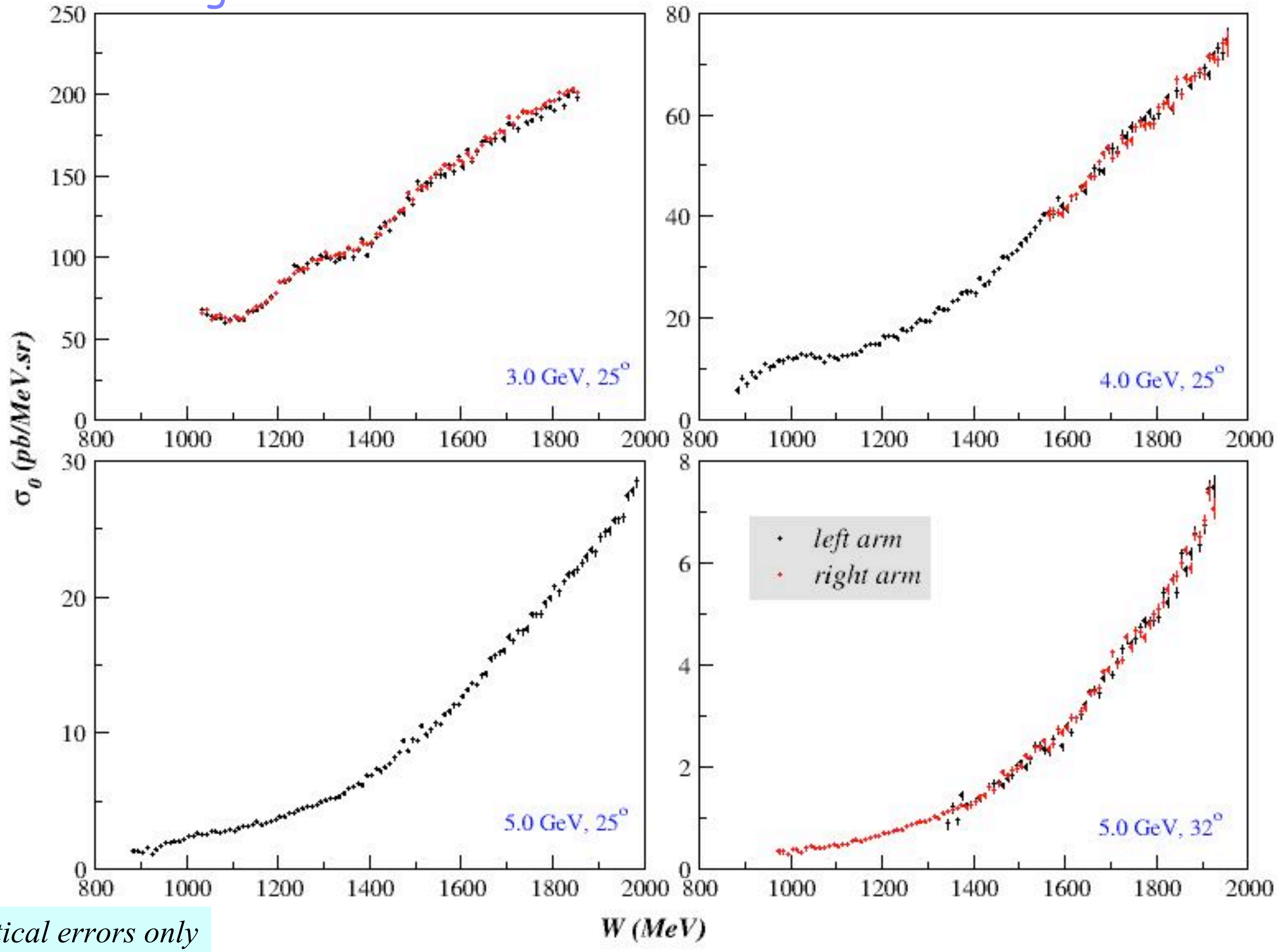
$$A_{\parallel,\perp} = \frac{A_{raw}}{f_{N_2} P_{tg} P_{beam}}$$

Analysis scheme



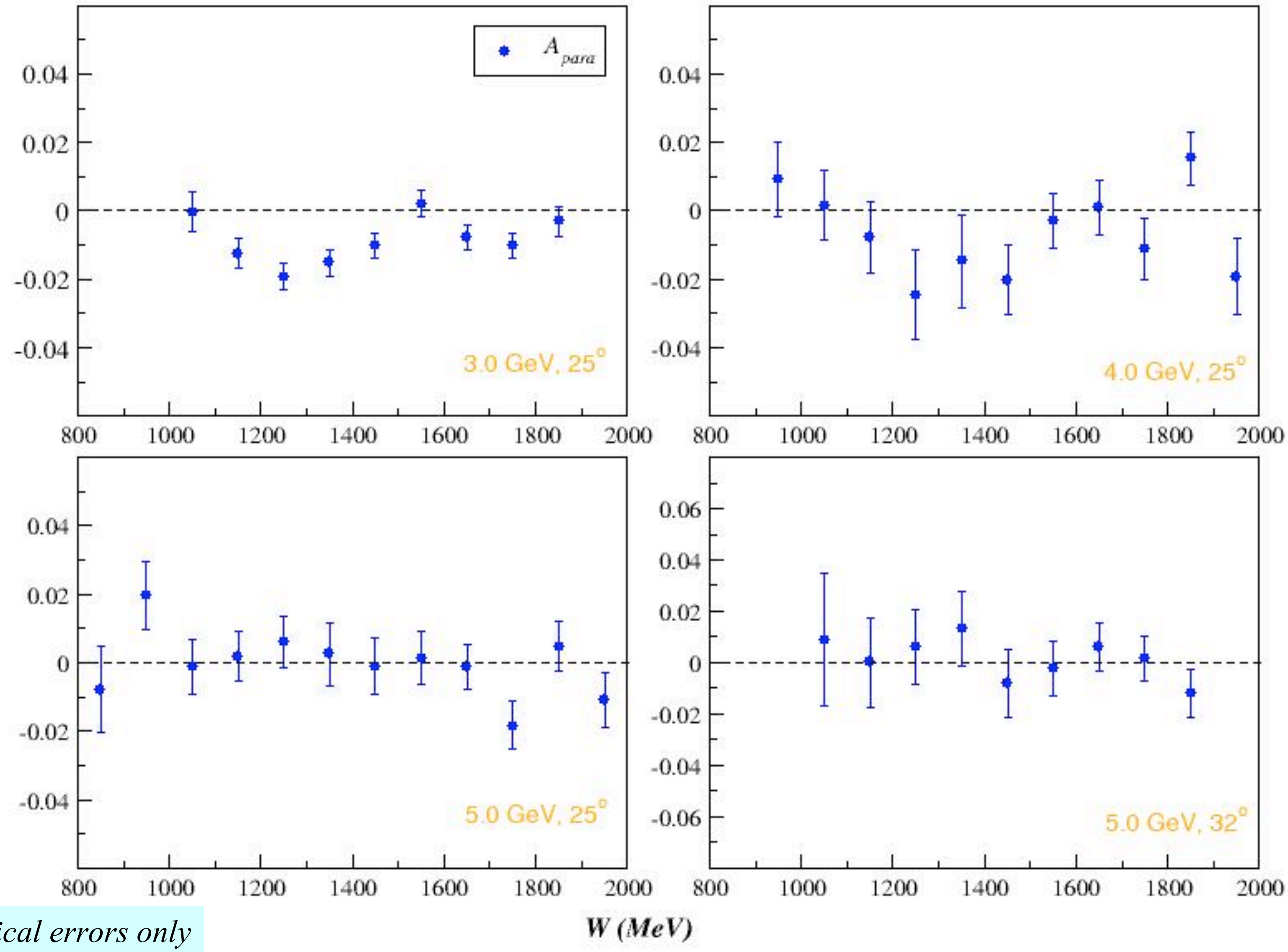
Unpolarized cross sections

Agreement between both HRS better than 2%



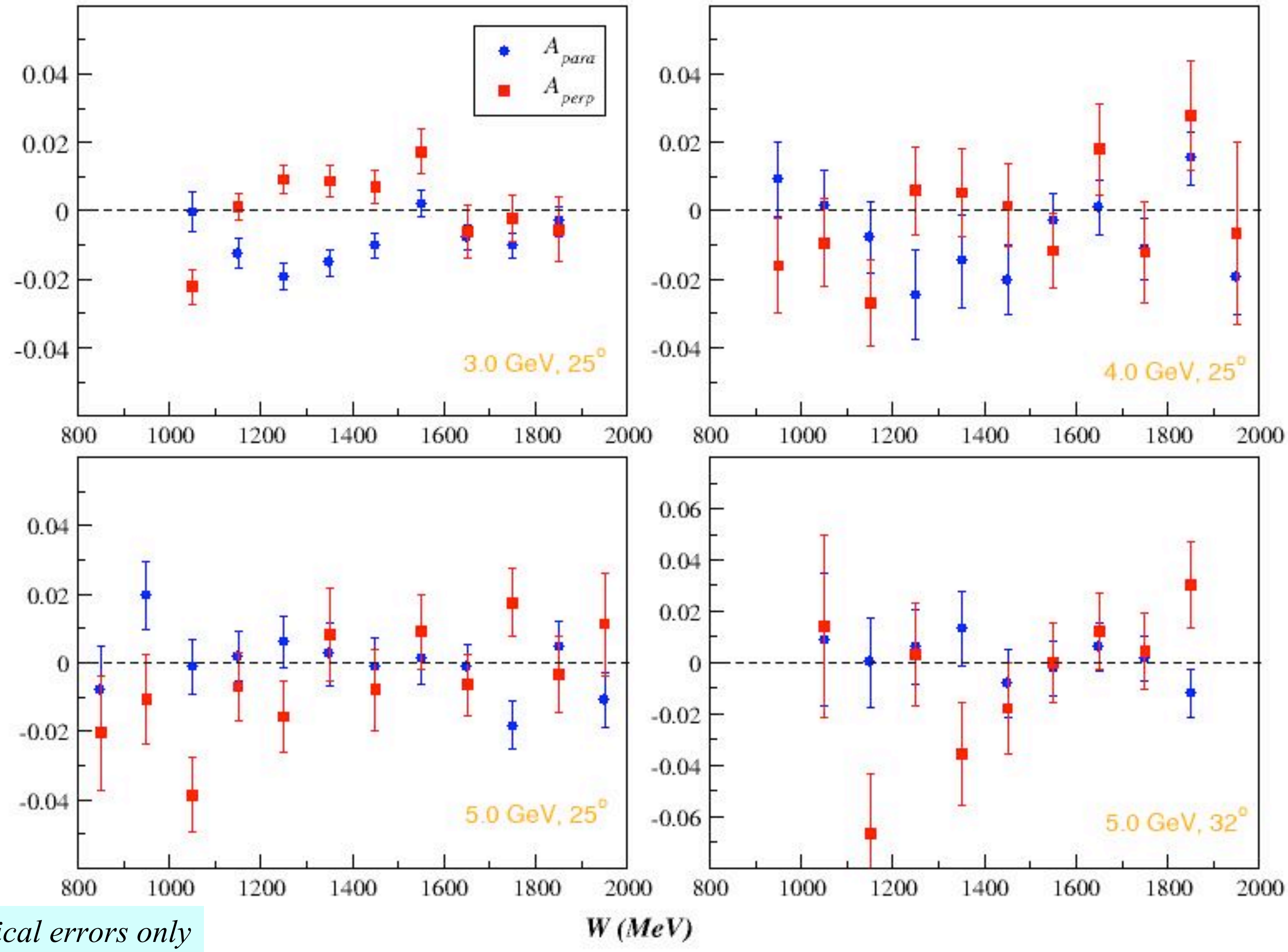
Statistical errors only

Asymmetries



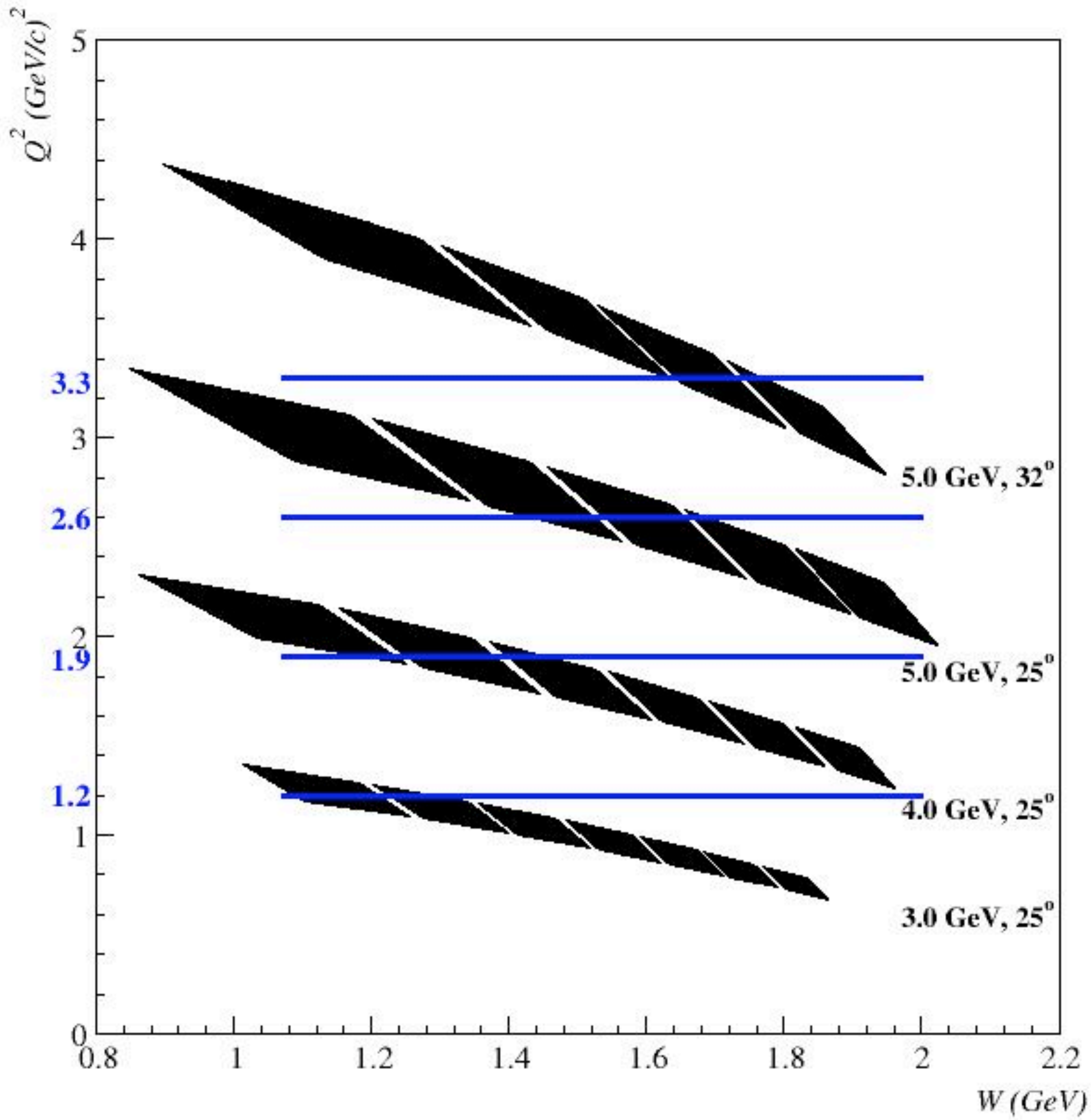
Statistical errors only

Asymmetries

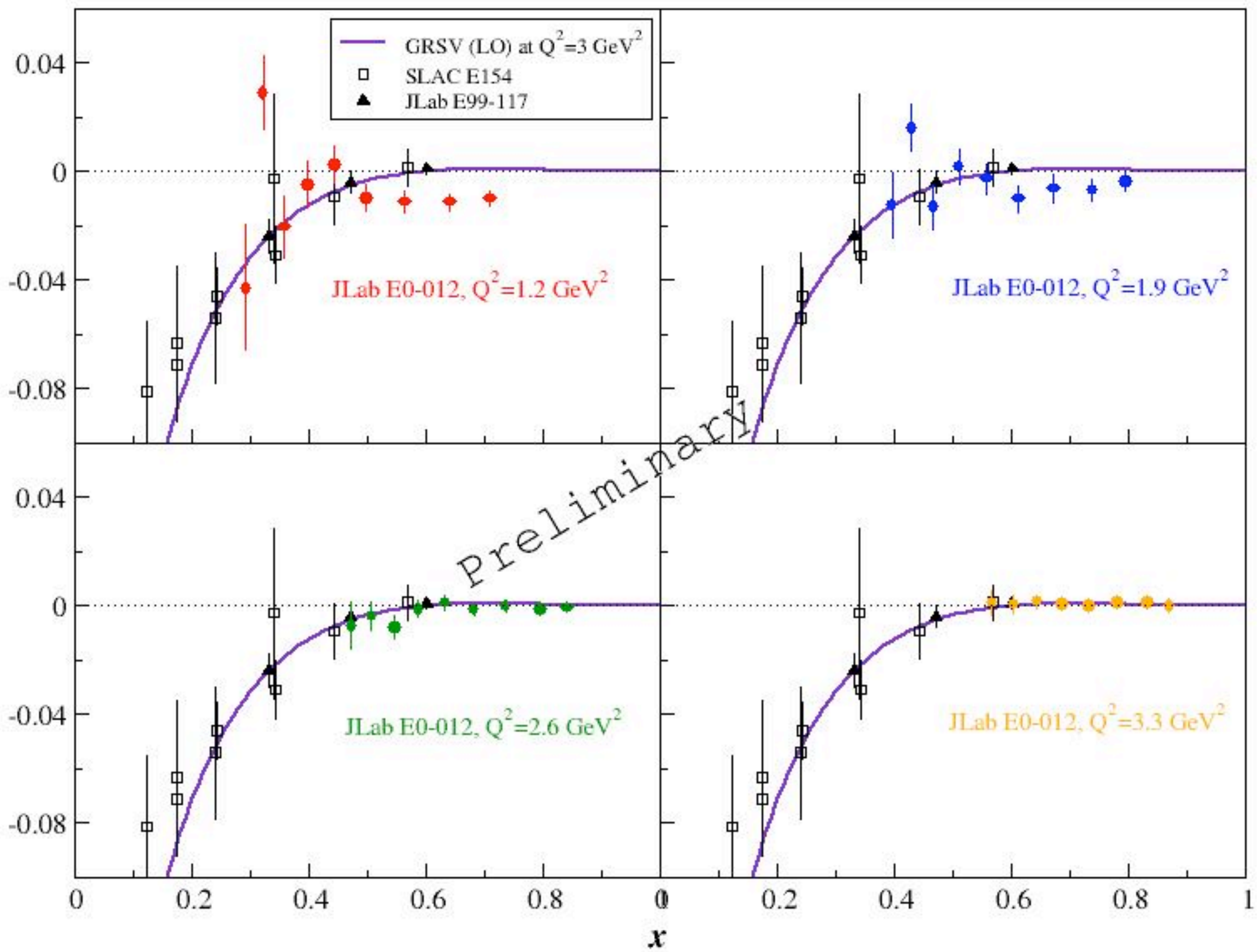


Statistical errors only

From constant E to constant Q^2



$g_1^{^3He}$ at constant Q^2

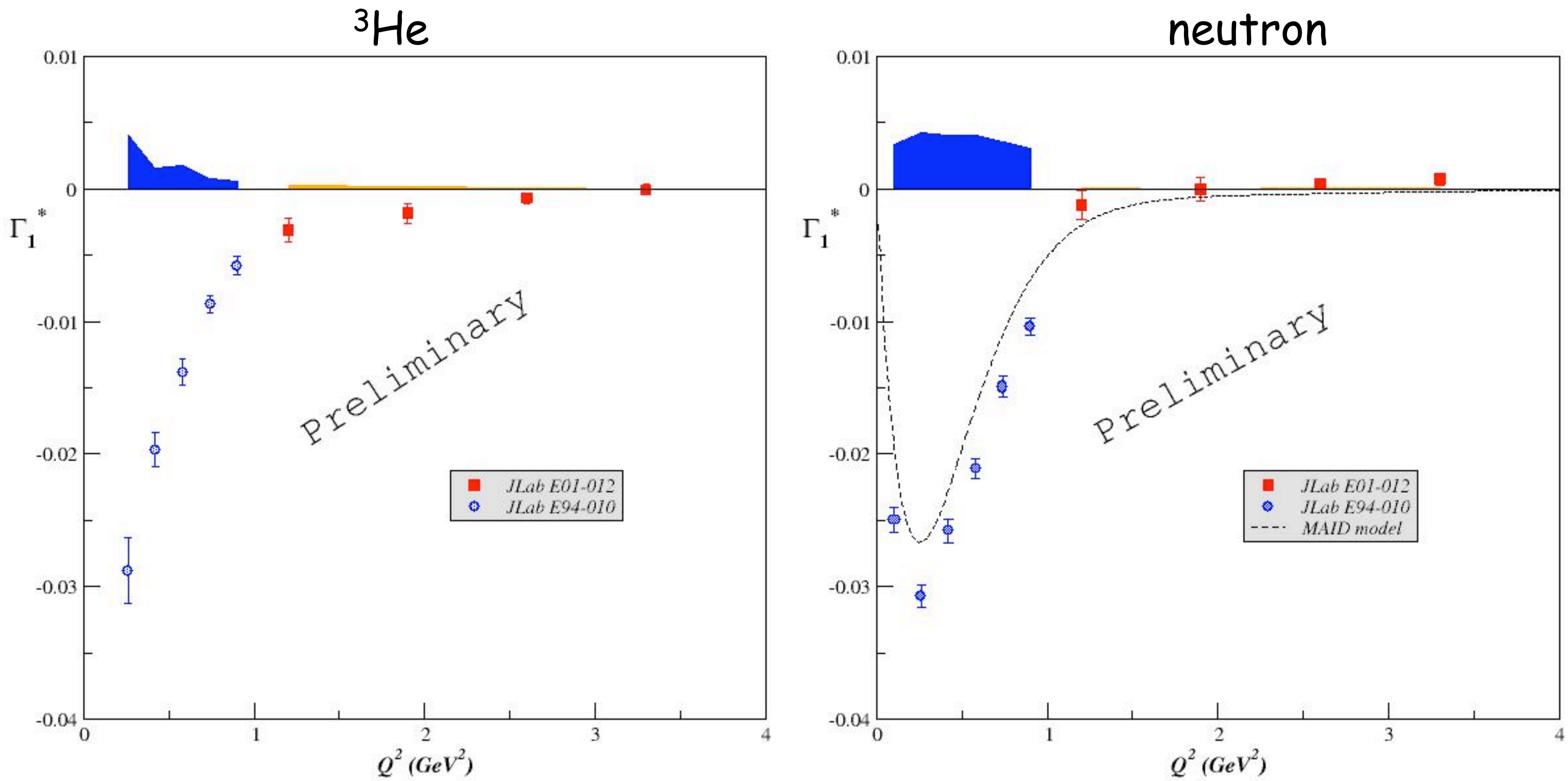


g_1 in the resonance region

Extract the neutron from effective polarization equation:

$$\tilde{\Gamma}_1^{^3He} = P_n \tilde{\Gamma}_1^n + 2P_p \tilde{\Gamma}_1^p$$

P_n=86%
P_p=-2.8%



Test of Duality on Neutron and ^3He

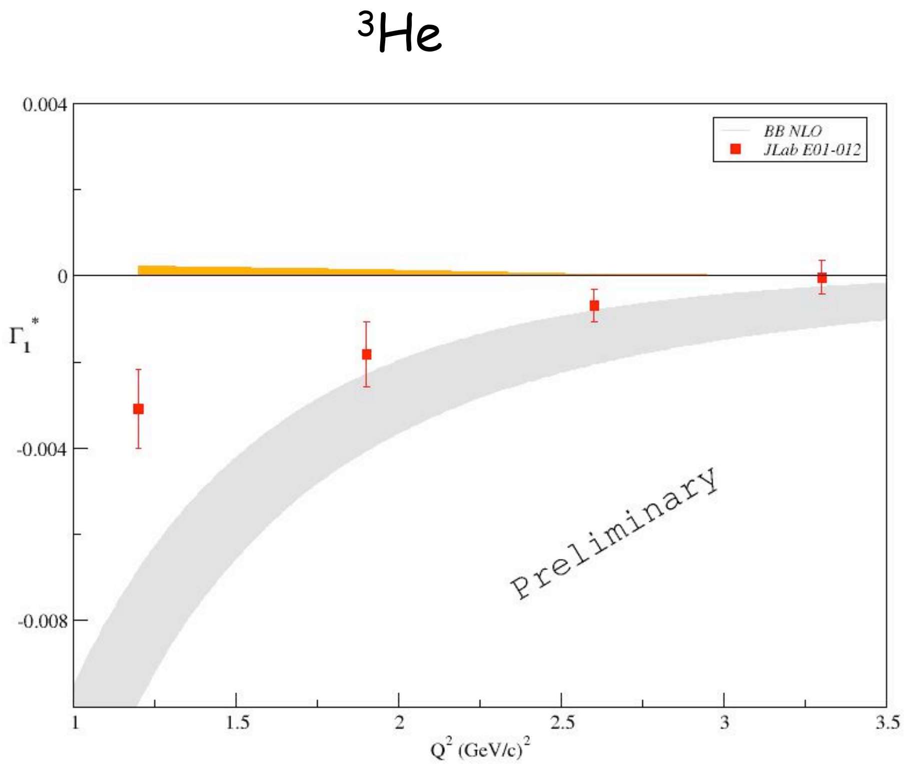
Used method defined by N. Bianchi, A. Fantoni and S. Liuti on g_1^p PRD 69 (2004) 014505

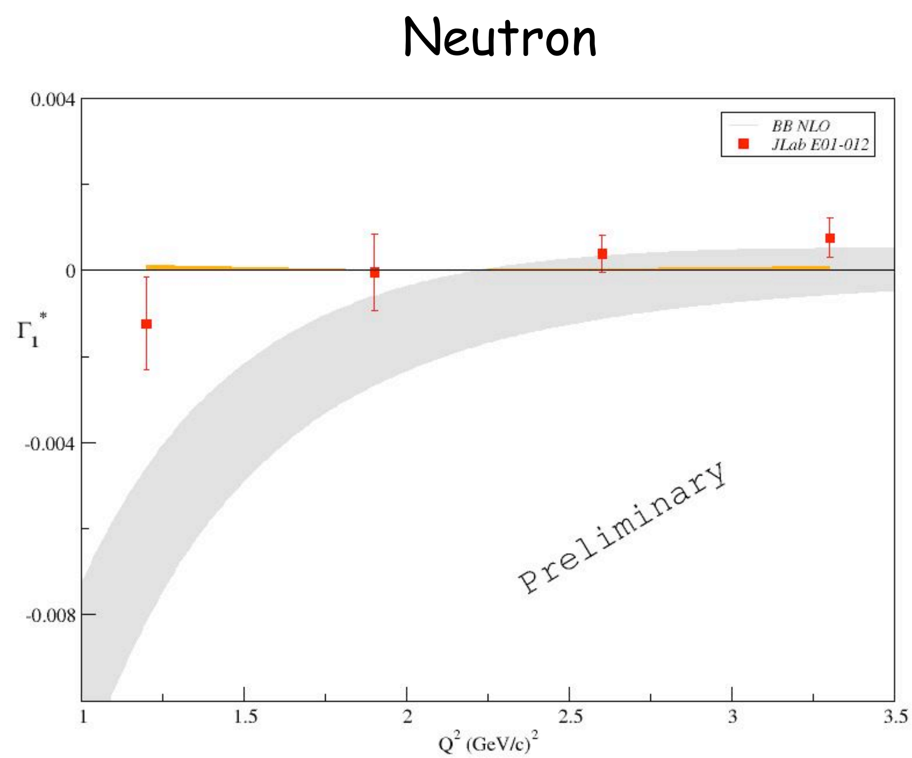
1. Get g_1 at constant Q^2
2. Define integration range in the resonance region in function of W
3. Integrate g_1^{res} and g_1^{dis} over the same x-range and at the same Q^2

$$\tilde{\Gamma}_1^{res} = \int_{x_{\min}}^{x_{\max}} g_1^{res}(x,Q^2)dx \qquad \tilde{\Gamma}_1^{dis} = \int_{x_{\min}}^{x_{\max}} g_1^{dis}(x,Q^2)dx$$

If $\tilde{\Gamma}_1^{res} = \tilde{\Gamma}_1^{dis} \Rightarrow$ **duality is verified**

Test of Duality on Neutron and ^{3}He





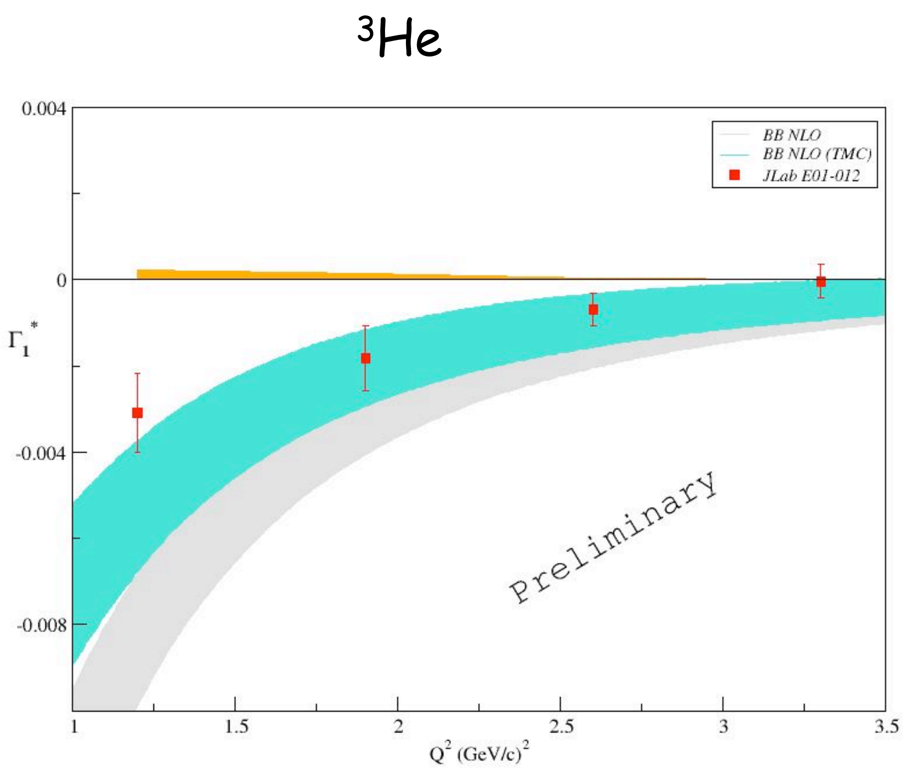
Target mass corrections

$$g_1(x,Q^2) = g_1(x,Q^2;M=0) + \frac{M^2}{Q^2} g_1^{(1)TMC}(x,Q^2) + \frac{h(x,Q^2)}{Q^2} + O(1/Q^4)$$

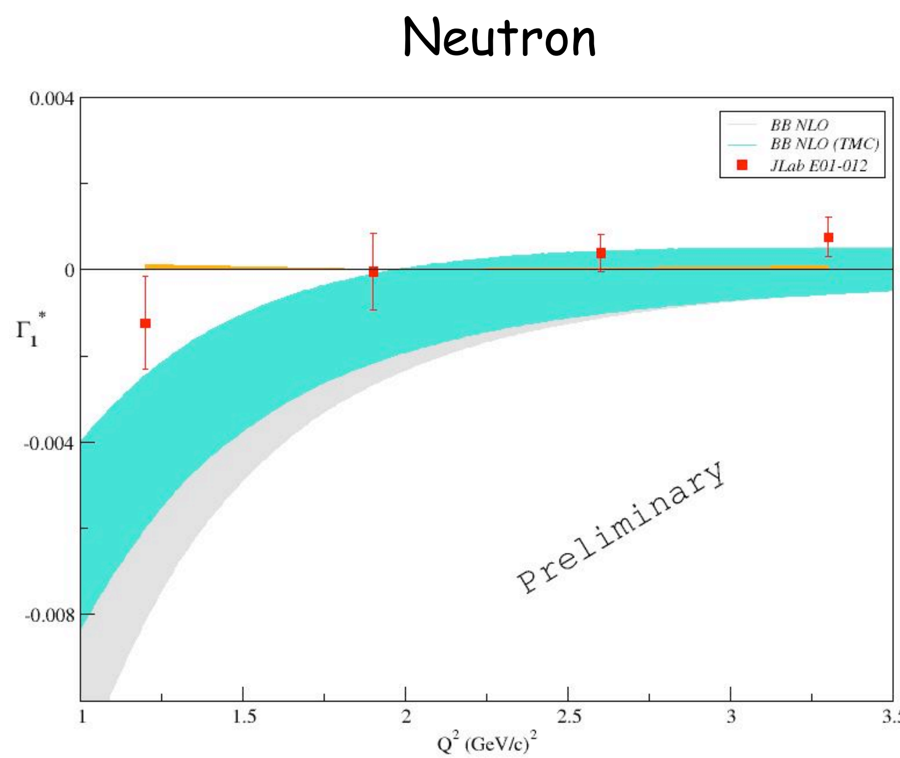
from experiments

from pQCD

- Purely kinematic effects: finite value of $4M^2x^2/Q^2$
- Need to be applied before calculating higher twist effects
- TMCs are expressed by higher moments of $g_1(x,Q^2;M=0)$

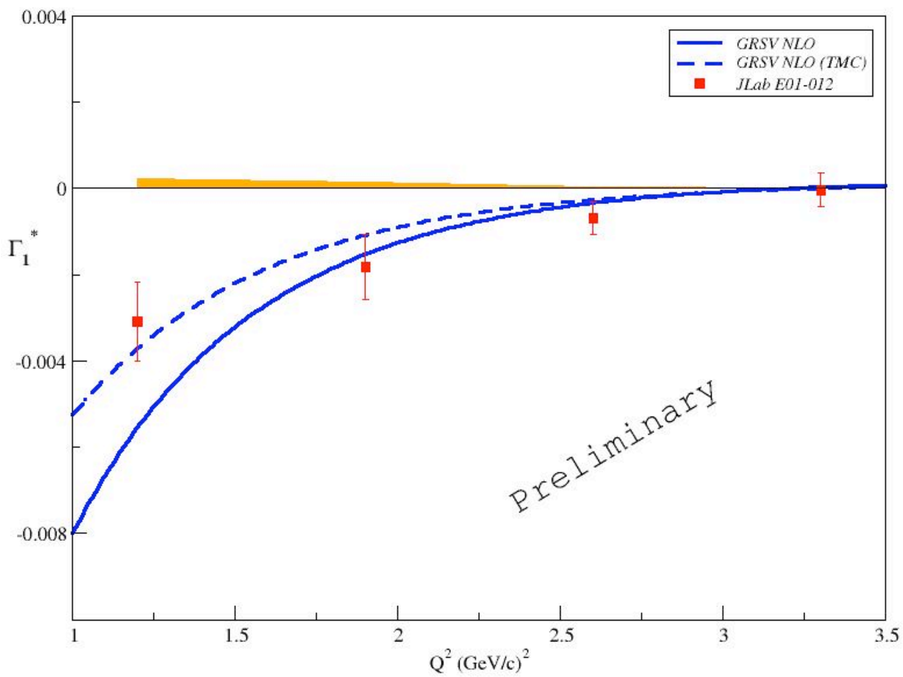


^{3}He
0.004
0
-0.004
-0.008
Γ_1^*
BB NLO
BB NLO (TMC)
JLab E01-012
Preliminary
1
1.5
2
2.5
3
3.5
Q^2 (GeV/c)^2



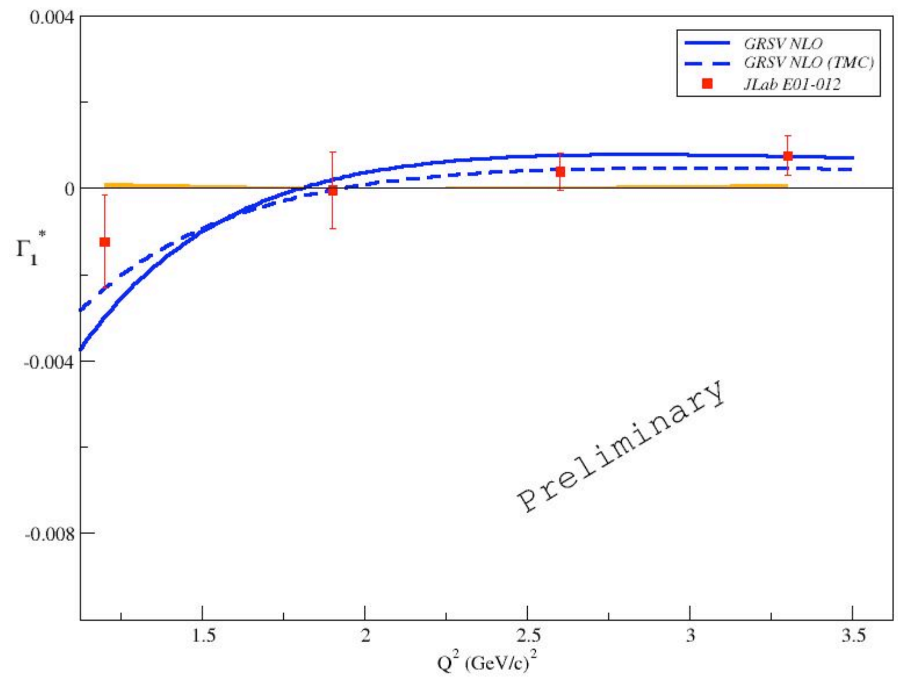
Neutron
0.004
0
-0.004
-0.008
Γ_1^*
BB NLO
BB NLO (TMC)
JLab E01-012
Preliminary
1
1.5
2
2.5
3
3.5
Q^2 (GeV/c)^2

^{3}He



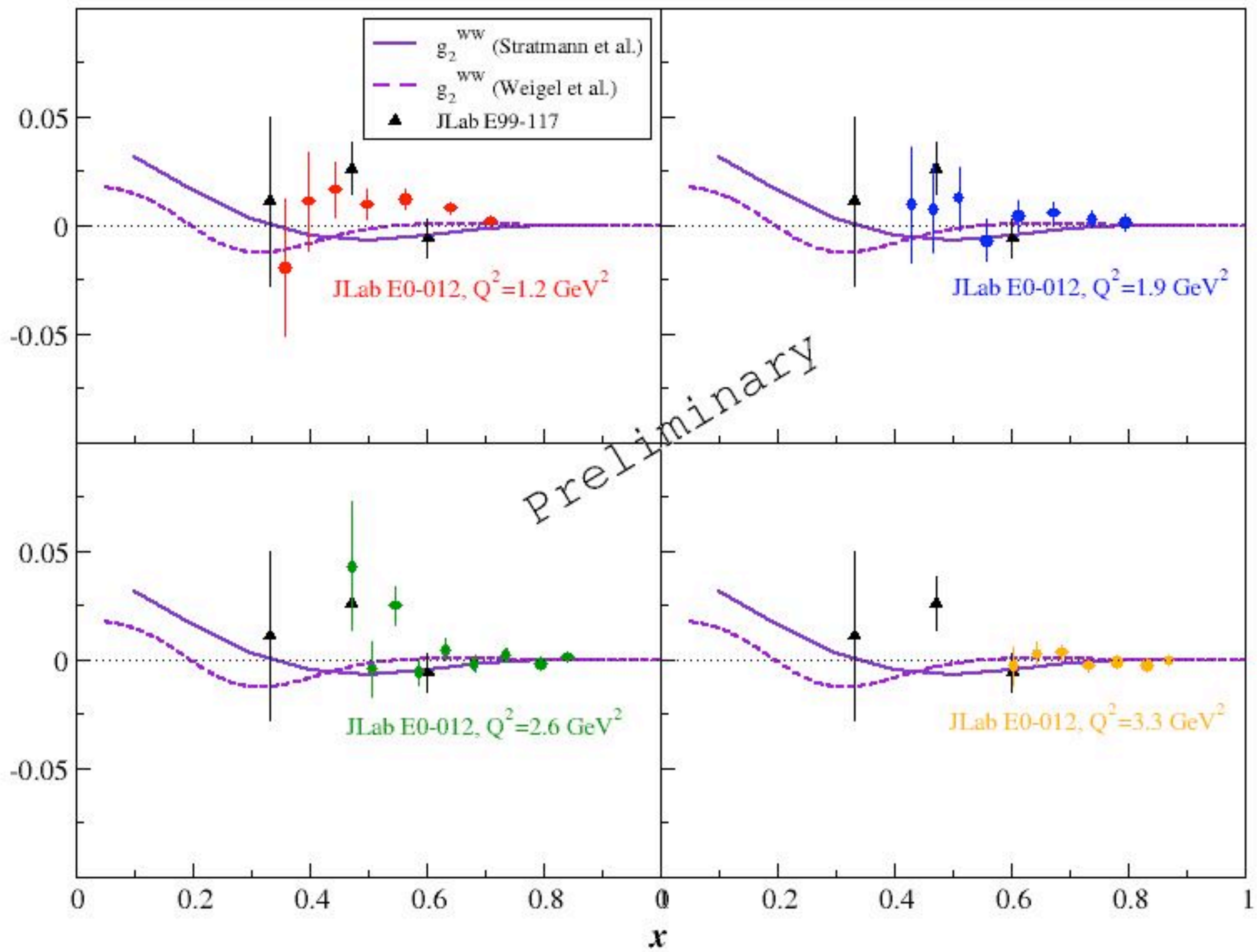
0.004
0
-0.004
-0.008
Γ_1^*
1
1.5
2
2.5
3
3.5
Q^2 (GeV/c)^2
GRSV NLO
GRSV NLO (TMC)
JLab E01-012
Preliminary

Neutron



0.004
0
-0.004
-0.008
Γ_1^*
1.5
2
2.5
3
3.5
Q^2 (GeV/c)^2
GRSV NLO
GRSV NLO (TMC)
JLab E01-012
Preliminary

$g_2^{^3He}$ at constant Q^2



Virtual Photon-Nucleon Asymmetry

In the parton model:

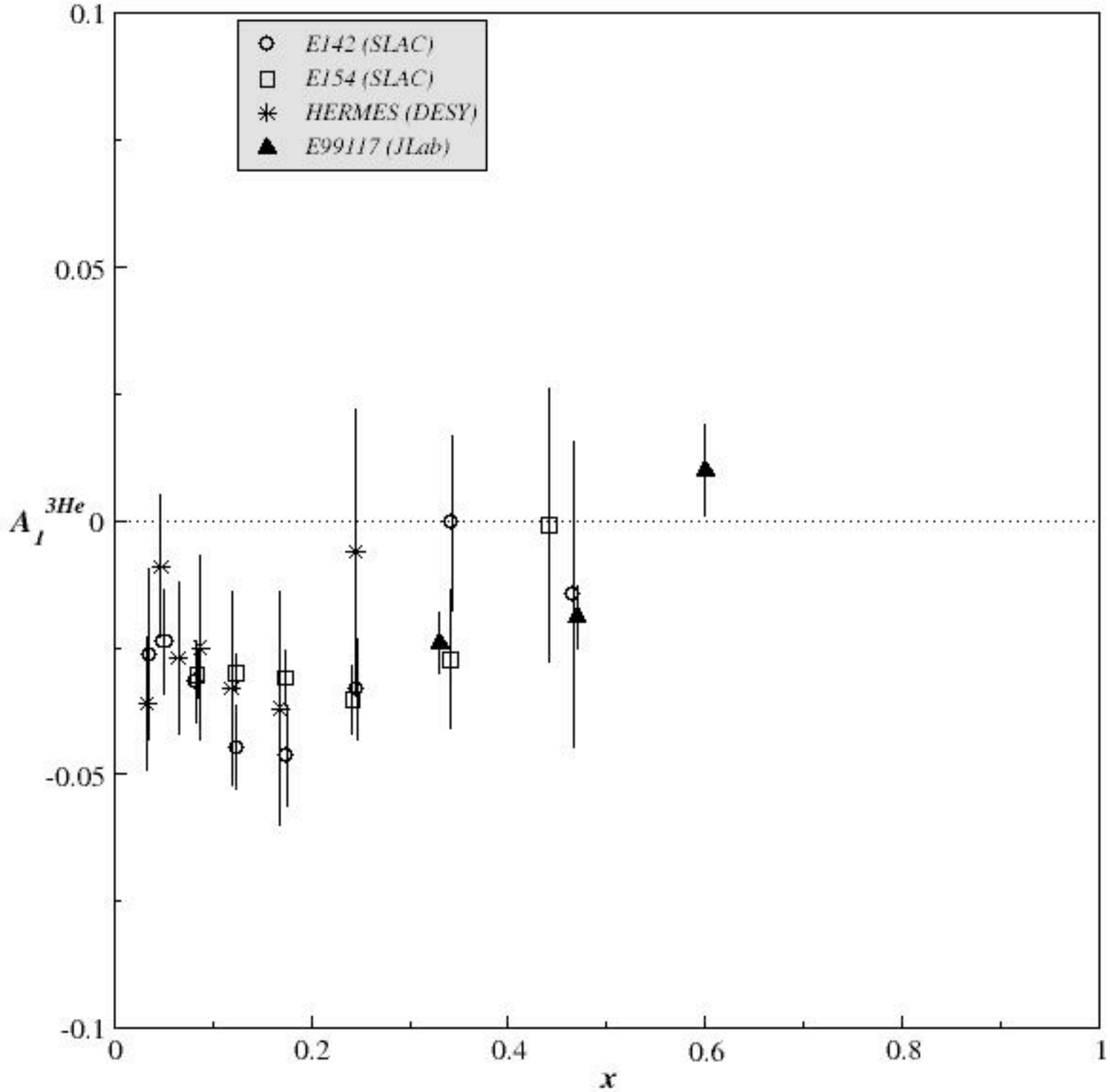
$$A_1(x,Q^2) \approx \frac{g_1(x,Q^2)}{F_1(x,Q^2)}$$

If Q^2 dependence similar for g_1 and for F_1 $\Rightarrow$ weak Q^2 dependence of A_1

From the resonance:

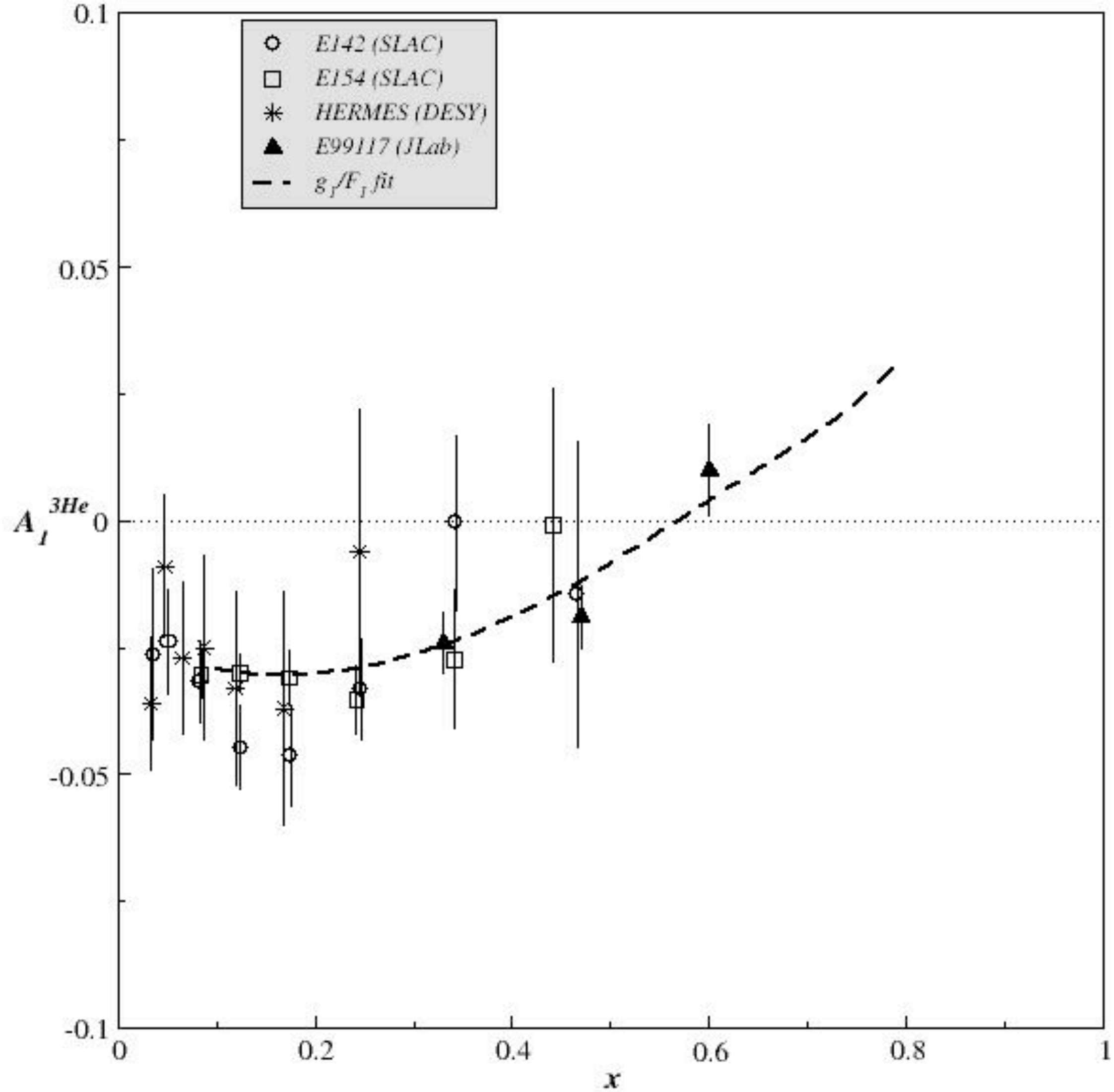
If local duality observed in g_1 and F_1 ⟶ $A_1^{res} = A_1^{dis}$

A_1 ^3He



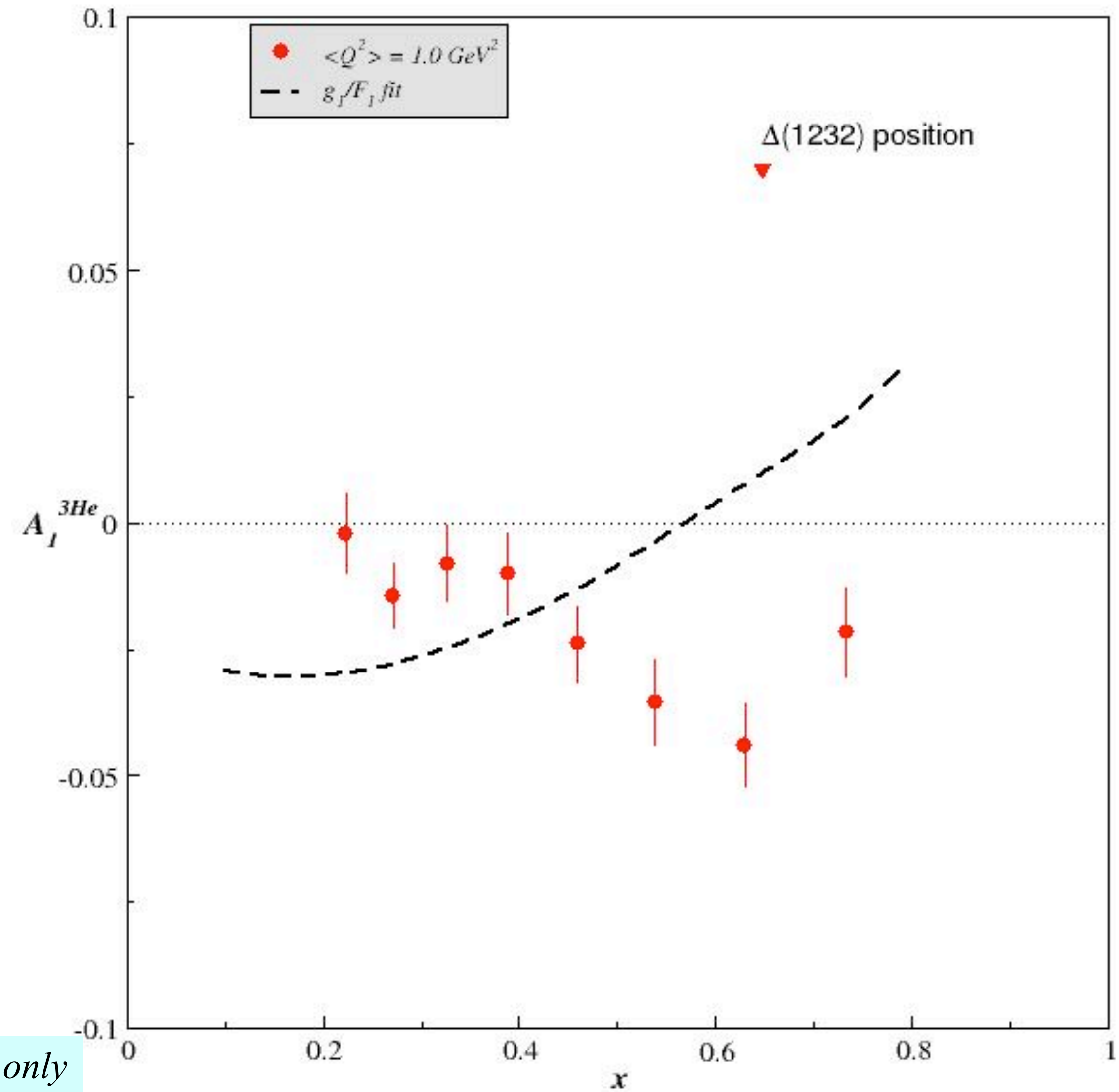
E142 (SLAC)
E154 (SLAC)
HERMES (DESY)
E99117 (JLab)
0.1
0.05
0
-0.05
-0.1
A1 3He
0
0.2
0.4
0.6
0.8
1
x

A_1^{3He}



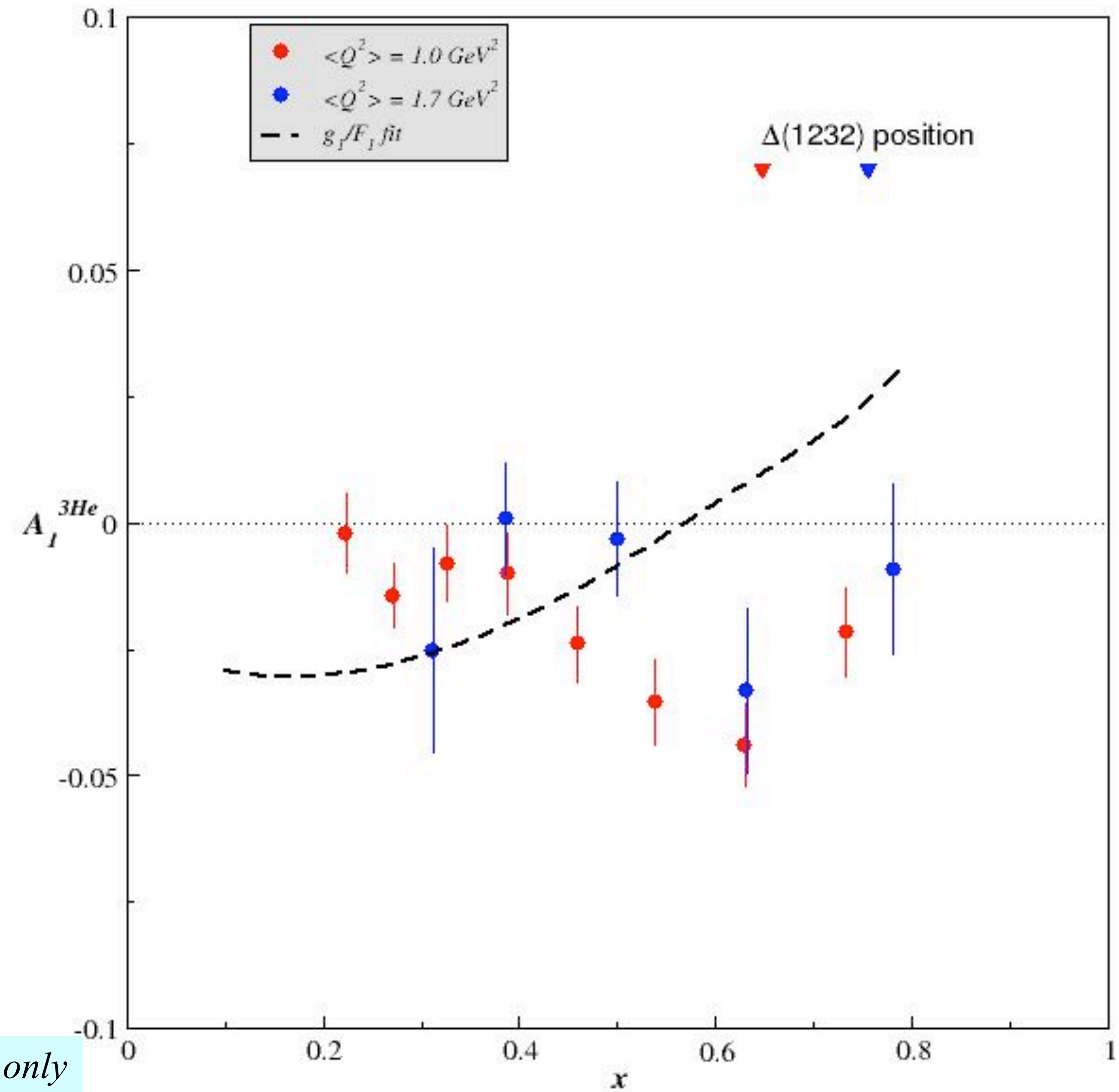
E142 (SLAC)
E154 (SLAC)
HERMES (DESY)
E99117 (JLab)
g1/F1 fit
0.1
0.05
0
-0.05
-0.1
A1 3He
0
0.2
0.4
0.6
0.8
1
x

A_1^{3He}



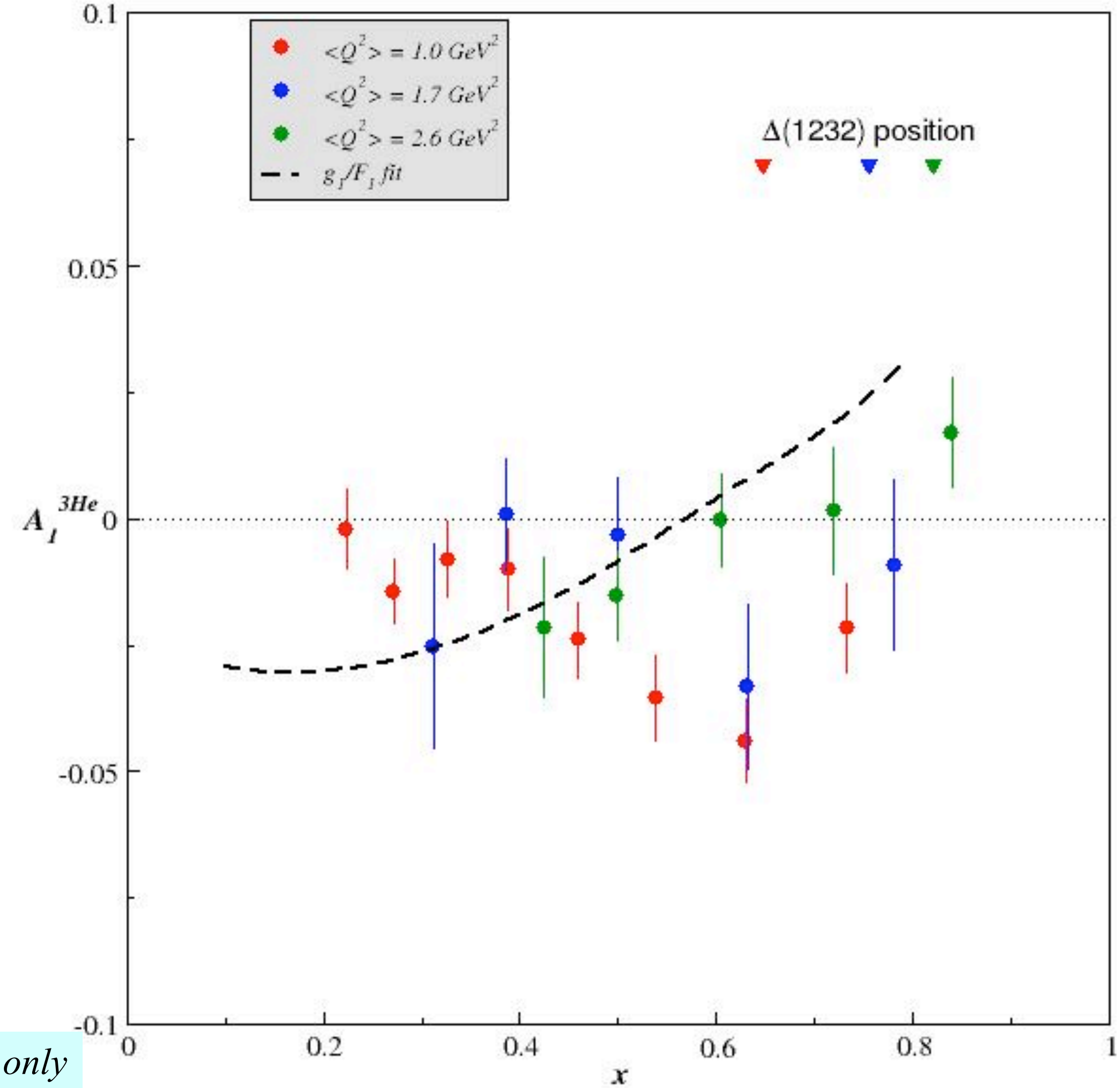
Statistical errors only

A_1 ^3He



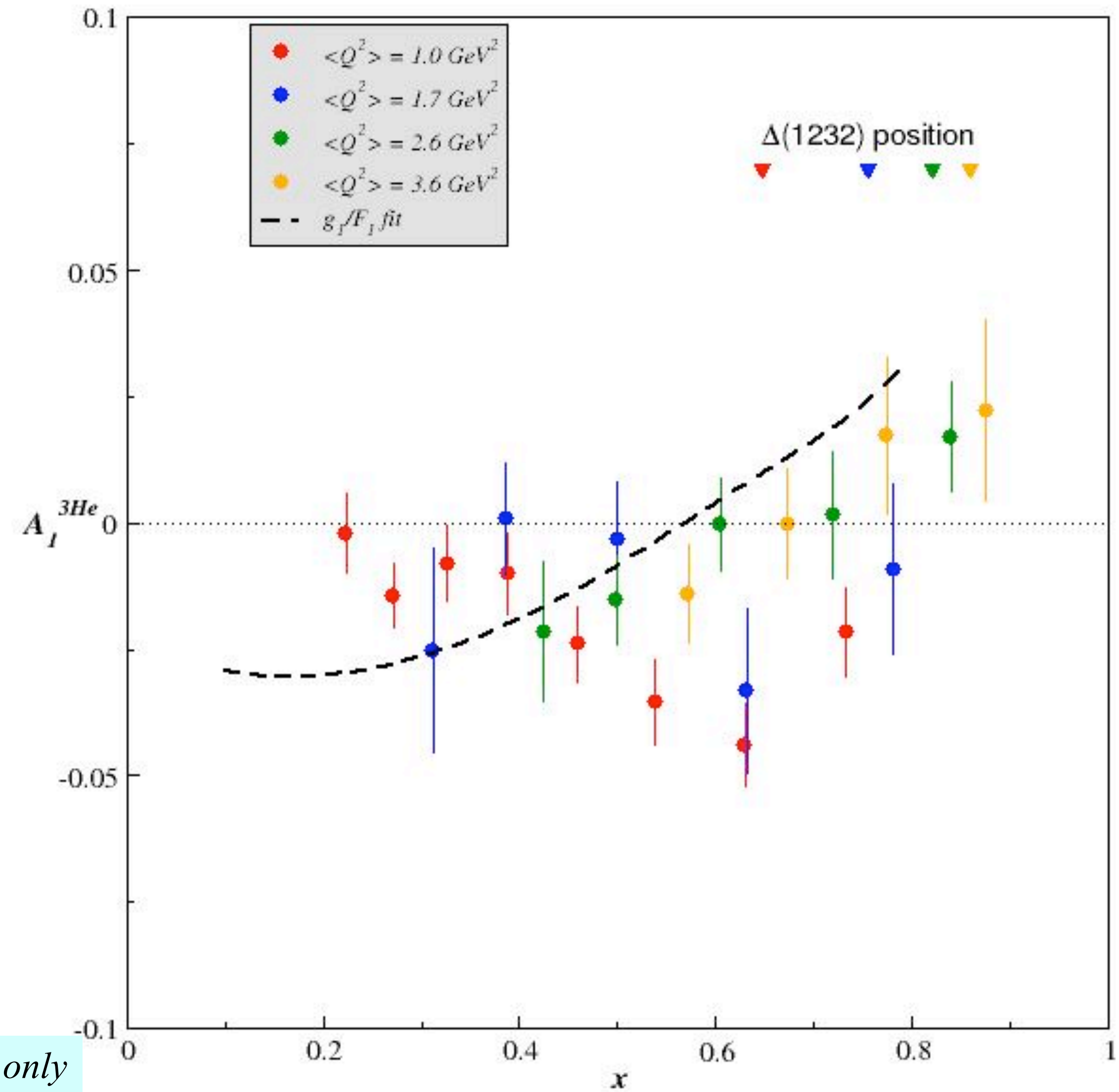
Statistical errors only

$A_1^{\ 3He}$



Statistical errors only

A_1^{3He}



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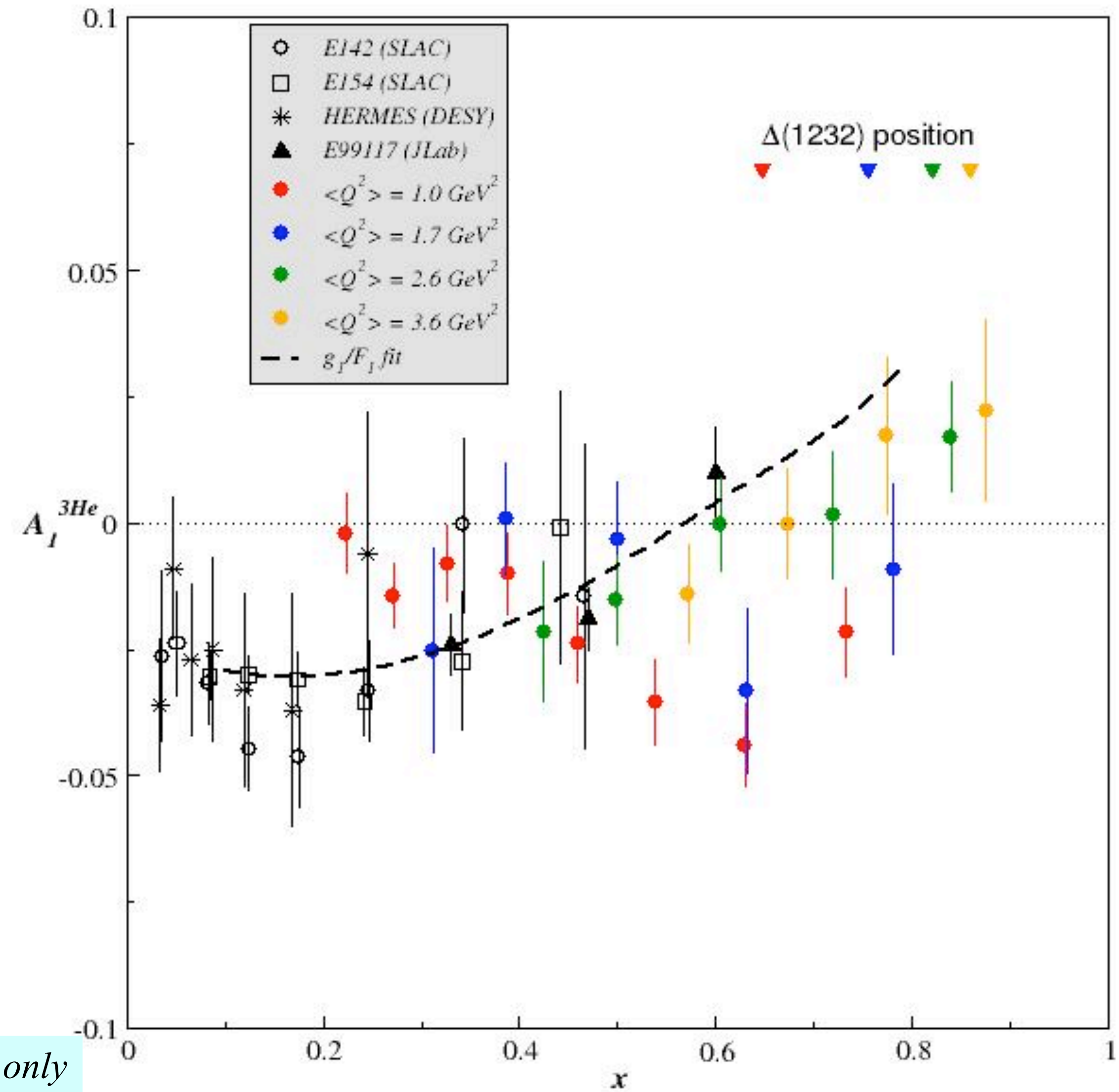
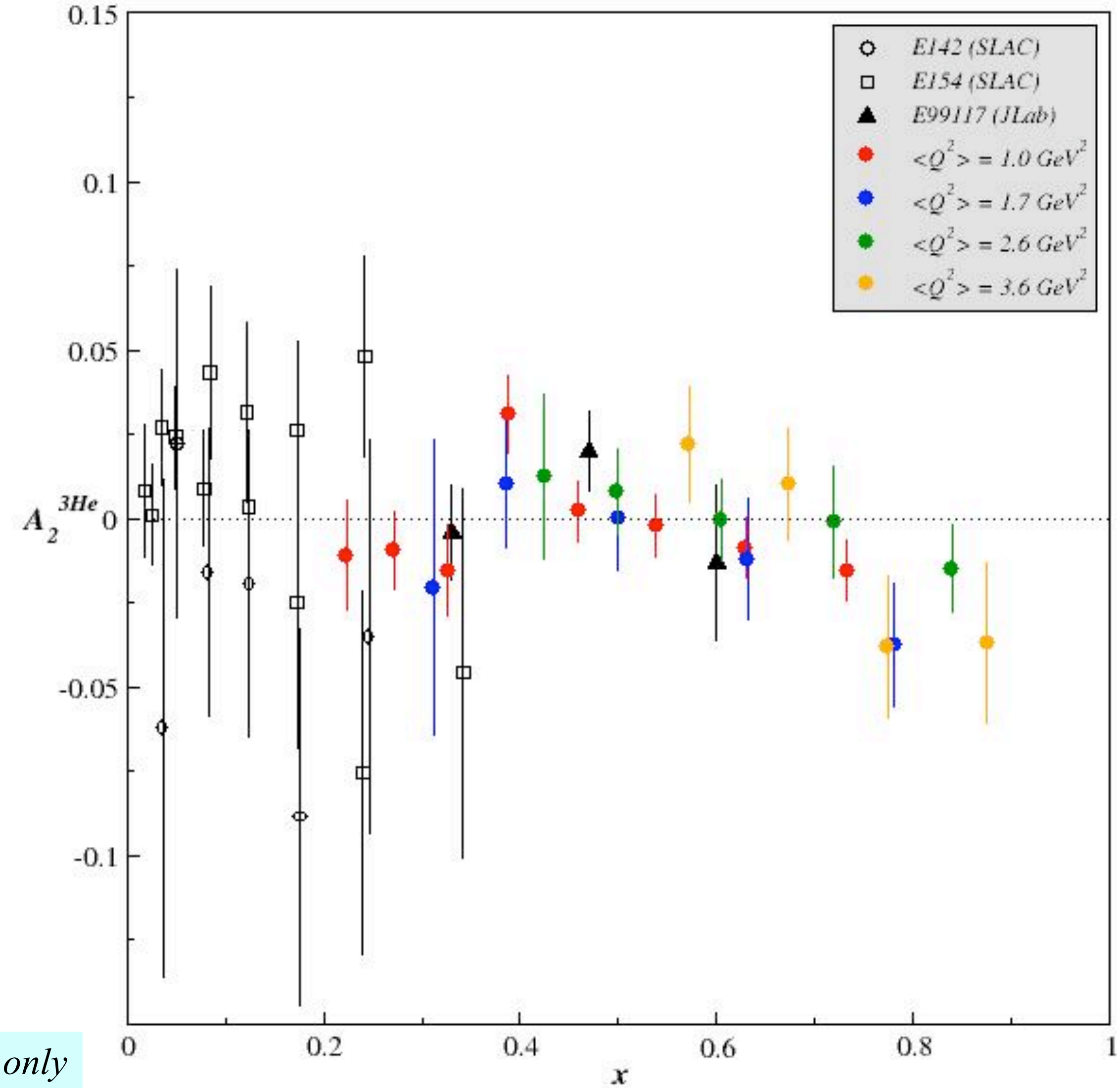
A_1^{3He}



Statistical errors only

A_2^{3He}



Statistical errors only

Summary

- E01-012 provides first data of Spin Structure Functions on neutron (^3He) in the resonance region for $1.0 < Q^2 < 4.0 GeV^2$

- Direct extraction of g_1 and g_2 from our data

- Overlap between E01-012 resonance data and DIS data
→ First dedicated test of Quark-Hadron Duality for neutron and ^3He SSF

- E01-012 data combined with proton data
→ test of spin and flavor dependence of duality

- Our data can also be used to extract moments of SSF (e.g. Extended GDH Sum Rule, BC Sum Rule)

- First paper in preparation