Neutron Spin Structure in the Resonance Region and Quark-Hadron Duality

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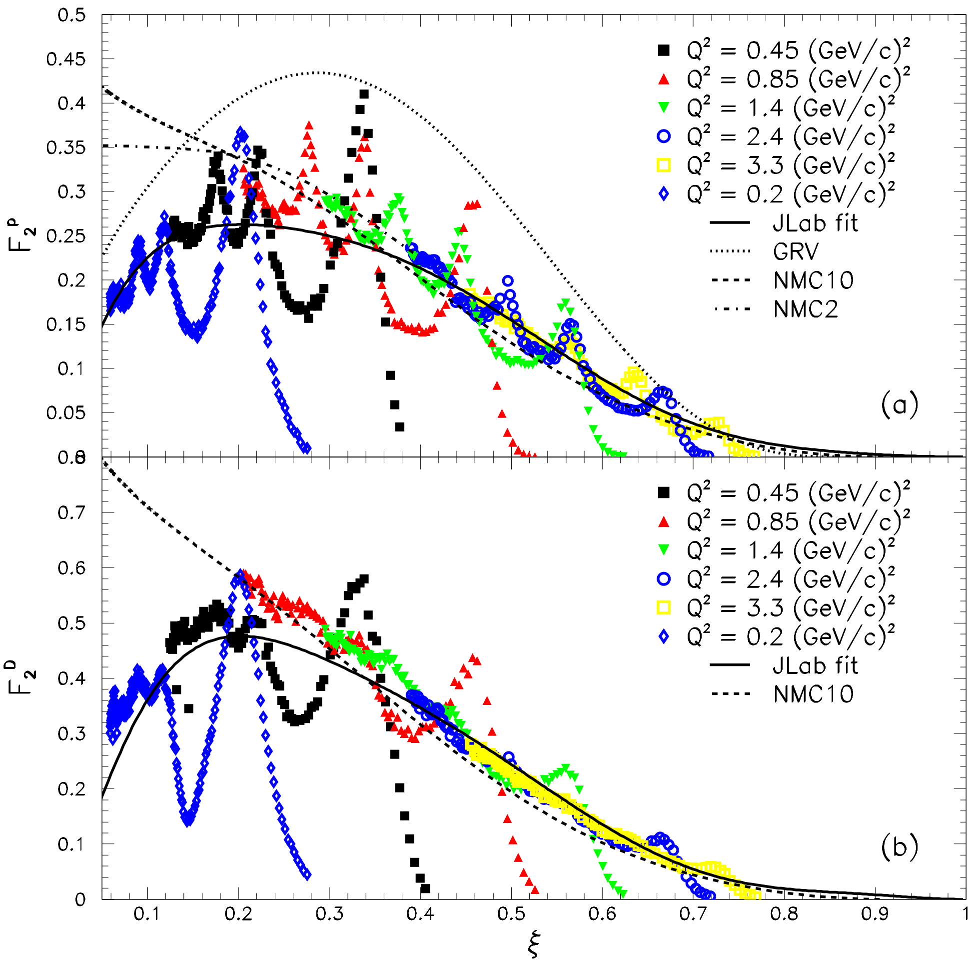
Quark-Hadron Duality

- First observed by Bloom and Gilman at SLAC in the 70's on the spin independent structure function F_2

  E.D. Bloom and F.J. Gilman, Phys. Rev. D **4**, 2901 (1971)

- Structure functions in the resonance region at low Q^2 average to the scaling curve at high Q^2 when the proper scaling variable is used.



Duality holds when higher twists are suppressed.

Why is Duality important ?

→ Study of higher twists.

→ Understanding duality might help us understand confinement.

→ Structure functions at high x more easily accessible via resonance region.

Theoretical understanding:

→ Carlson and Mukhopadhyay (pQCD)

Phys. Rev. D **58**, 094029 (1998)

→ Ji and Unrau, Ji and Melnitchouk (extraction of higher-twist matrix elements)

Phys. Rev. D **52**, 72 (1995), Phys. Rev. D **56**, 1 (1997)

→ Close and Melnitchouk (SU(6) breaking)

hep-ph/0302013 (2003)

→ Close and Isgur (SU(6) quark model)

hep-ph/0102067 (2001)

→ and much more.

Experimental confirmation

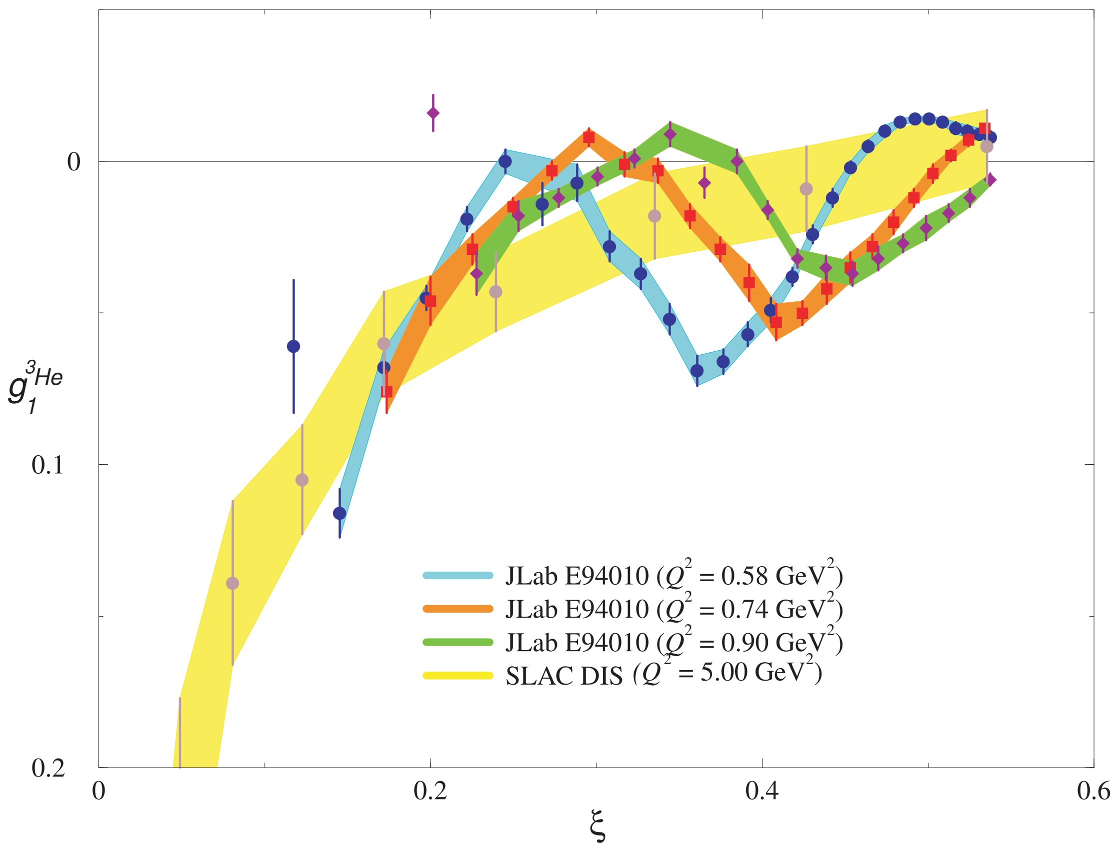
- Confirmation of duality:
  - JLab Hall C for F_2^p

    I. Niculescu et al., Phys. Rev. Lett. **85**, 1186 (2000)

- Indications of duality on spin structure functions:
  - HERMES for A_1^p

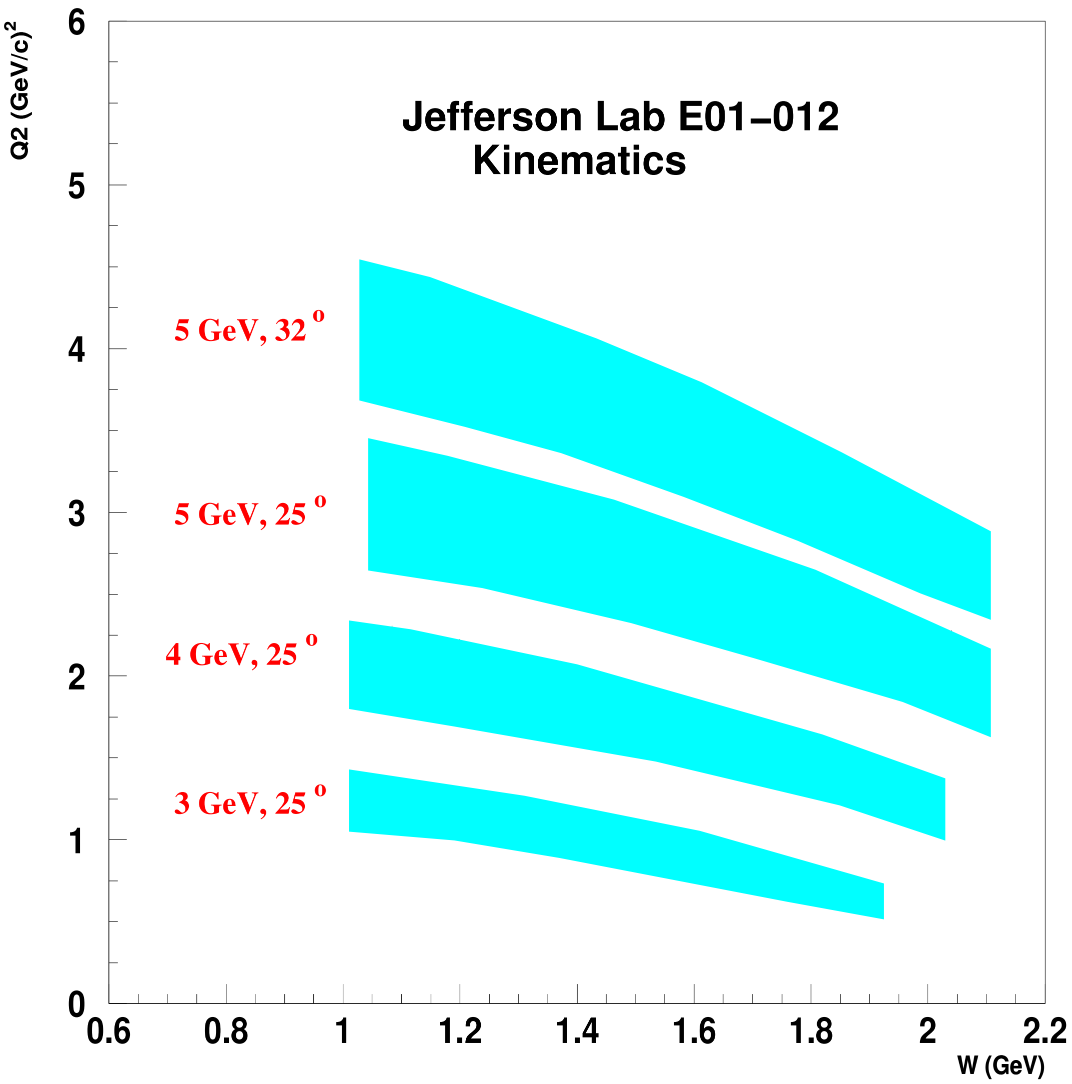
    A.Airapetian et al., Phys. Rev. Lett. **90**, 092002 (2003)

  - JLab Hall B for g_1^p and g_1^d
  - JLab Hall A for $g_1^{^3\mathrm{He}}$



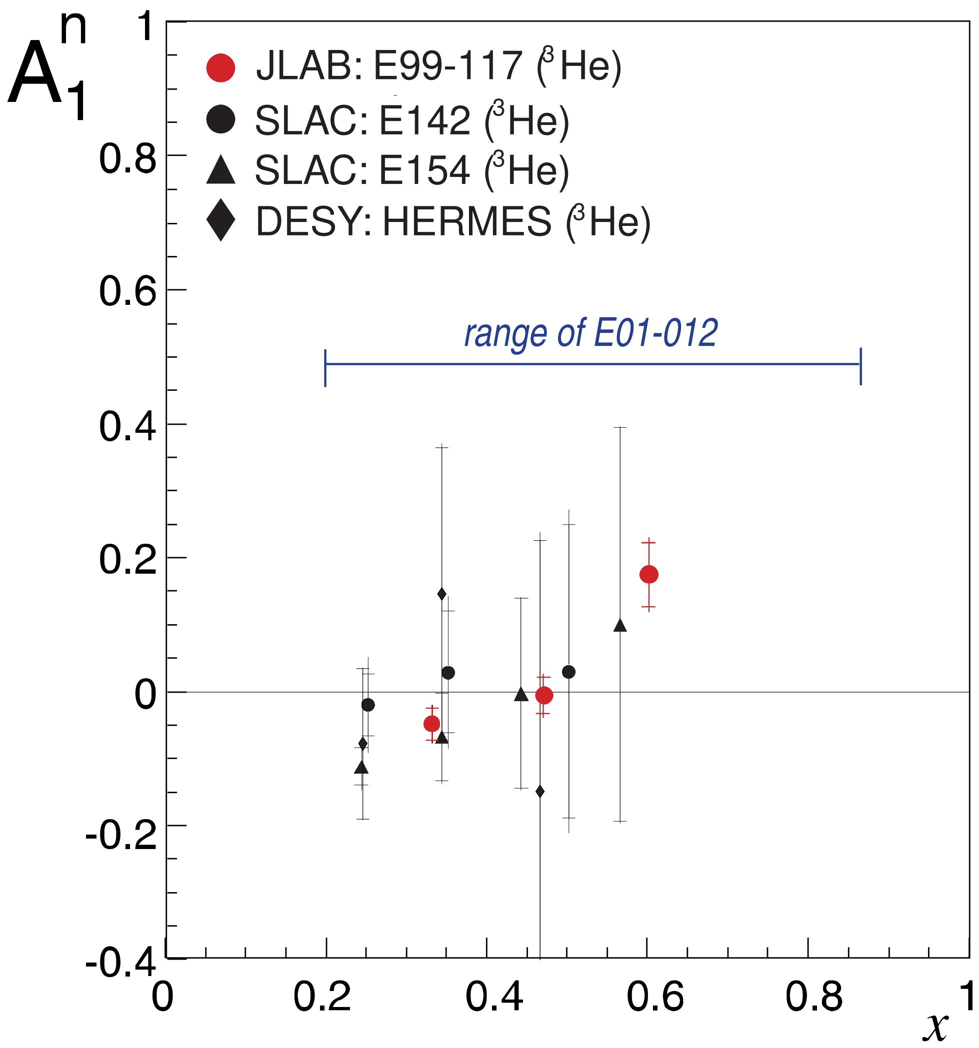
The experiment E01-012

- Inclusive experiment: $^3\overrightarrow{\mathrm{He}}(\vec{\mathrm{e}},\mathrm{e}')\mathrm{X}$
- E01-012 measured asymmetries and cross section differences in the resonance region.



- will form $g_1^{^3\mathrm{He}}$, $g_2^{^3\mathrm{He}}$, $A_1^{^3\mathrm{He}}$ and $A_2^{^3\mathrm{He}}$.

- Test duality on the neutron spin structure functions:
  - $\rightarrow$ E01-012 data cover $0.2 < x < 0.87$.
  - $\rightarrow$ For $x < 0.65$: test of duality with available DIS data.
  - $\rightarrow$ If duality is confirmed, resonance data will provide first precise measurement of g_1^n and A_1^n in the range $0.65 < x < 0.87$.



Experiment setup

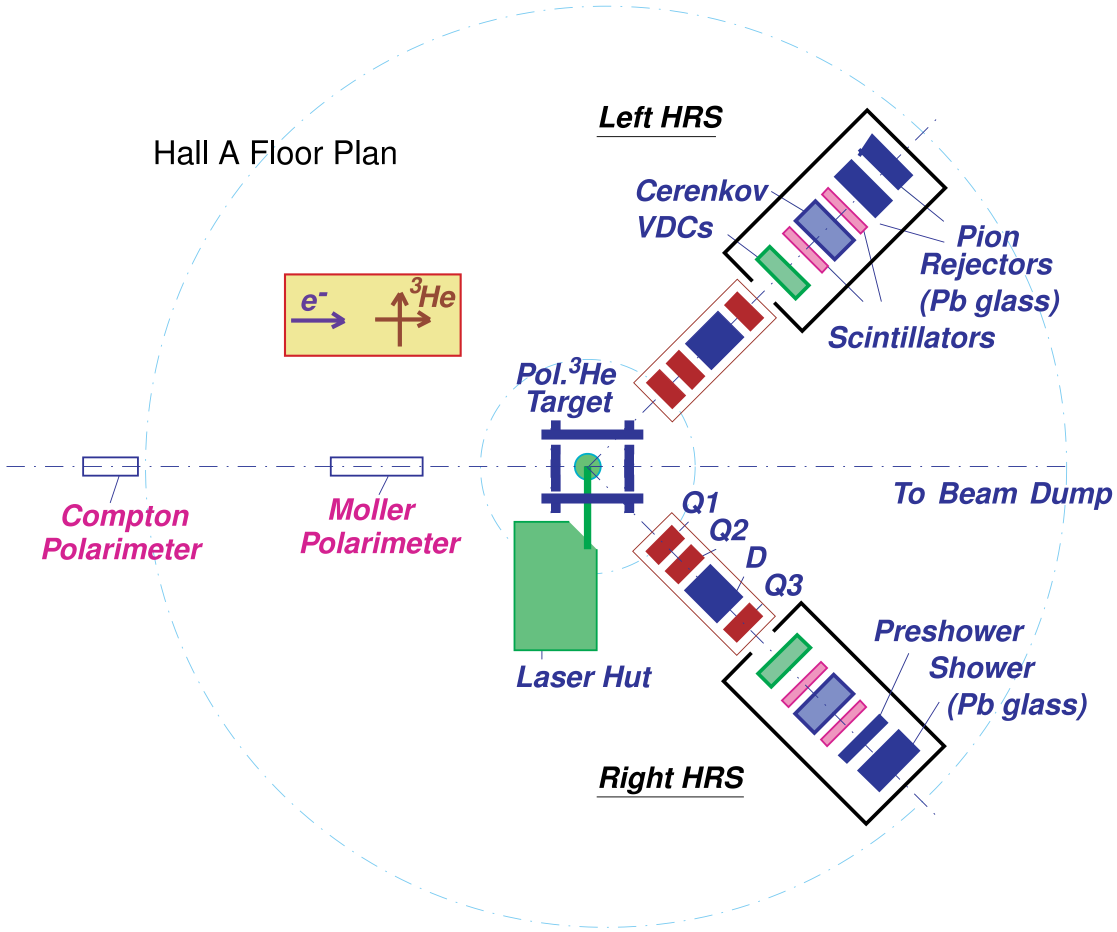
Polarized e⁻ beam:

→ 3 incident energies (3 GeV, 4 GeV and 5 GeV)

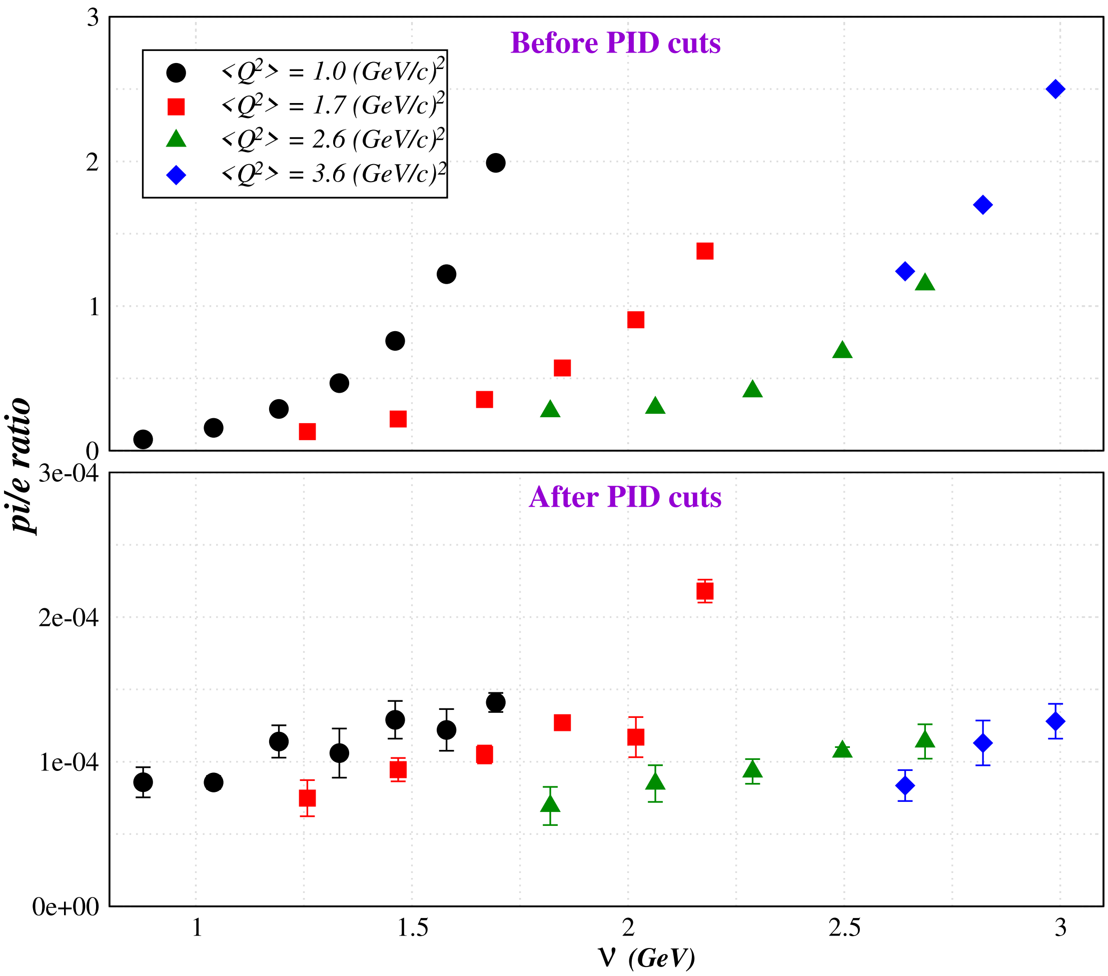
→ Average polarization: $(77 \pm 3)\%$

Hall A High Resolution Spectrometers:

→ Both HRS in a symmetric configuration at 25° and 32°.
$\Rightarrow$ double the statistics + check of the systematics



$\rightarrow$ Gas Cerenkov + lead glass $\rightarrow$ pion rejection $> 10^4$ with electron efficiency $> 99\%$.



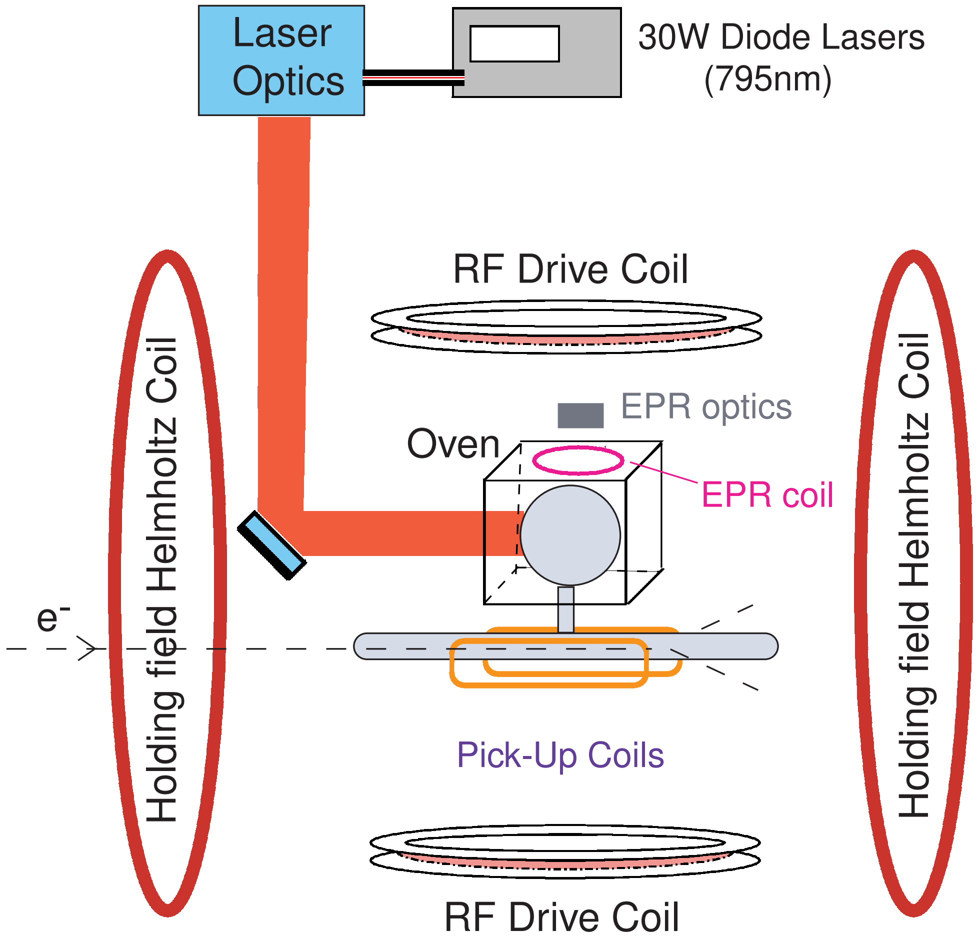
Hall A Polarized ^{3}He target:

→ Spin exchange between optically pumped Rb and ^{3}He.

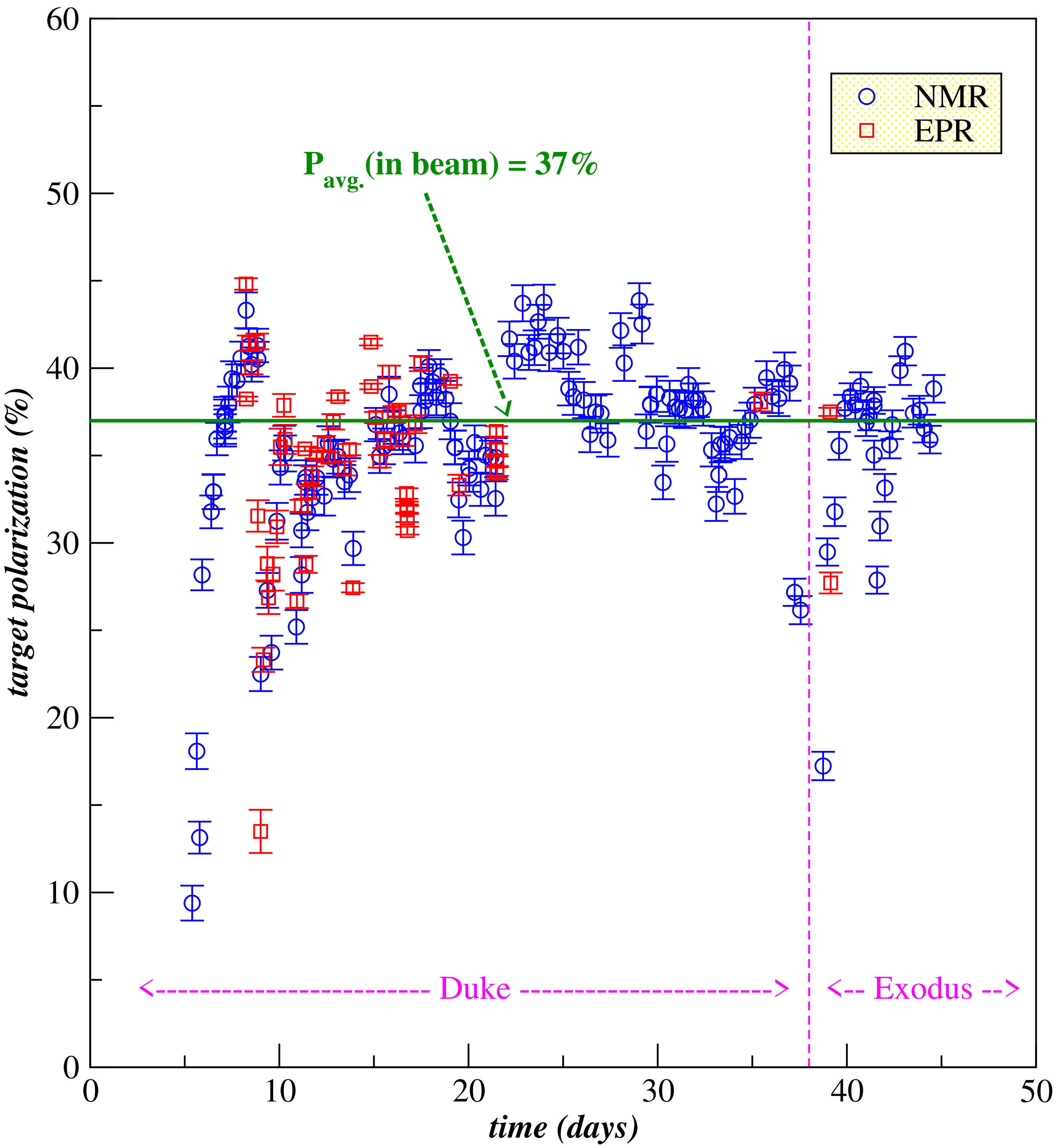
→ Longitudinal and transverse configurations.

→ Two independent polarimetries: NMR and EPR.

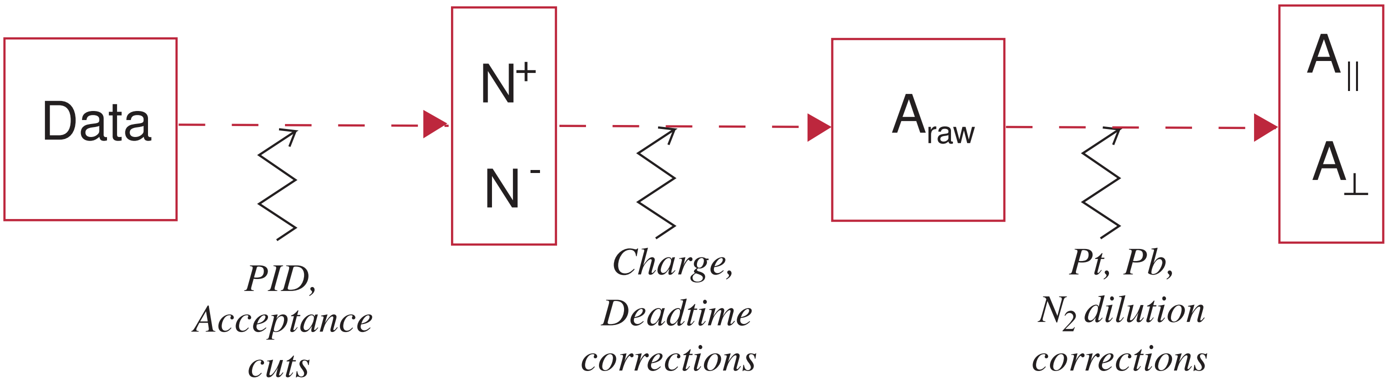
→ Target polarization in beam $\sim 40\%$.



E01-012 target polarization:



From data to asymmetries



$$A^{raw}_{\parallel,\perp} = \frac{N^{-}_{corr.} - N^{+}_{corr.}}{N^{-}_{corr.} + N^{+}_{corr.}}$$

$$A^{phys}_{\parallel,\perp} = \frac{A^{raw}_{\parallel,\perp}}{f_{N_2} \cdot P_{beam} \cdot P_{targ}}$$

In the following:

→ Nitrogen dilution ~ 0.94

→ Form A_1 and A_2 from $A_\parallel$ and $A_\perp$ for ^{3}He

→ Radiative corrections not applied yet

Polarized structure functions

$\rightarrow$ From asymmetries: 1$^{\text{st}}$ pass analysis

$$A_{\parallel} = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\downarrow\Uparrow} + \sigma^{\uparrow\Uparrow}} \quad \text{and} \quad A_{\perp} = \frac{\sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}}{\sigma^{\downarrow\Rightarrow} + \sigma^{\uparrow\Rightarrow}}$$

$$A_1 = \frac{A_{\parallel}}{D(1+\eta\xi)} - \frac{\eta A_{\perp}}{d(1+\eta\xi)}, \quad A_2 = \frac{\xi A_{\parallel}}{D(1+\eta\xi)} + \frac{A_{\perp}}{d(1+\eta\xi)}$$

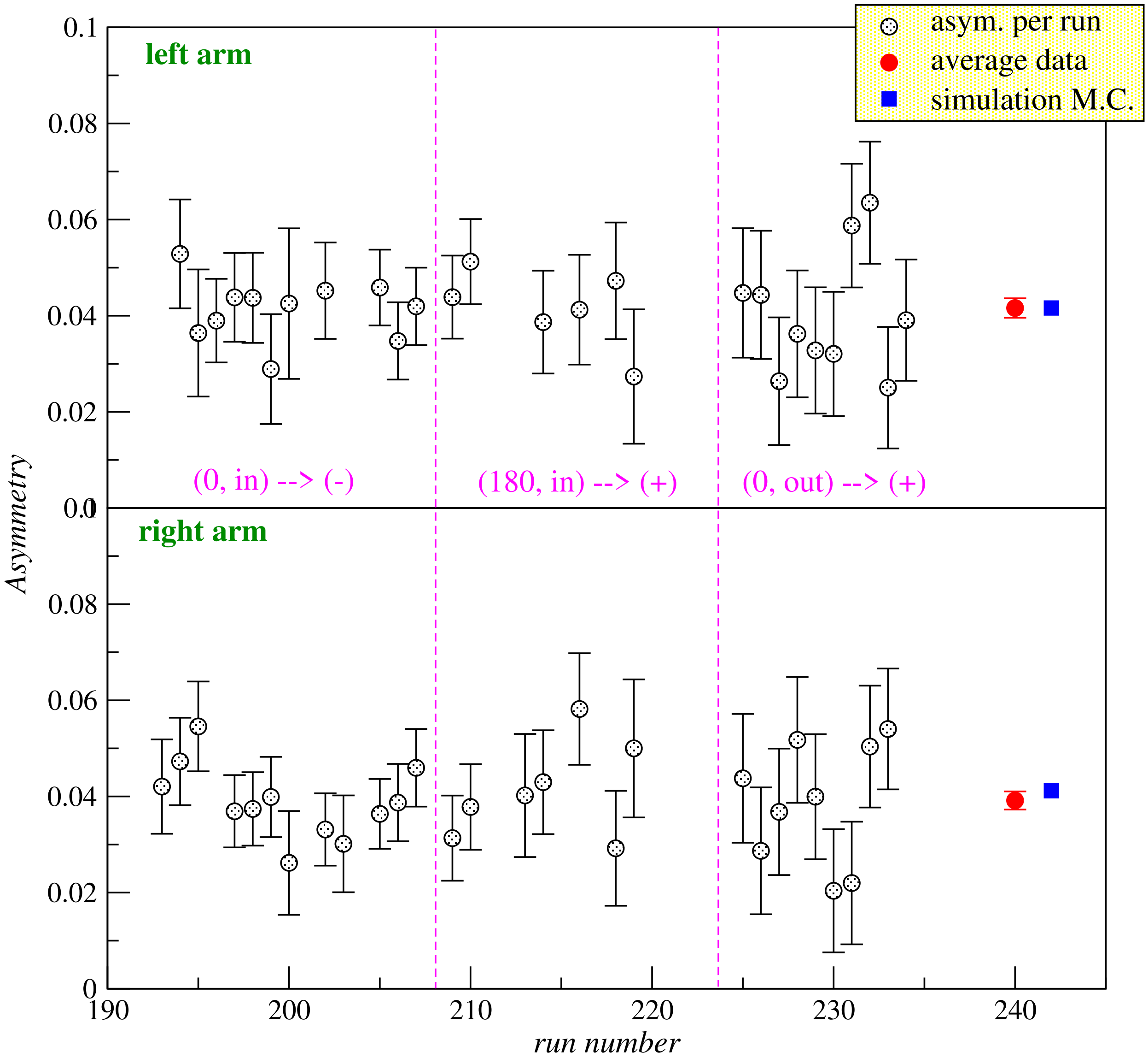
$\rightarrow$ From cross sections: 2$^{\text{nd}}$ pass analysis

$$g_1 = \frac{MQ^2\nu}{4\alpha_e^2}\frac{E}{E'}\frac{1}{E+E'}\left[\Delta\sigma_{\parallel} + tan(\frac{\theta}{2})\Delta\sigma_{\perp}\right]$$

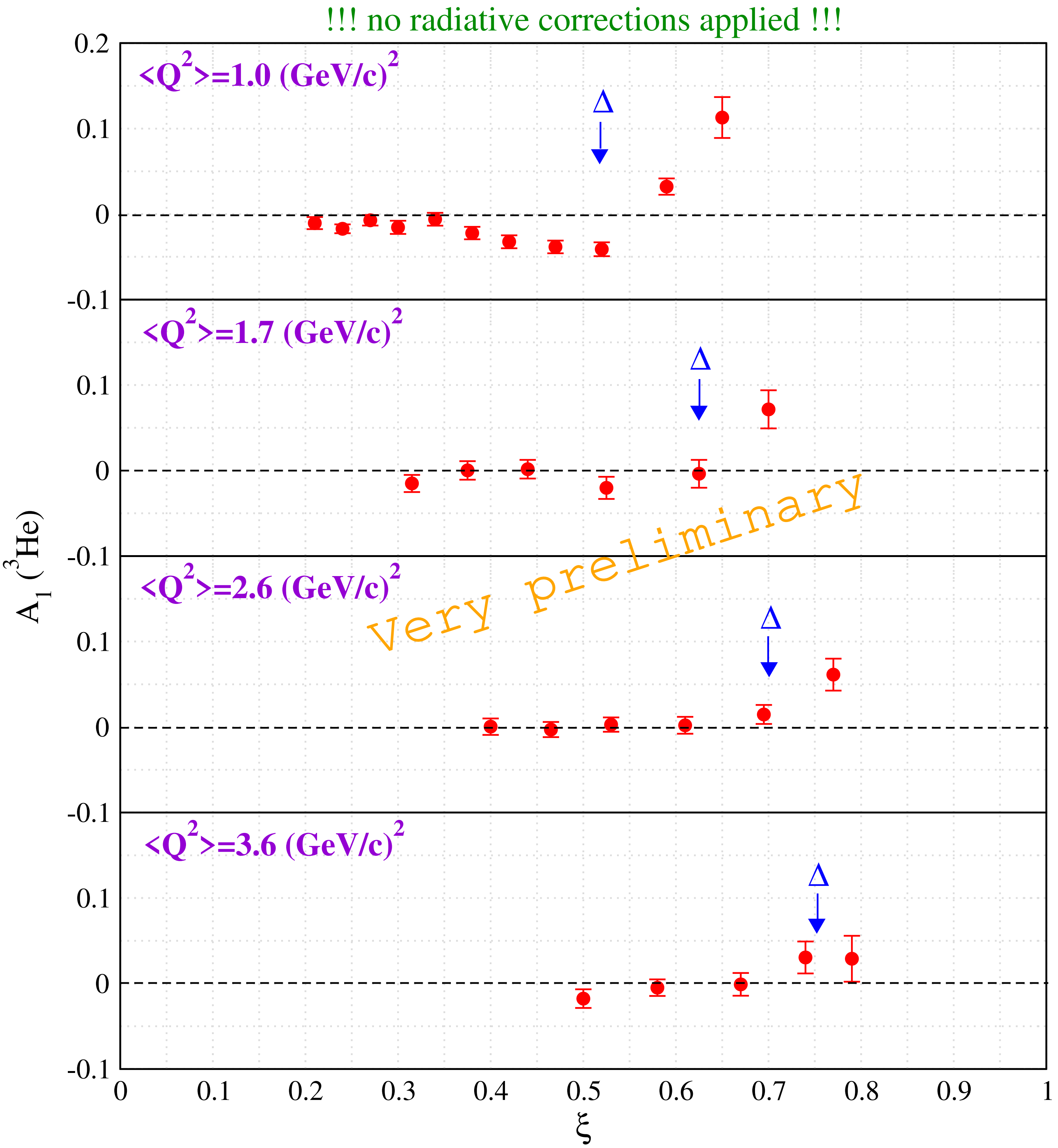
$$g_2 = \frac{MQ^2\nu^2}{4\alpha_e^2}\frac{1}{2E'(E+E')}\left[-\Delta\sigma_{\parallel} + \frac{E+E'cos\theta}{E'sin\theta}\Delta\sigma_{\perp}\right]$$

$$A_1 = \frac{g_1 - \gamma^2 g_2}{F_1} \quad \text{and} \quad A_2 = \frac{\gamma[g_1 + g_2]}{F_1}$$

Elastic analysis

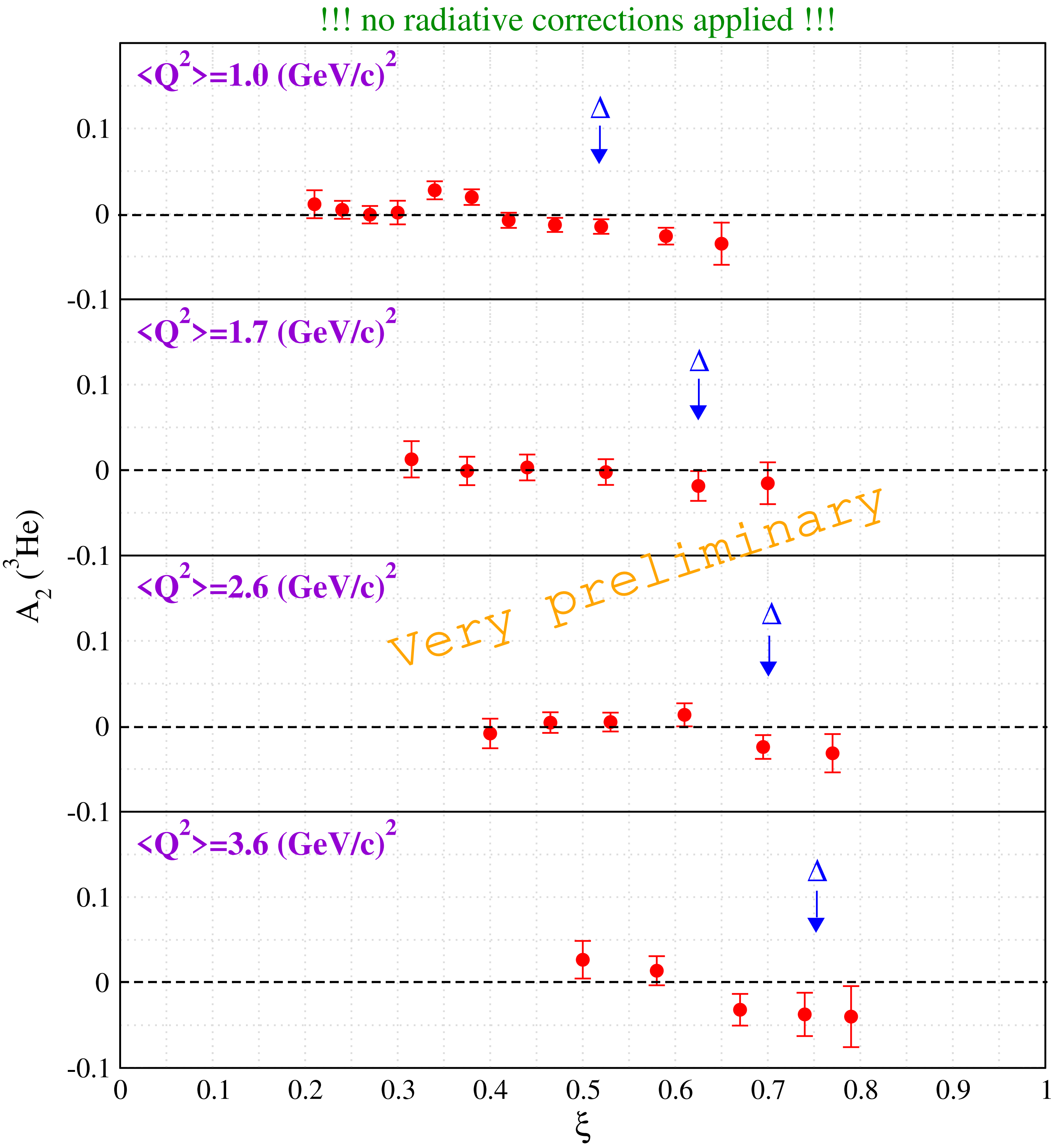


A_1 for ^3He



!!! no radiative corrections applied !!!
<Q²>=1.0 (GeV/c)²
<Q²>=1.7 (GeV/c)²
<Q²>=2.6 (GeV/c)²
<Q²>=3.6 (GeV/c)²
Δ
Very preliminary
A1 (3He)
ξ
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

A_2 for ^3He


!!! no radiative corrections applied !!!
<Q^2>=1.0 (GeV/c)^2
<Q^2>=1.7 (GeV/c)^2
<Q^2>=2.6 (GeV/c)^2
<Q^2>=3.6 (GeV/c)^2
Δ
Very preliminary
A_2 (^{3}He)
ξ
0.1
0
-0.1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Conclusion

- ⋆ E01-012 provides precision data of SSF on the neutron for $1.0<Q^2<4.0(\mathrm{GeV/c})^2$.

- ⋆ Direct extraction of g_1 and g_2 from our data.

- ⋆ Overlap between E01-012 resonance data and DIS data $\Rightarrow$ test of Quark-Hadron Duality for the neutron SSF.

- ⋆ Results from E94-010 show a hint of Quark-Hadron Duality.

- ⋆ E01-012 data combined with proton data will be a test of spin-flavor dependence of duality.

- ⋆ These data can also be used to extract higher moments of the SSF (e.g. GDH sum rule, d_2, BC sum rule).