d2n Analysis Workshop

Asymmetry Update

Matthew Posik

[1]Temple University
Philadelphia, PA 19122

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Outline

Outline

Contamination

- Main source of contamination is from electrons via pair-production from π^0 and γ decay
- Pair-produced electrons will dilute the electron asymmetry trying to be measured
- In principal, there are two corrections that can be made to remove the pair-produced electrons:
  - A dilution factor can be applied to account for the pair-produced electron dilution
  - Pair produced asymmetry can be subtracted off measured electron asymmetry

Dilution Factor

The pair-Production dilution factor can be defined as:

$$D = 1 - \frac{\sigma_{e^+}}{\sigma_{e^-}} = 1 - R$$

- Switching the magnetic field on the BigBite magnet, e^+ yields can be measured with the same acceptance as the measured e^- yields during production
- However, BigBite only took e^+ at one (4.74 GeV) of the two beam energies of E06-014

Determining the BigBite Dilution Factor

To determine the BigBite pair-production dilution factor at E = 5.89 GeV:

- Use LHRS (4.74 and 5.89 GeV e^+/e^- ratios
- Use BigBite 4.74 GeV e^+/e^- ratios
- Use CLAS EG1b e^+/e^- ratios at E = 5.7 GeV and $\theta = 41.1^\circ$
- Fit $\left(\frac{e^+}{e^-}\right)\frac{1}{E_0^2}$ vs p_T
- Use fitted results to extract 5.89 GeV dilution factor for BigBite

Fitting the Data

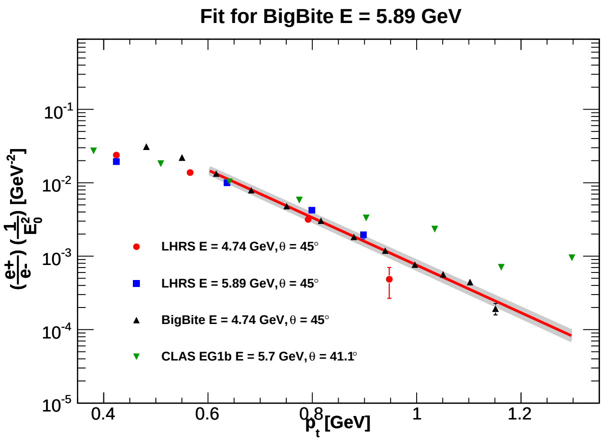


Figure: Fit to positron-electron ratios measured by CLAS, LHRS and BigBite.

Positron-Electron Ratio Results

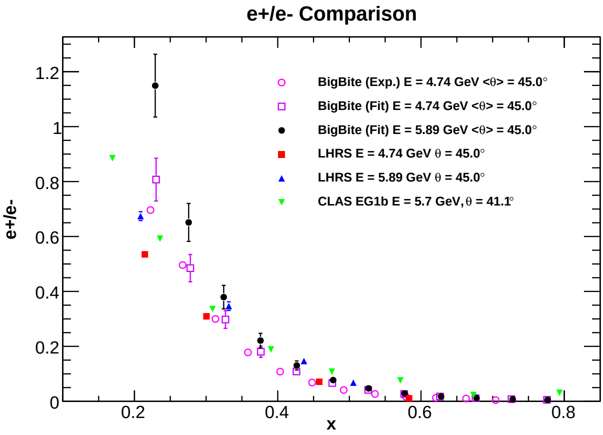


Figure: Positron-electron ratios measured by CLAS, LHRS and BigBite, compared to the fitted results.

Subtracting Pair-Produced Asymmetries

Asymmetry from pair-produced electron can also be subtracted from the measured asymmetry:

$$A^{e-} = \frac{1}{D}\left(A^{rawe-} - RA^{e+}\right)$$

where:

- $R = \frac{e+}{e-}$ ratio
- D = dilution factor for pair production
- A^{rawe-} = measured asymmetry using PID cuts
- A^{e+} = measured positron asymmetry
- A^{e-} = electron asymmetry with pair-produced contamination removed

Measuring Positron Asymmetry

- Because of BigBites large acceptance; positive charged particles that bend-down away from the detector can also be measured
- For each production run, a positron asymmetry can also be measured
- But is the bend-down positron asymmetry the same as the bend-up asymmetry?

Positron Asymmetry Comparison

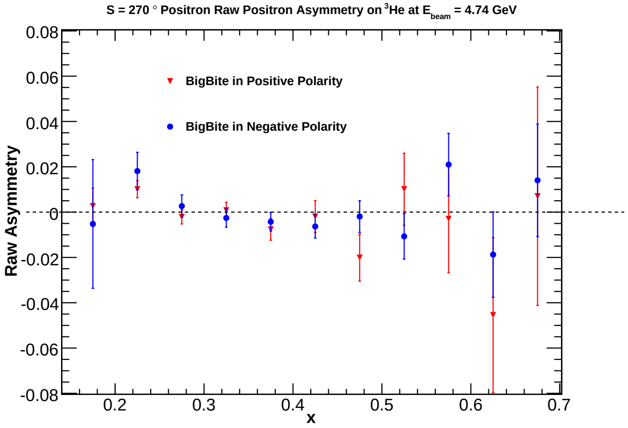


Figure: Compares the bend-up and bend-down positron asymmetries for E = 4.74 GeV and target spin of 270°.

Positron Asymmetries (1)

5.89 GeV

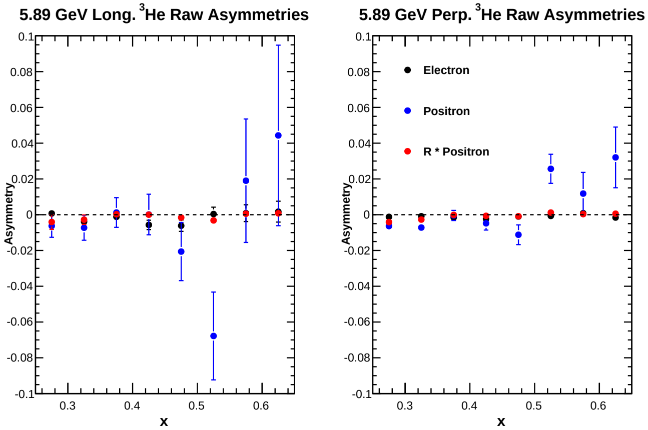


Figure: Compares the raw positron and electron asymmetries, as well as the positron asymmetry weighted by the positron-electron ratio.

Positron Asymmetries (2)

4.74 GeV

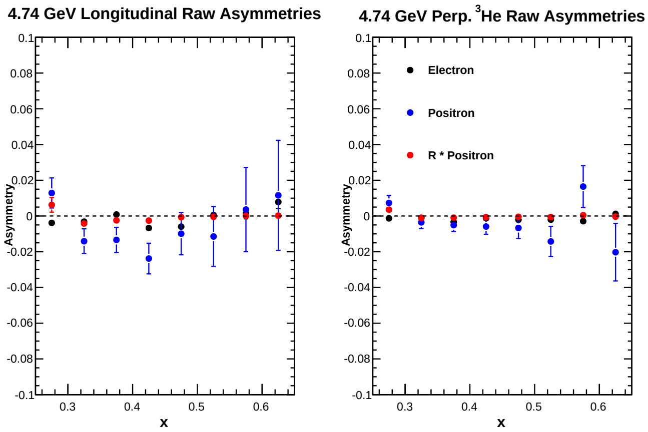


Figure: Compares the raw positron and electron asymmetries, as well as the positron asymmetry weighted by the positron-electron ratio.

Applied Pair-Production Corrections

- Pair-production dilution factor is applied in current analysis
- Positron asymmetry corrections are not currently used in analysis

Preliminary g_1 and g_2

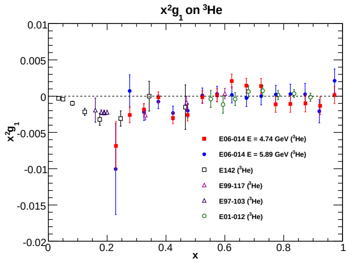


Figure: Preliminary g_1 results on ^{3}He.

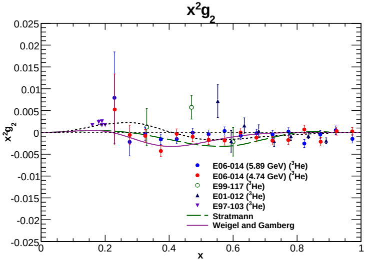


Figure: Preliminary g_2 results on ^{3}He.

Preliminary A_1

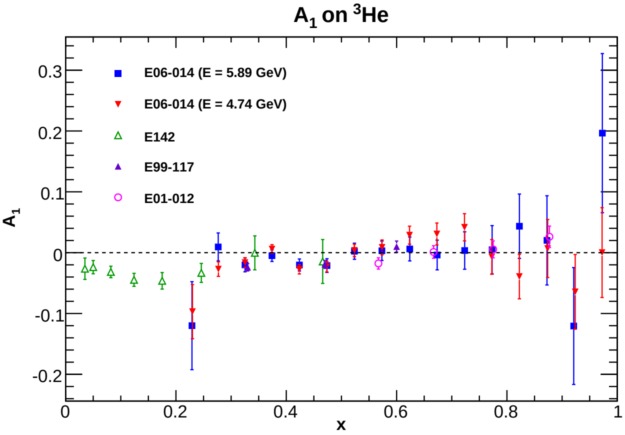


Figure: Compares the raw positron and electron asymmetries, as well as the positron asymmetry weighted by the positron-electron ratio.

Summary

Pair Production

- Asymmetries are corrected for dilution from pair-production contamination
- Asymmetries from pair-production are not subtracted from measured asymmetry

Outline

Overview

In order to extract neutron information from ^{3}He:

- Use polarizations of neutron and proton
- Correct for off-shell nucleon spin structure functions
- Use several models to compute g_1^p and $g_2^{p,WW}$
- Models used:
  - DSSV - Phys.Rev.Lett.101:072001,2008
  - BB - hep-ph/0203155
  - DNS2005 - D.de Florian, G.A. Navarro, and R. Sassot, Phys. Rev. D71 (2005) 094018.
  - GS - T. Gehrmann and W.J. Stirling, Phys.Rev. D53 (1996) 6100.
- **NOTE:**
  - $g_2^p = g_2^{p,WW}$
  - Neutron corrections valid for DIS region only ($x \lessapprox 0.5 - 0.6$)

^{3}He Correction

Calculate g_1^n and g_2^n from equations 1 and 2

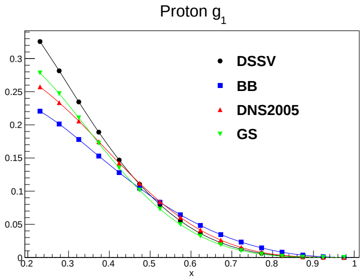
$$g_1^{^3He} = (P_n + 0.056)\, g_1^n + (2P_p - 0.014)\, g_1^p \quad (1)$$
$$g_2^{^3He} = (P_n + 0.056)\, g_2^n + (2P_p - 0.014)\, g_2^{p,WW}$$

(2)

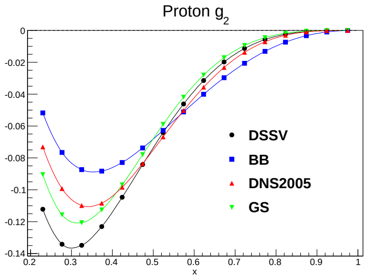
where:

- $g_1^{^3He}$ and $g_2^{^3He}$ are E06-014 data
- g_1^p and $g_2^{p,WW}$ are calculated from 4 models
- P_n = 0.86 $\pm$ 0.02 (neutron polarization)
- P_p = -0.028 $\pm$ 0.004 (proton polarization)
- 0.056 and -0.014 come from off-shell nucleon corrections (See Xiaochao Zheng thesis)

Polarized Structure Functions: g_1^p,g_2^p



(a) 4.74 GeV, g_1^p



(b) 4.74 GeV, g_2^p

Figure: Each of the four models results for the proton g_1 and g_2 polarized structure function at beam energy of 4.74 for E06-014 x and Q^2 values. 5.89 GeV data is similar.

Nuclear Correction Size

5.89 GeV

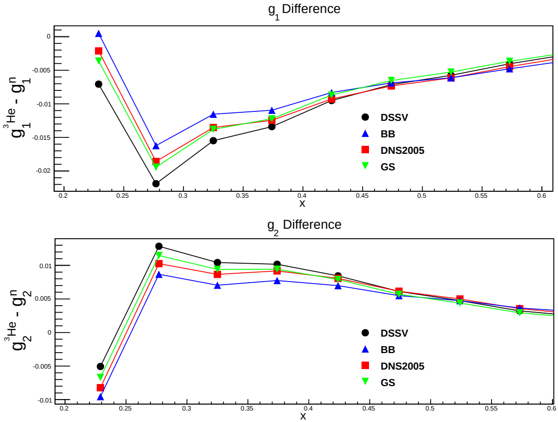


Figure: The difference between the ^{3}He and extracted neutron structure functions are shown as a function of x at a beam energy of 5.89 GeV.

Systematic Uncertainty Contributions

The following uncertainties contribute to the total uncertainty:

- Neutron and proton polarizations
- Dependence from all models
- Dependence on a single model

The first two contributions are considered here

Polarization Uncertainties

The uncertainty from the neutron and proton polarization are given by:

$$(\delta g_1^n)^2_{P_p} = \left(\frac{2g_1^p}{P_n + 0.056}\delta P_p\right)^2 \tag{3}$$

$$(\delta g_1^n)^2_{P_n} = \left(\frac{g_1^{^3He} - (P_p - 0.014)\, g_1^p}{(P_n + 0.056)^2}\delta P_n\right)^2 = \left(\frac{g_1^n}{P_n + 0.056}\delta P_n\right)^2 \tag{4}$$

$$(\delta g_1^n)_{Pol} = \sqrt{(\delta g_1^n)^2_{P_p} + (\delta g_1^n)^2_{P_n}} \tag{5}$$

- Similar for g_2^n, with $g_1^n \rightarrow g_2^n$, $g_1^p \rightarrow$ and $g_1^{^3He} \rightarrow g_2^{^3He}$
- Each model gave similar uncertainties, so they were averaged together for each x bin.

Model Difference Uncertainty

Assign an uncertainty based on difference between the 4 models

- Computed the difference of g_1^n and g_2^n from each of the models (i.e. $|{g_1^n}_{DSSV} - {g_1^n}_{GS}|$)
- The differences varied in size between the models, so largest difference was taken as the uncertainty for each x-bin
- Total systematic uncertainty is quadrature sum of the model difference and polarization uncertainties
- Total systematic uncertainty approximately order of magnitude smaller than statistical error.

Preliminary g_1^n

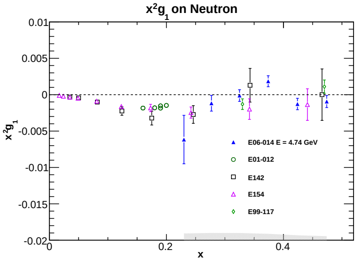


Figure: Preliminary 4.74 GeV g_1^n results. The gray band represents the systematic uncertainty currently assigned to the neutron extraction. Note that these results are only valid up to x = 0.5 in the 4.74 GeV data and x = 0.6 in the 5.89 GeV data.

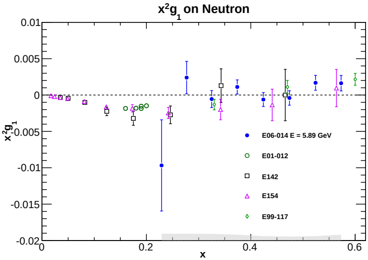
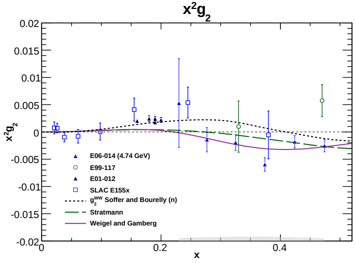


Figure: Preliminary 5.89 GeV g_1^n results. The gray band represents the systematic uncertainty currently assigned to the neutron extraction. Note that these results are only valid up to x = 0.5 in the 4.74 GeV data and x = 0.6 in the 5.89 GeV data.

Preliminary g_2^n



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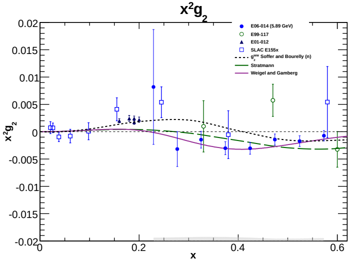


Figure: Preliminary 5.89 GeV g_2^n results. The gray band represents the systematic uncertainty currently assigned to the neutron extraction. Note that these results are only valid up to x = 0.5 in the 4.74 GeV data and x = 0.6 in the 5.89 GeV data.

Summary

Neutron Corrections

- All 4 models used lead to similar polarized neutron structure functions
- Good agreement with world data
- For a second approach:
  - Working with Wally Melnitchouk to extract neutron information in DIS and resonance regions
  - Apply single model dependence uncertainty
  - Follow similar analysis for A_1^n and A_2^n

Outline

BigBite GEANT4 Simulation

- BigBite GEANT4 simulation was written by Vahe
- Simulations main uses:
    - Particle bend trajectories (bend-up/ bend-down)
    - Contamination contributions

GEANT4 BigBite Makeup

BigBite GEANT4 Simulation includes:

- All detector materials are present (but not fully implemented)
- Uses hits in first MWDC to do simple track reconstruction
- Full shower is implemented
- weights for DIS electrons using F1F209
- weights for $\pi^{0,\pm}$ from Wiser

GEANT4 BigBite Material

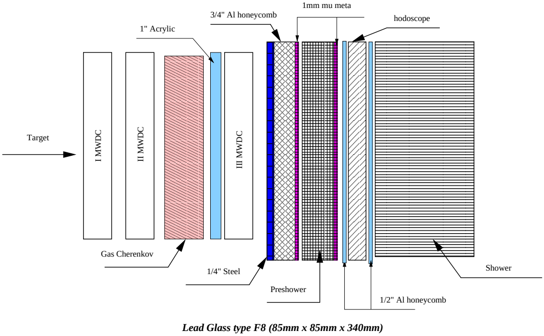
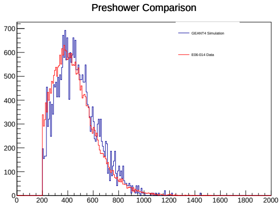
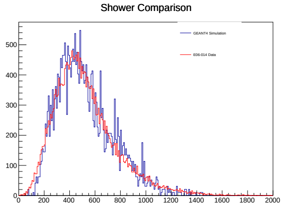
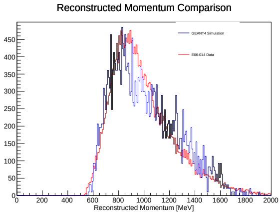


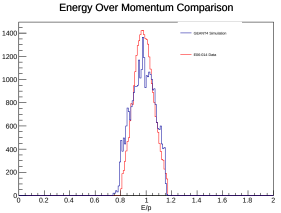
Figure: Materials defined in GEANT4 BigBite simulation.

5.89 GeV GEANT4 Comparison (1)

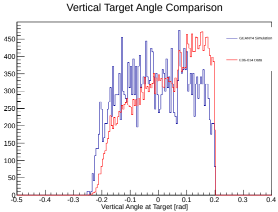


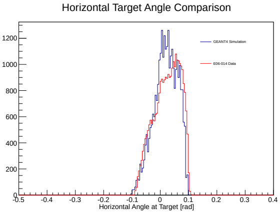


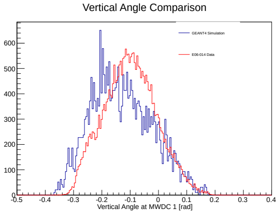


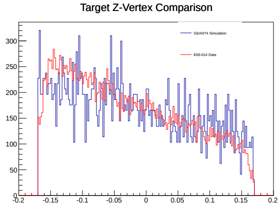


5.89 GeV GEANT4 Comparison (2)









Positron to Electron Ratio Comparison

GEANT4 Definition

- Looked at $\pi^0 \rightarrow 2\gamma \rightarrow e^+e^-$
- BigBite in negative polarity (e- bends up)
- GEANT4 bend-up positrons to bend-up electrons:

$$R = \frac{e^-[\pi^0]}{e^-[\pi^0] + e^-[DIS]}$$

Positron to Electron Ratio Comparison

4.74 GeV Bend-Up e+/ Bend-Up e-

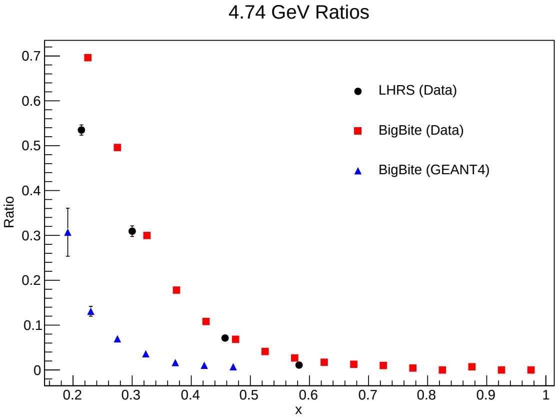


Figure: e^+/e^- ratios measured in the LHRS and BigBite at beam energy of 4.74 GeV, compared to GEANT4 prediction.

Summary

GEANT4 BigBite Simulation

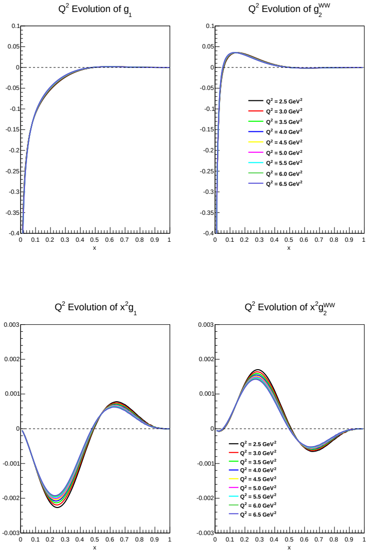
- GEANT4 Energy distributions agree well with data
- Improvement can be made in tracking variable distributions
- GEANT4 pair production ratios disagree with data
- Look into hadron and positron distributions

Outline

Q^2 Dependence

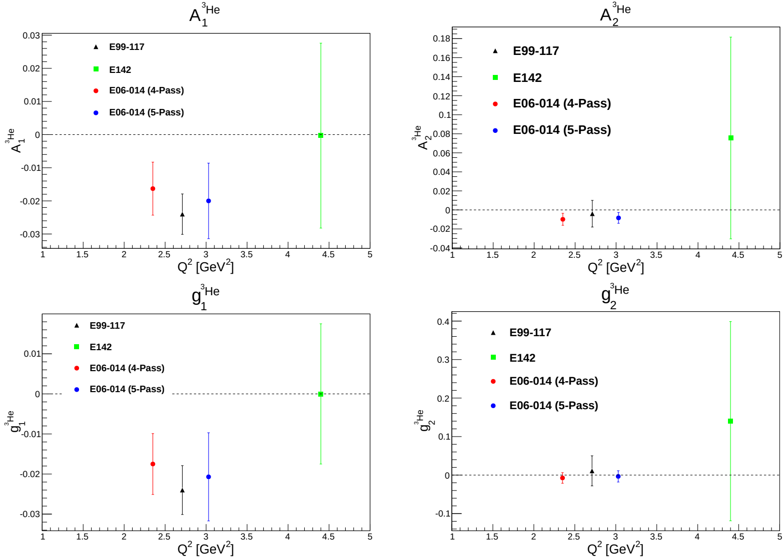
- Polarized structure functions depend on Q^2
- Investigate the Q^2 dependence:
  - On g_1 and g_2 using DSSV
  - Compare our g_1,g_2,A_1 and as a function of Q^2 from other experiments

Q^2 Dependence from DSSV Fits



Q^2 Dependence from Data

$< x >= 0.33$



Interpolating to Constant Q^2

- We took data at constant x and varying Q^2 for two beam energies (4.74 and 5.89 GeV)
- Would like to evolve all data to a constant Q^2 Could interpolate between two beam energies to a constant Q^2

Limitations of Interpolating Data

When interpolating to constant Q^2...

- Only two data points can be fitted. So a linear fit is used.
- We can not interpolate over our entire Q^2 range since some 4 and 5 pass data do not fall between a common Q^2 value
- Divide data into DIS and resonance regions

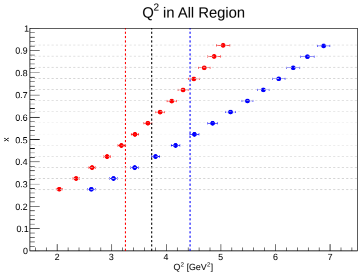


Figure: x vs Q^2 for 4 and 5 pass data. Red dashed line shows average Q^2 for the 4-pass data set, the blue dashed line shows average Q^2 for the 5-pass data set and the black dashed line shows the average Q^2 value over the entire data set.

Interpolation in the DIS Region

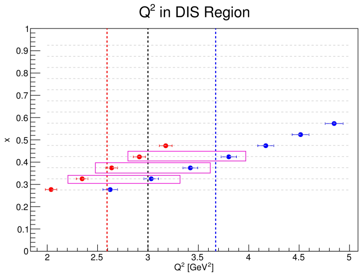


Figure: x vs Q^2 for 4 and 5 pass data. Red dashed line shows average Q^2 in the DIS region for the 4 pass data, the blue dashed line shows average Q^2 in the DIS region for the 5 pass data and the black dashed line shows the average Q^2 value in the DIS region over the entire data set.

- 3 overlapping data points
- $< Q^2 >$
  - 2.594 GeV^2 (4-pass)
  - 3.672 GeV^2 (5-pass)
  - 3.078 GeV^2 (4+5 pass)
- (4+5 pass) Drawn at Q^2 = 3.0 GeV^2 here to get more data points for interpolation

g_1 DIS $< Q^2 >$ = 3.0 GeV^2 Interpolation Results

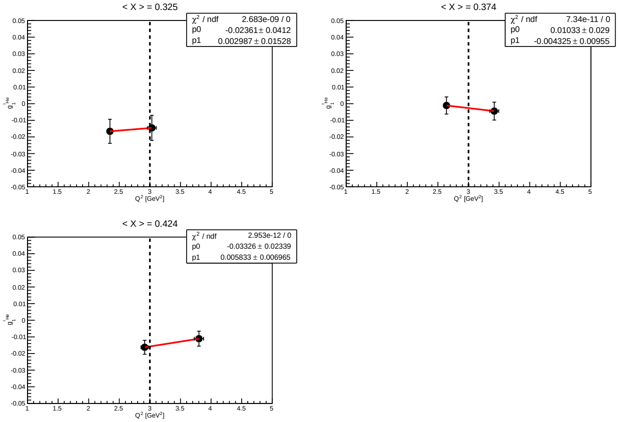


Figure: Interpolation of 4 and 5 pass g_1 data to constant Q^2 of 3.0 GeV^2 in the DIS region.

g_1 and g_2: DIS Region

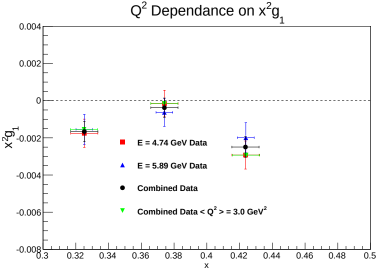


Figure: g_1 on ^{3}He as a function of x in the DIS region for various Q^2 treatments.

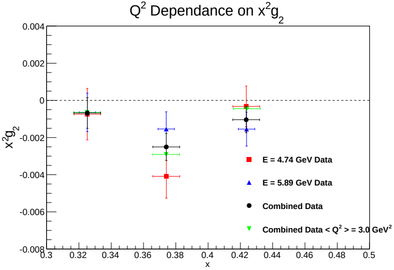


Figure: g_2 on ^{3}He as a function of x in the DIS region for various Q^2 treatments.

g_1 and g_2: Resonance Region

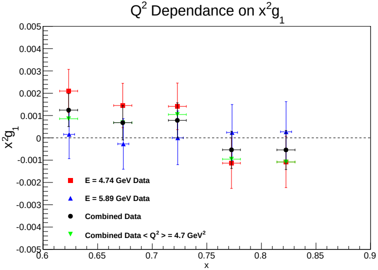


Figure: g_1 on ^{3}He as a function of x in the resonance region for various Q^2 treatments.

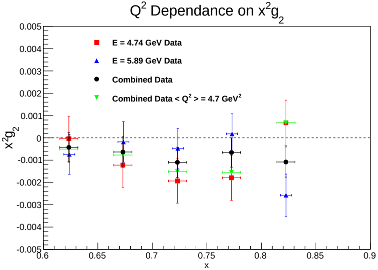


Figure: g_2 on ^{3}He as a function of x in the resonance region for various Q^2 treatments.

Summary

Q^2 Dependence

- Can't use data to evolve to constant Q^2 value
- DSSV model shows little Q^2 dependence
- Mild variation at constant $< x >= 0.33$ relative to precision when comparing to other experiments
- Averaged Q^2 value at each x bin show agreement with interpolated values

Outline

Pion Asymmetries

π^-

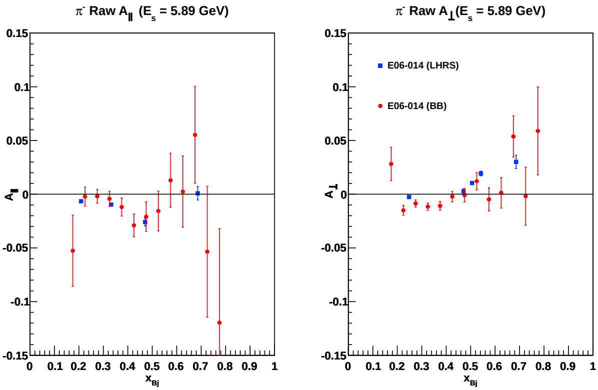


Figure: 5.89 GeV pi-minus asymmetries.

Pion Asymmetries

π^+

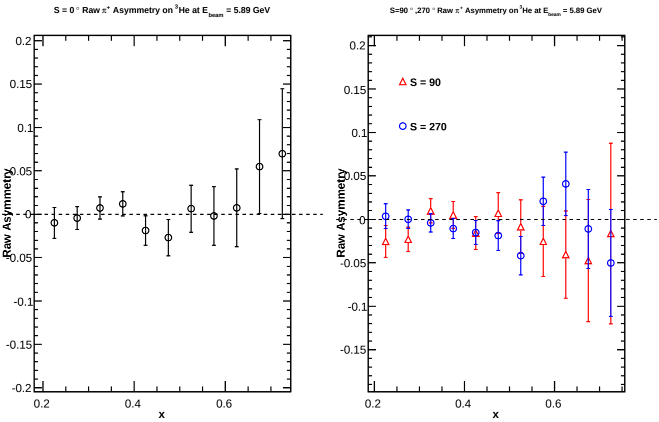


Figure: 5.89 GeV pi-plus asymmetries.

Pion Asymmetries

π^+

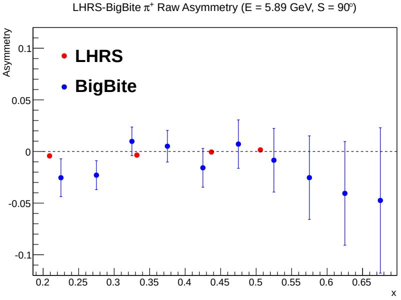


Figure: 5.89 GeV pi-plus asymmetries.

Nuclear Correction Size

4.74 GeV

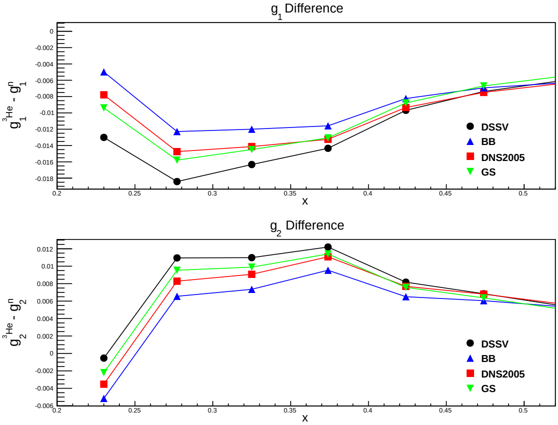


Figure: The difference between the ^{3}He and extracted neutron structure functions are shown as a function of x at a beam energy of 4.74 GeV.