A Precision Measurement of d_2^n: A Probe of the Color Force

On behalf of the d2n/E06014 Collaboration

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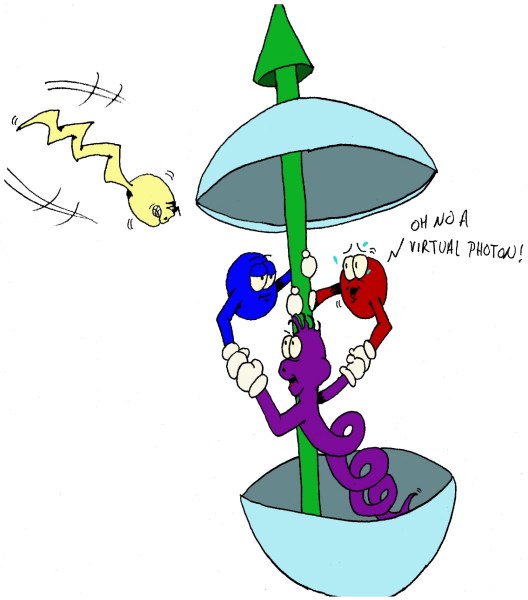
Probing QCD through Quark-Gluon Dynamics

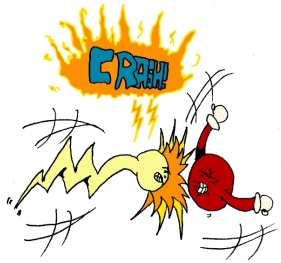
d_2^n gives access to quark-gluon correlations

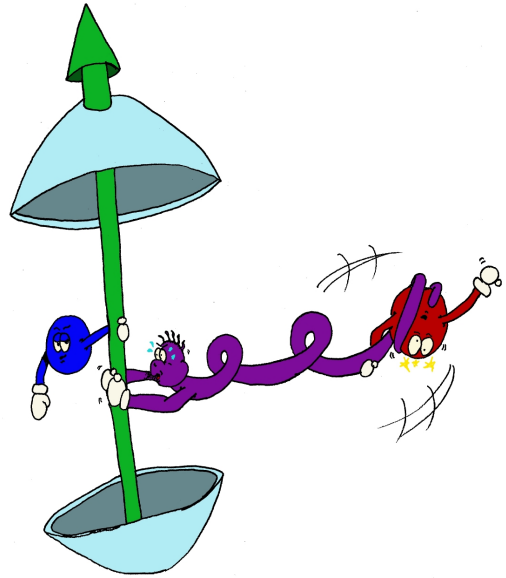
$$d_2^n = \int_0^1 x^2 \left(2g_1\left(x, Q^2\right) + 3g_2\left(x, Q^2\right)\right) dx$$

- What is d_2^n?
  - Average Lorentz color transverse force acting on a quark immediately after being struck by a virtual photon (M. Burkardt)
  - d_2^n is dominated by large x contributions

What is d_2^n?







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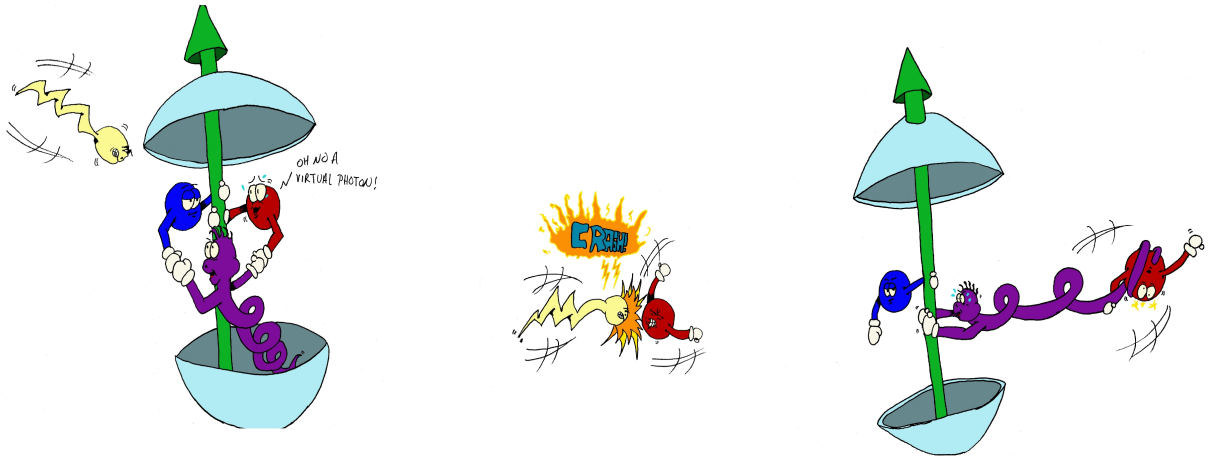
What is d_2^n?

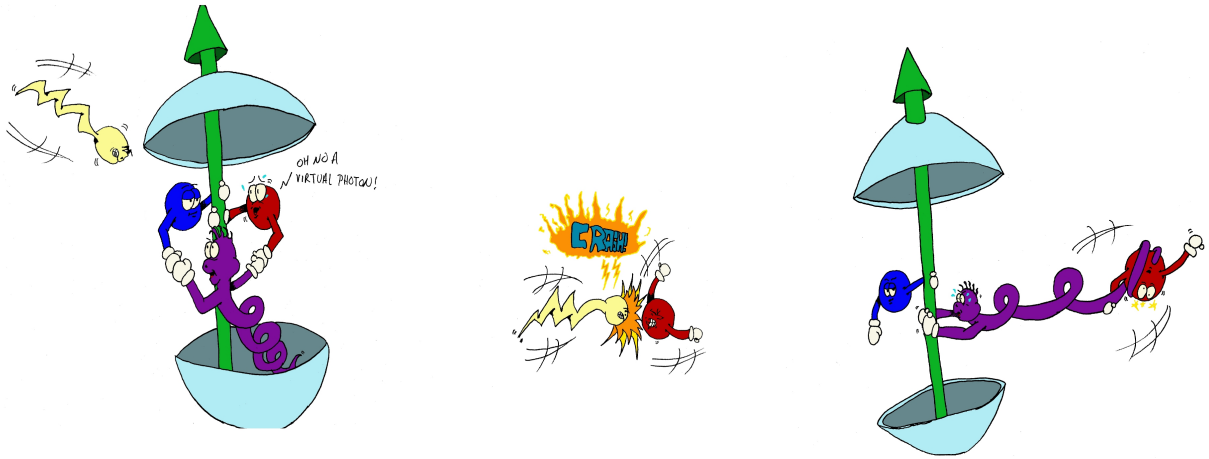
So d_2^n is...



- A measure of quark-gluon correlations

What is d_2^n?

So d_2^n is...



- A measure of quark-gluon correlations
- A force felt between the quark and gluon due to a virtual photon knocking a quark out of the nucleon

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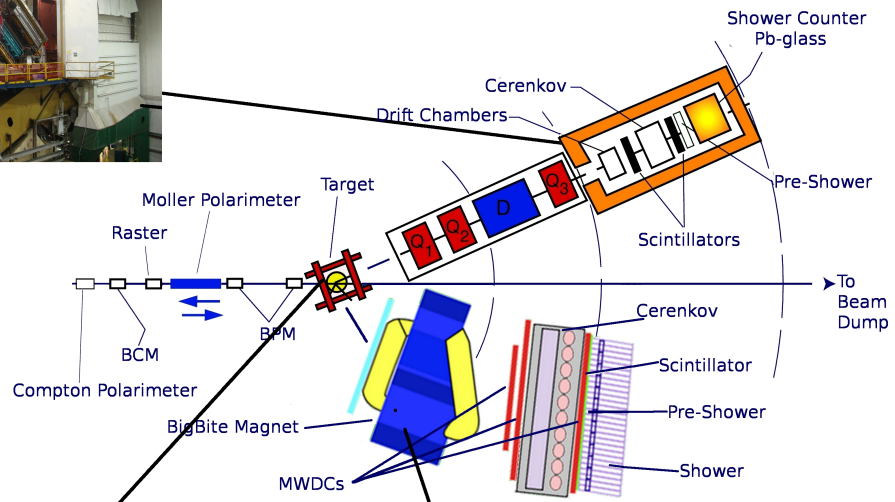
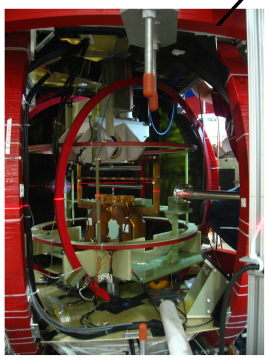
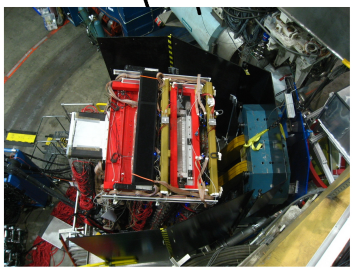
Experimental Set-Up

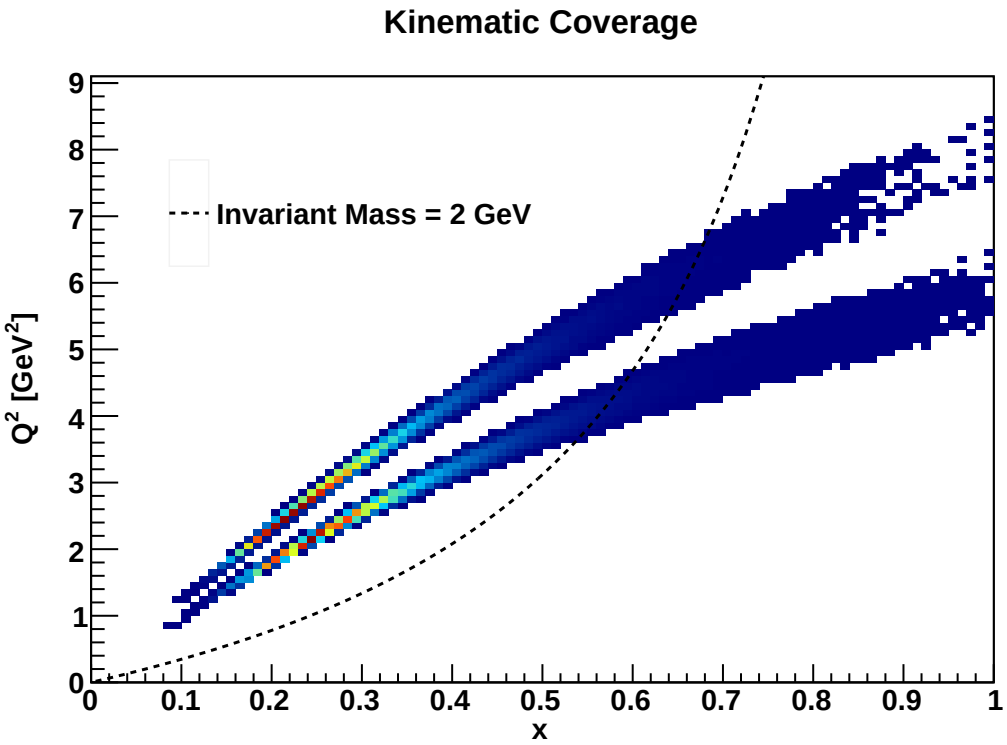
- Scattered longitudinally polarized electrons from longitudinally/transversely polarized ^{3}He target
- Two single arm detectors position 45° relative to the beam line







Kinematic Coverage



- $0.2 < x < 0.925$
- $2 < Q^2 < 7$ GeV^2

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Measuring d_2^n

d_2^n can be measured through the total cross section and the asymmetries

$$A_\perp = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{2\sigma_0}, A_\parallel = \frac{\sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}}{2\sigma_0}$$

$$d_2^n = \int_0^1 dx \left(\frac{MQ^2}{4\alpha^2}\frac{x^2y^2\sigma_0}{(1-y)(2-y)}\right)\left[\left(3\frac{1+(1-y)\,cos\theta}{(1-y)} + \frac{4}{y}tan\frac{\theta}{2}\right)A_\perp + \left(\frac{4}{y} - 3\right)A_\parallel\right]$$

- $\downarrow, \uparrow$ = minus, plus electron helicities
- $\Uparrow, \Rightarrow$ = down stream, towards BigBite detector

Beam Polarization

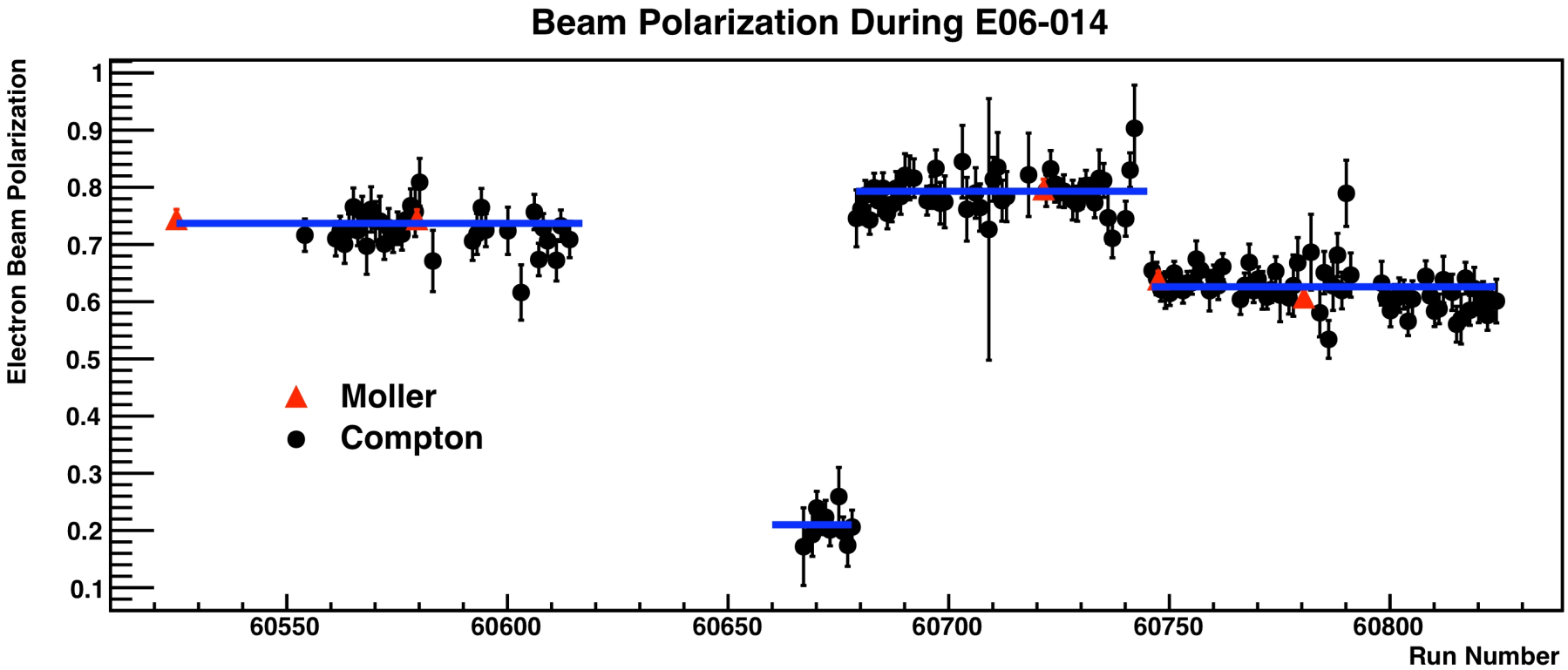

Figure: Beam Polarization

Target Polarization

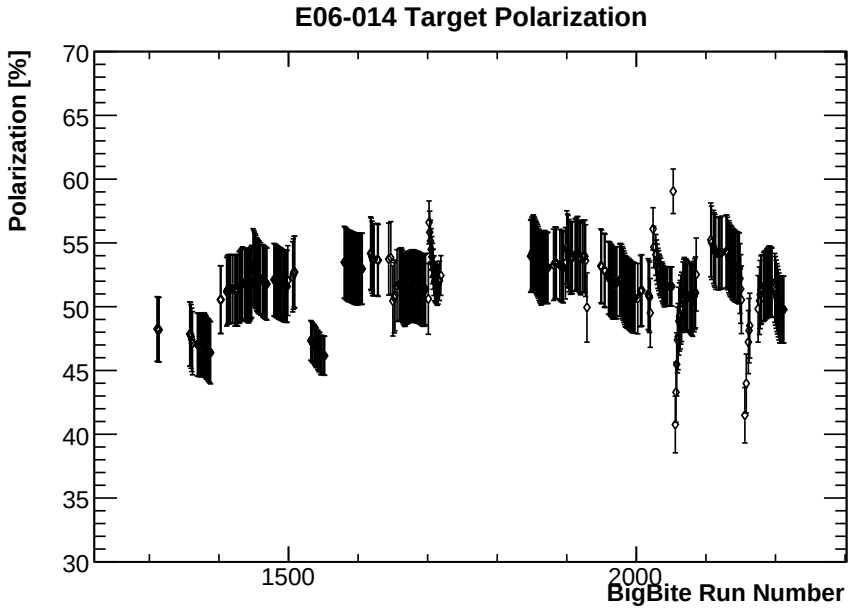

Figure: Target Polarization

- Calibrated using EPR
- Longitudinal polarization cross checked with water calibration

Pair Production Asymmetry Correction

$$N_n^{e-} = N_n^{rawe-} - N_n^{e+}$$

$$A_n^{e-} = \left(\frac{N_n^{rawe-}}{N_n^{e-}}\right) A_n^{rawe-} - \left(\frac{N_n^{e+}}{N_n^{e-}}\right) A_n^{e+}$$

$$R = \left(\frac{N_p^{e+}}{N_n^{rawe-}}\right) = \kappa \left(\frac{N_n^{e+}}{N_n^{rawe-}}\right)$$

$$\frac{N_n^{e-}}{N_n^{rawe-}} = 1 - R$$

$$A_n^{e-} = \frac{A_n^{rawe-} - R A_n^{e+}}{1 - R}$$

- Where p, n mean BigBite is in positive or negative polarity. $rawe-$ is measured electrons with PID cuts.
- κ found by measuring $\frac{e_p^+}{e_n^+}$ at beam energy of 4.74 GeV

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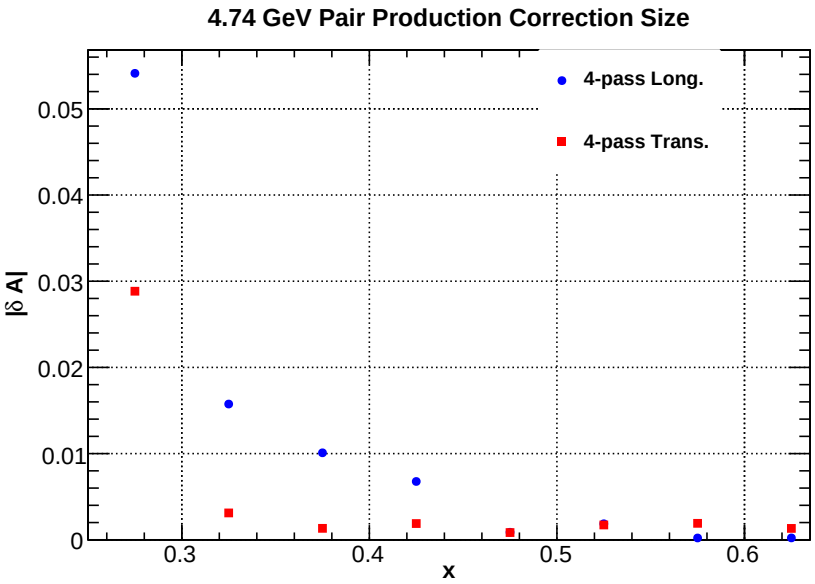
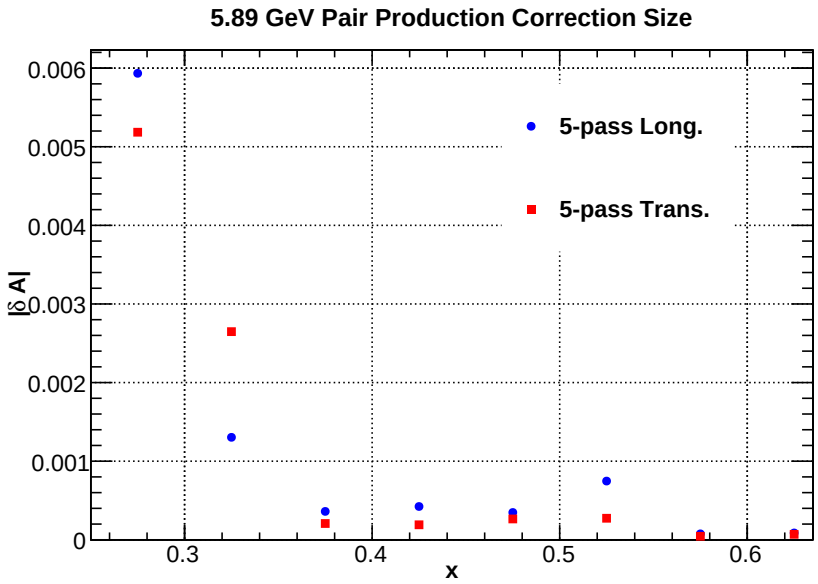
Pair Production Correction Size





Preliminary Electron Asymmetries

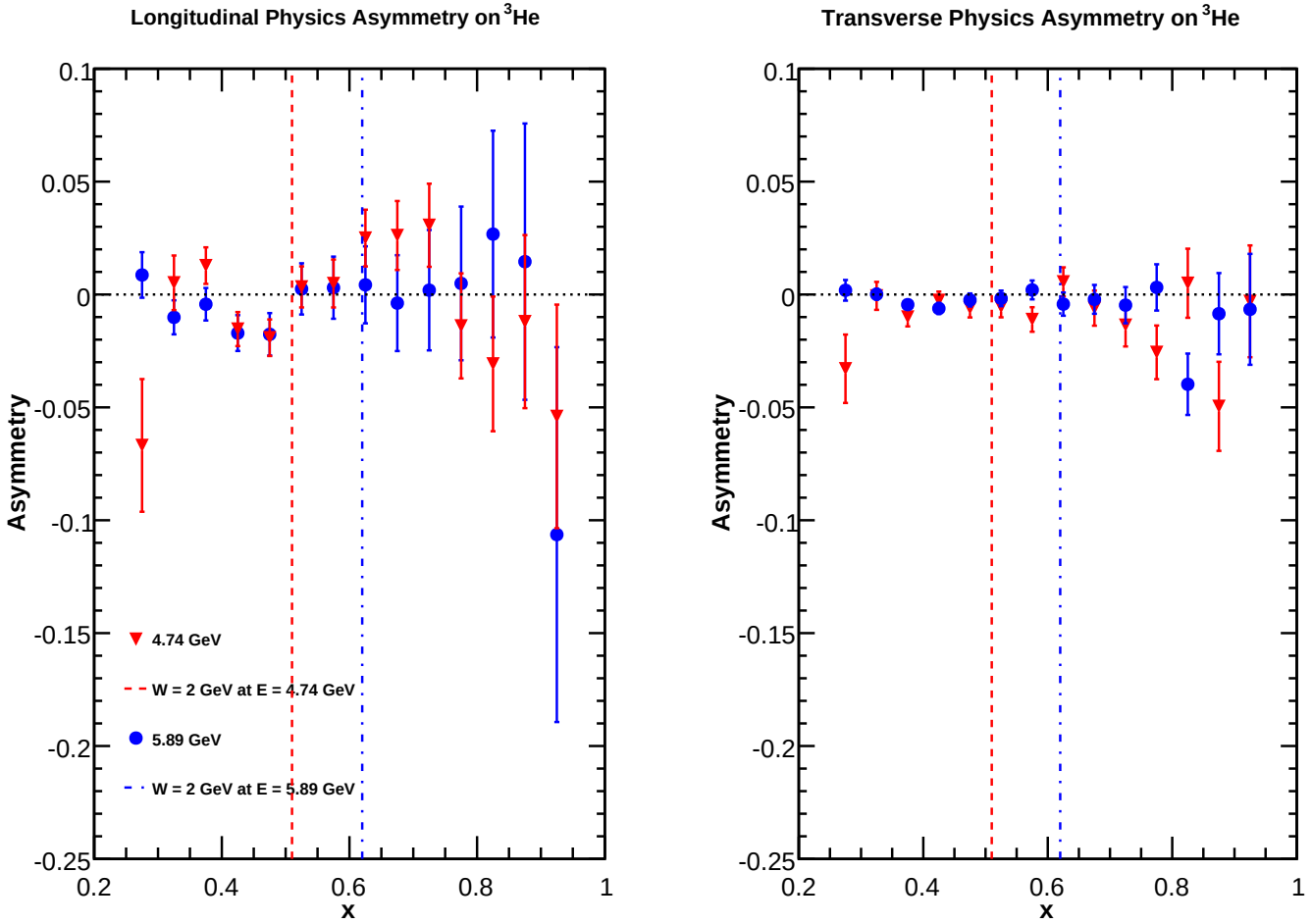
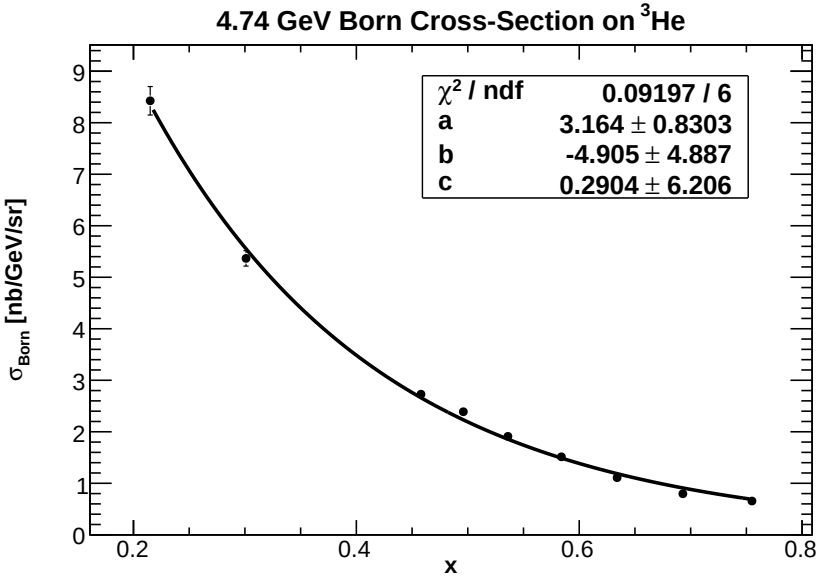
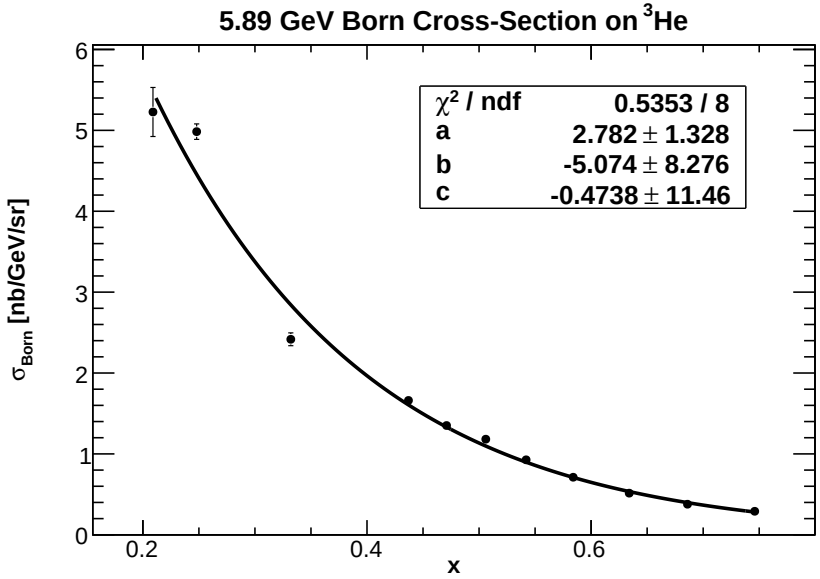


Figure: Preliminary electron asymmetries

Cross Sections





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Preliminary g_1 on ^{3}He

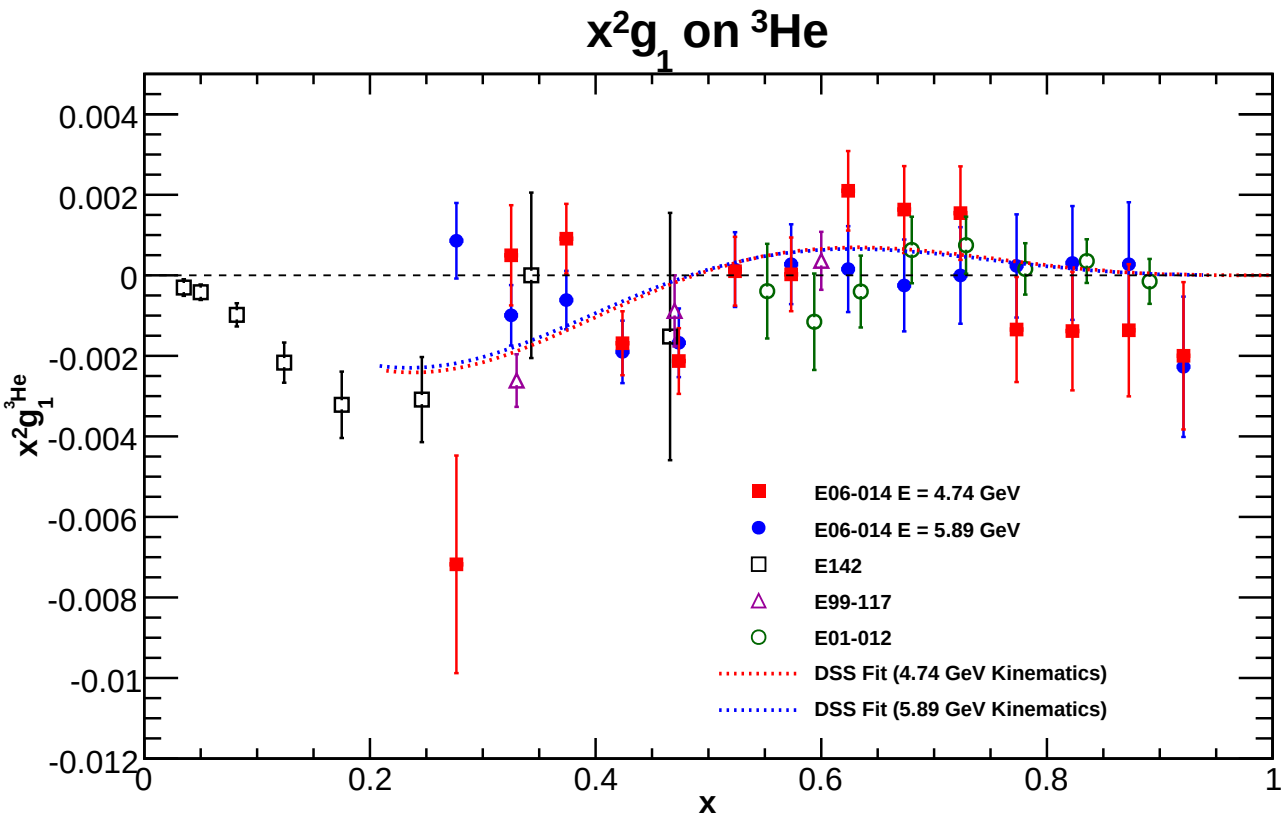

Figure: Preliminary g_1 structure function on ^{3}He

Preliminary g_2 on ^{3}He

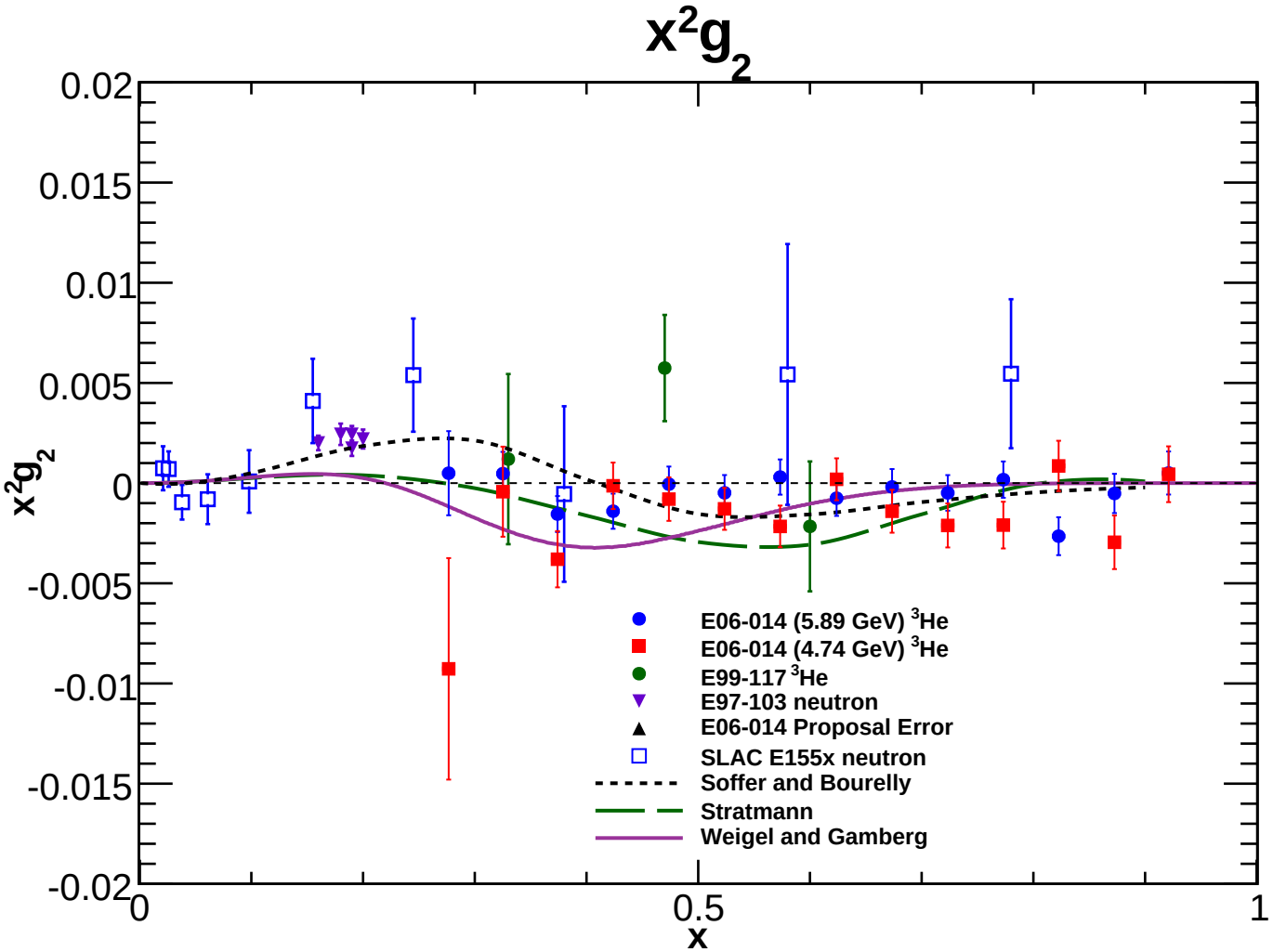

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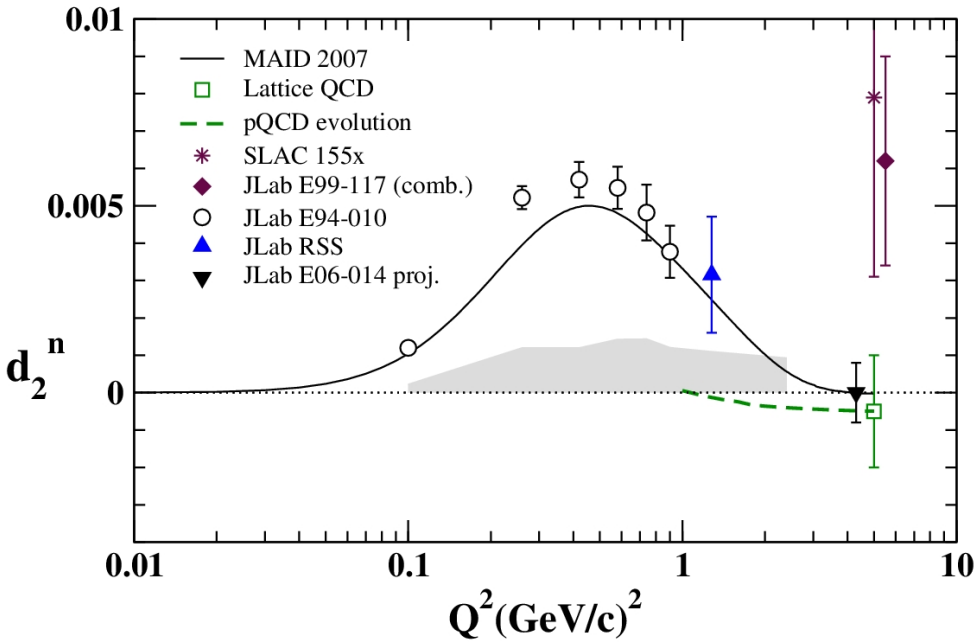
Figure: Preliminary g_2 structure function on ^{3}He

Current d_2 Uncertainty



Current statistical uncertainty on $d_2 \approx 8 \times 10^{-4}$ (at 5.89 GeV)

Summary

- Exploit transverse spin interactions through g_2 structure function, to study higher twist effects
- Gain insight of Lorentz color force inside the neutron through the matrix element d_2^n
- Provide a test to lattice QCD
- Born Cross-sections are finalized
- Radiative corrections to asymmetries are underway
- BigBite simulations also well underway

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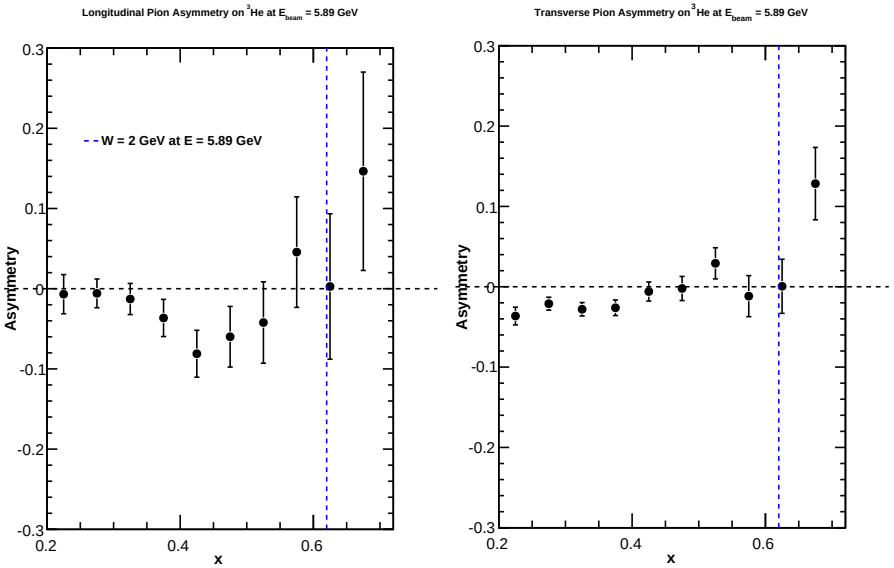
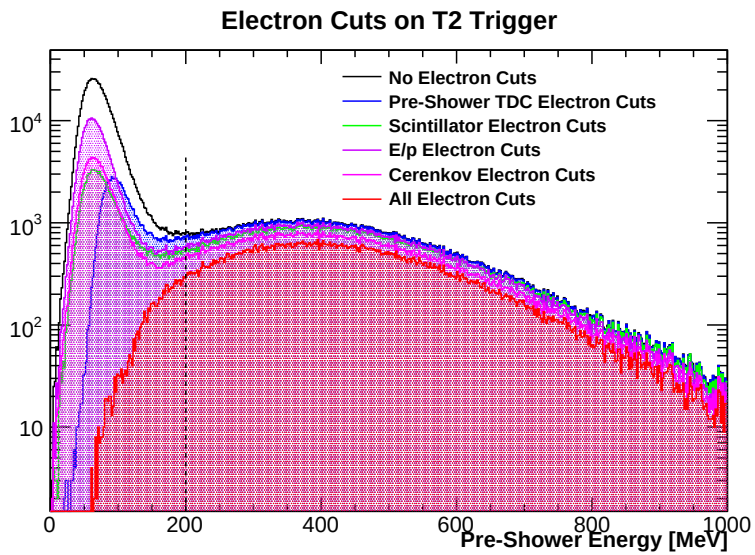
Acknowledgements

Thanks to ...

- The spokes people: X. Jiang, S. Choi, B. Sawatzky and Z.-E. Meziani
- The primary analysis team: D. Flay, G. Franklin, V. Mamyan, Z.-E. Meziani, D. Parno, M. Posik, B. Sawatzky and Y. Zhang
- Hall A Collaboration
- Transversity Collaboration
- d_2^n Collaboration
- This work is supported by:
  DOE Award #DE-FG02-94ER40844

Pion Asymmetry Contamination





- Pion asymmetries are sizable
- But pion rejection was good $\approx 10^5$
- Leads to negligible pion contamination

Positron to Electron Bend-Up Ratio

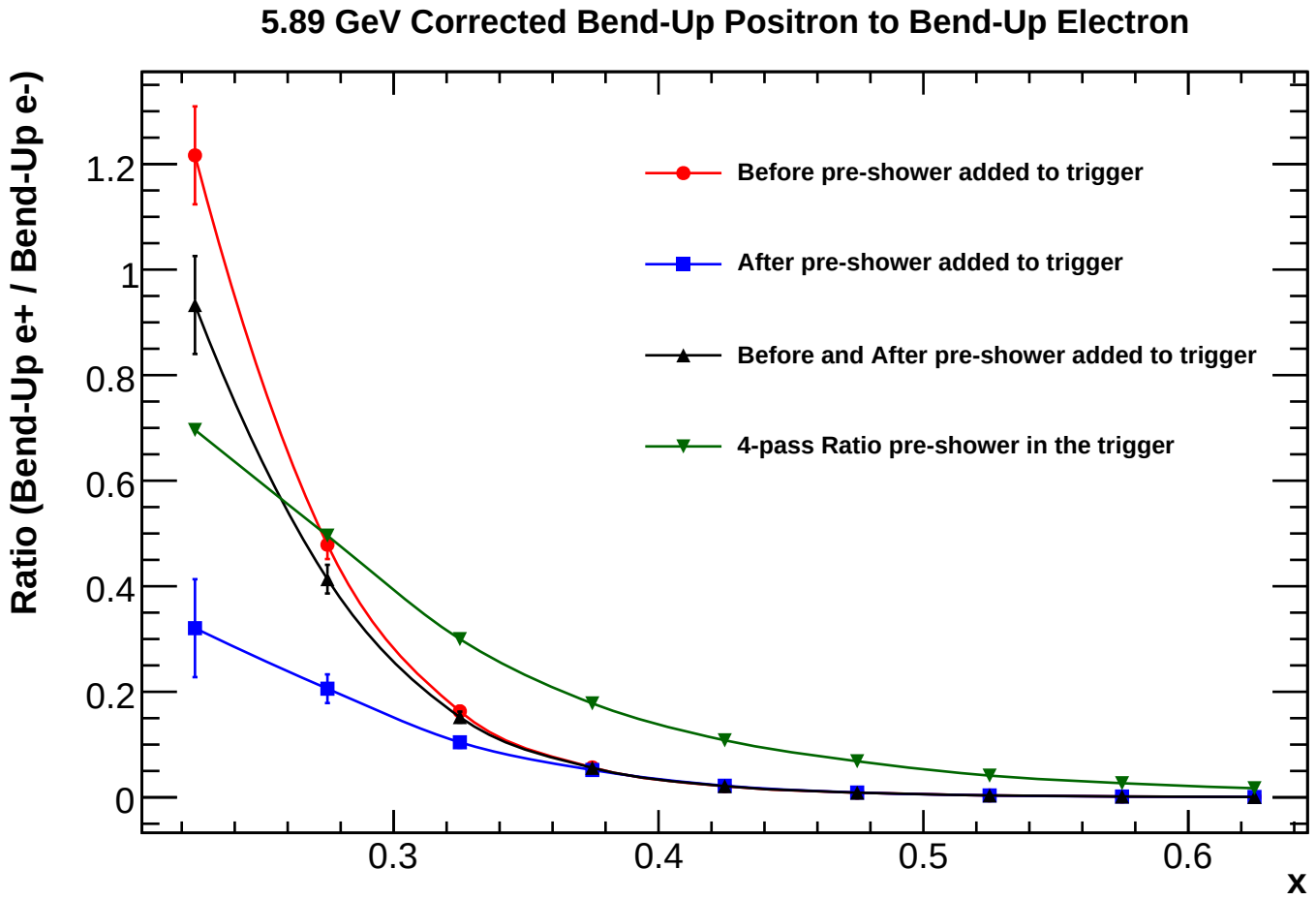


Figure: Ratio of bend-up positrons to bend-up electrons obtained by using κ factor.

Bend-Up and Bend-Down Positron Raw Asymmetries

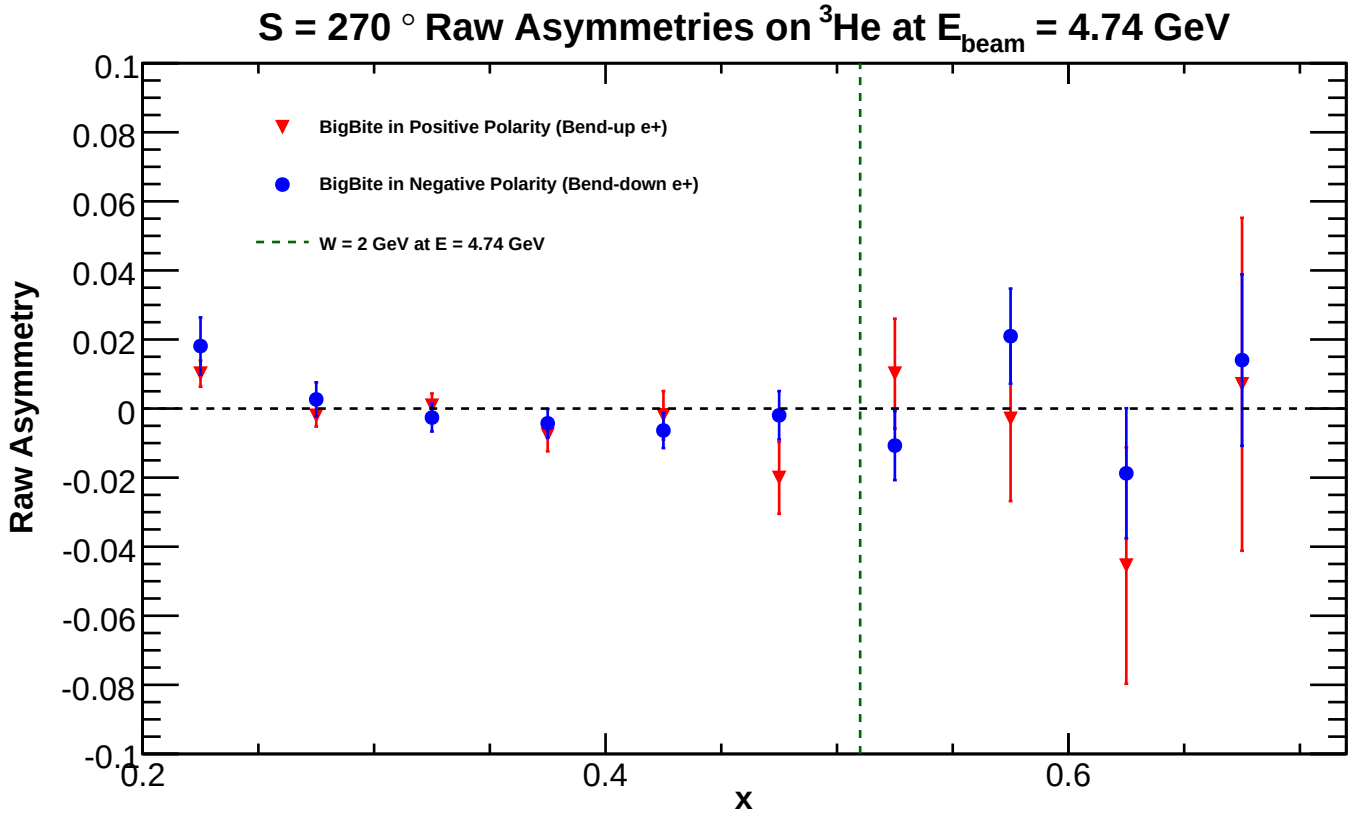


Figure: Comparison between bend-up and bend-down positron asymmetries.

Bend-Down Positron Asymmetries

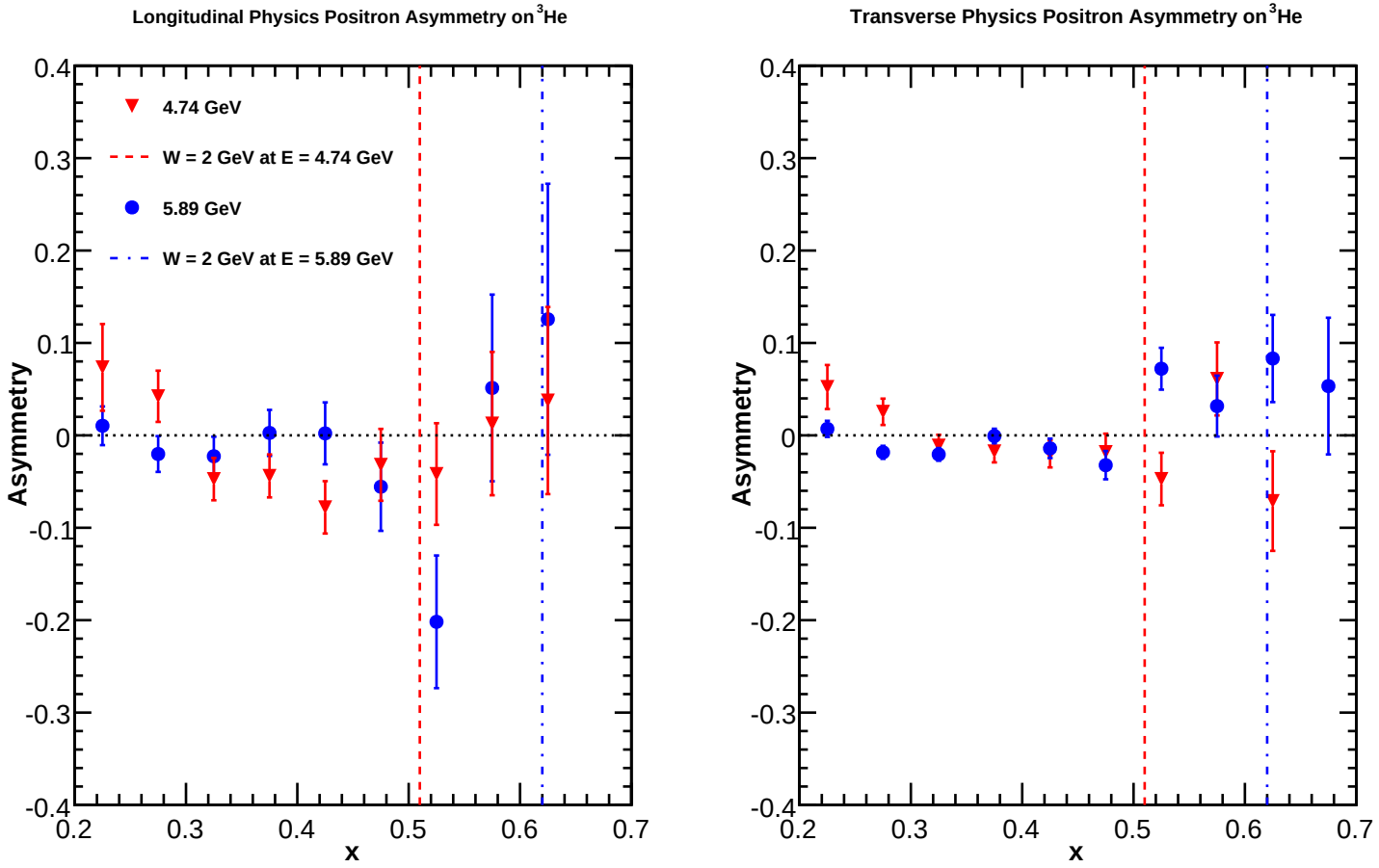
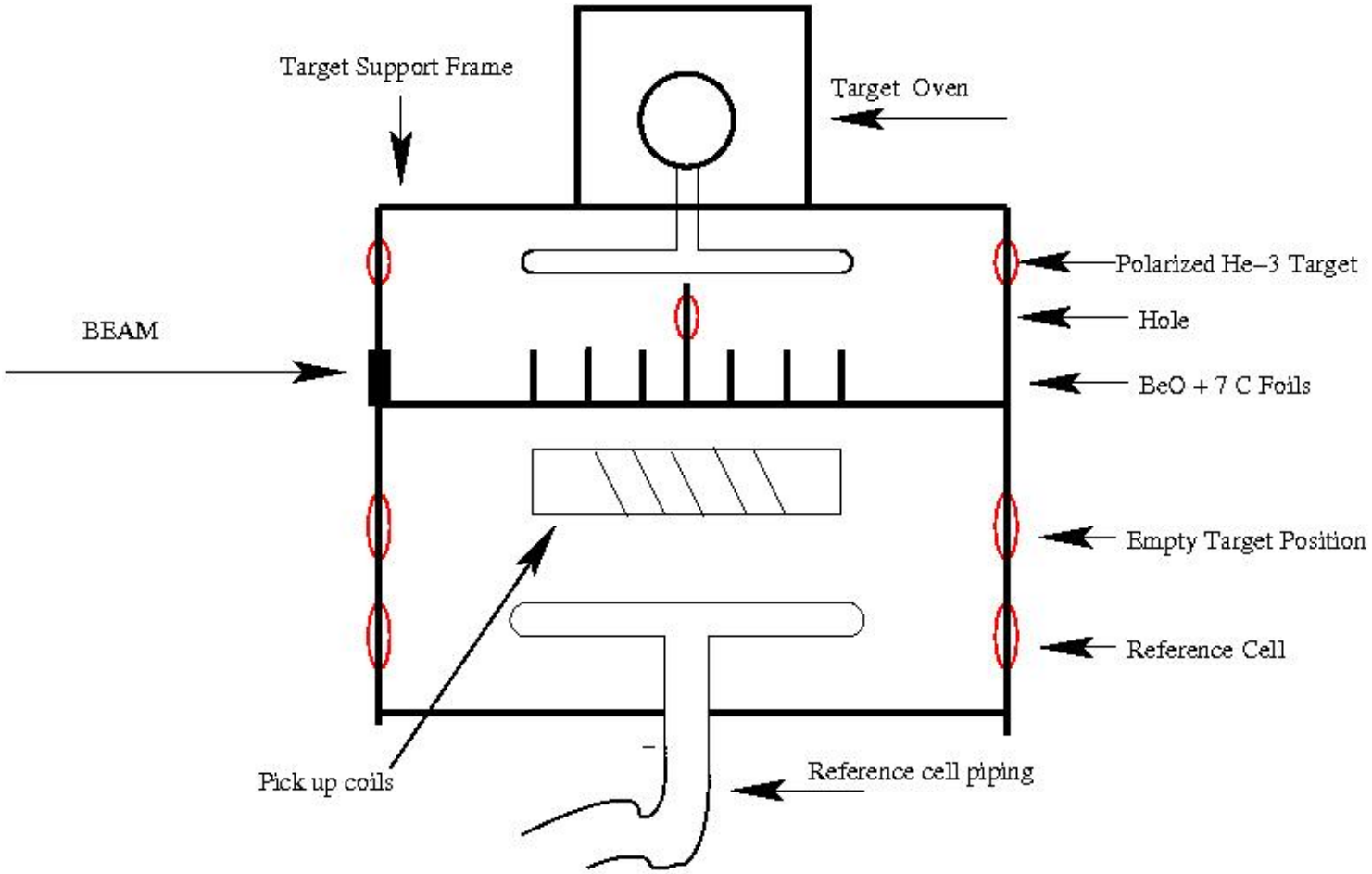


Figure: 4.74 and 5.89 GeV longitudinal and transverse positron asymmetries.

Target Ladder



Target Setup