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

On behalf of the d2n/E06014 Collaboration

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Lepton-Hadron Scattering

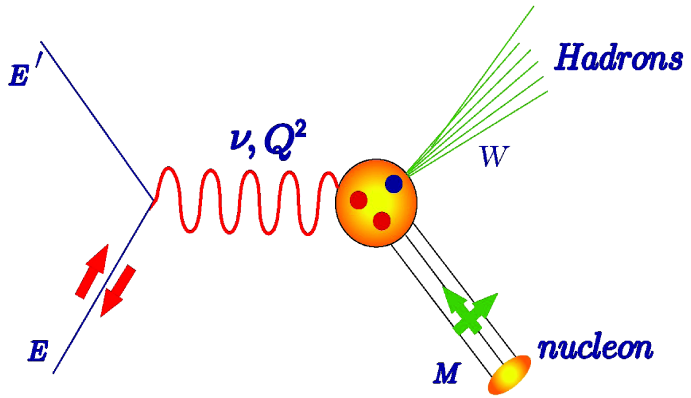
Lepton-Hadron scattering interaction is given by $l_{\mu,\nu}W^{\mu.\nu}$

- $l_{\mu,\nu}$ is the lepton tensor (describes a point particle i.e. an electron)
- $W^{\mu,\nu}$ is the hadron tensor (describes a composite particle i.e. a neutron)

The Hadron tensor can be decomposed as

$$W^{\mu,\nu} = W^{\mu,\nu}_{unpol} + W^{\mu,\nu}_{pol}$$

- Unpolarized term has spin independent F_1 and F_2 structure functions
- polarized term has spin dependent g_1 and g_2 structure functions



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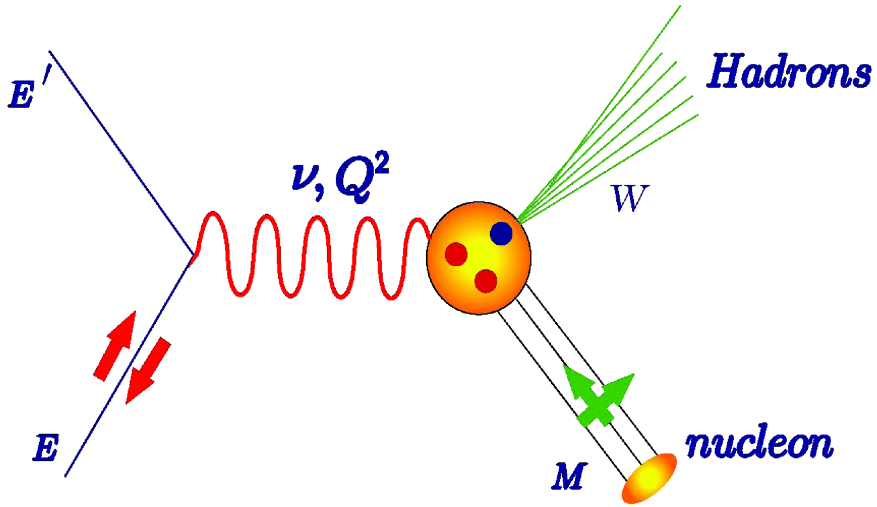
Deep Inelastic Scattering (DIS)



$$
\begin{aligned}
Q^2 &= -q^2 \text{ (Momentum transfer)} \\
q^2 &= k - k' \\
x &= \frac{Q^2}{2P \cdot q} \text{ (Momentum fraction of the quark)} \\
W &= \sqrt{M^2 + 2M\nu - Q^2} \text{ (Invariant mass)} \\
\nu &= E' - E \text{ (Energy transfer)}
\end{aligned}
$$

- $W > 2$ GeV : Defines DIS region
- $W < 2$ GeV : Defines Resonance region

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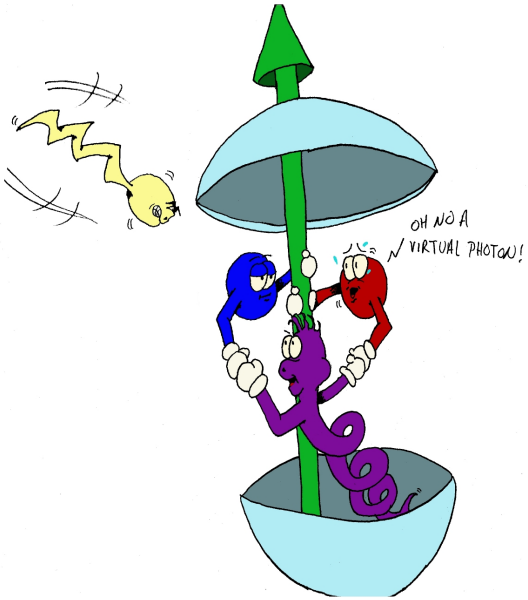
Probing Quark-Gluon Dynamics in the Nucleon

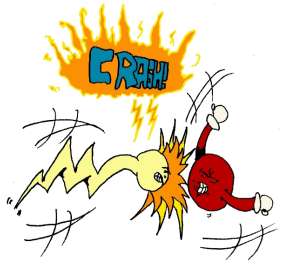
d_2^n gives access to quark-gluon correlations

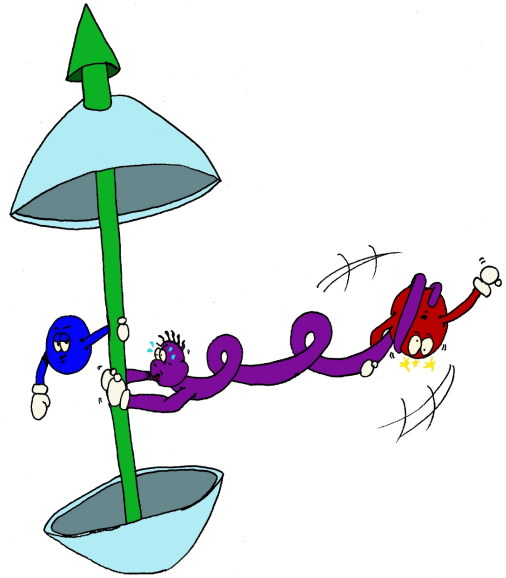
$$d_2^n = \int_0^1 x^2 \left(2g_1\left(x, Q^2\right) + 3g_2\left(x, Q^2\right)\right) dx$$

- What is d_2^n?
  - Average Lorentz color transverse force acting on a quark immediately after being struck by a virtual photon (M. Burkardt hep-ph/0905.4079v1)
  - d_2^n is dominated by large x contributions

What is d_2^n?







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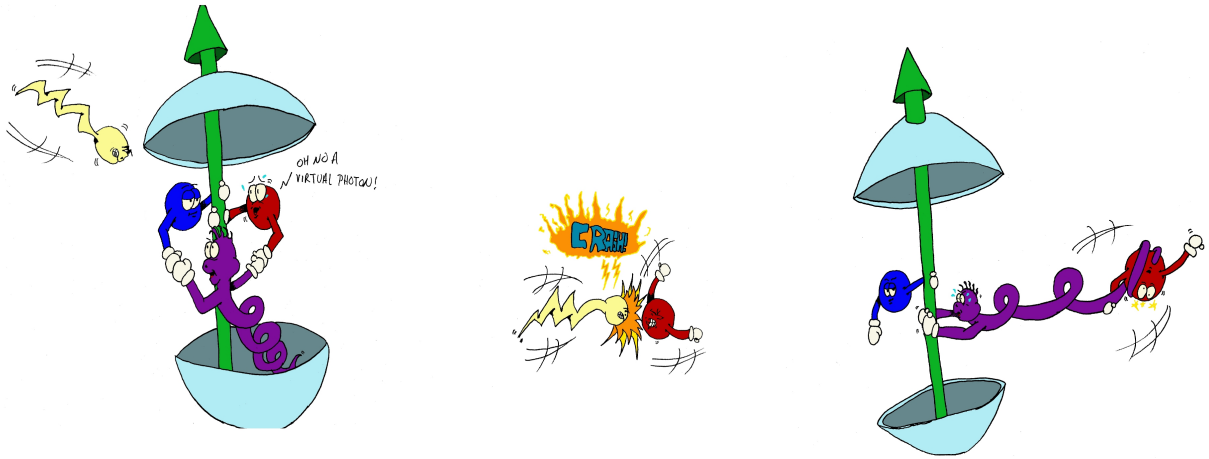
What is d_2^n?

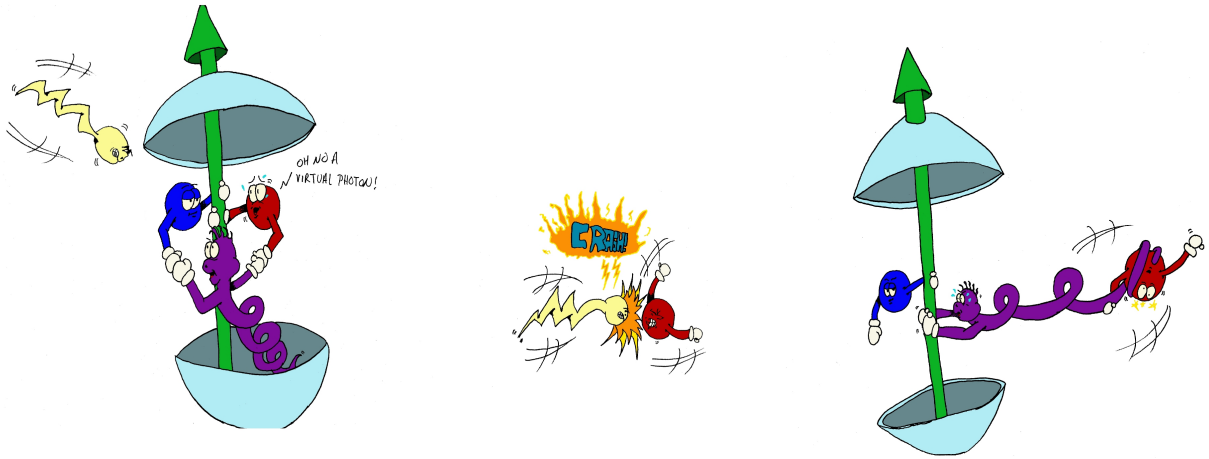
So d_2^n is...



- 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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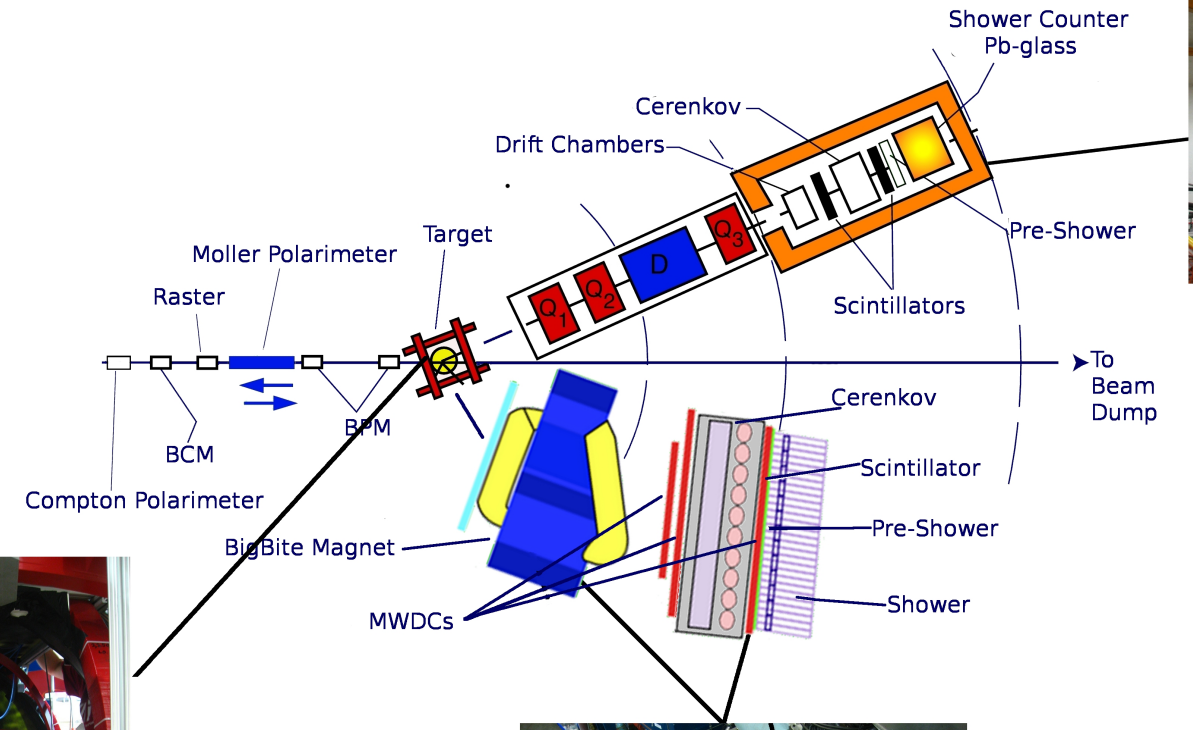
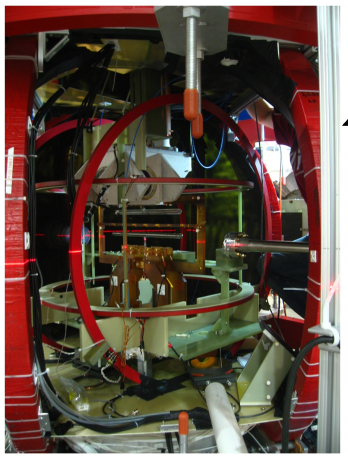
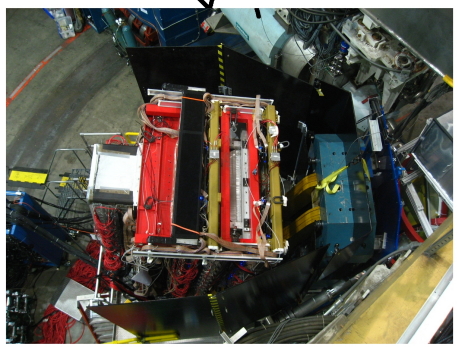
Experimental Set-Up







Measuring d_2^n

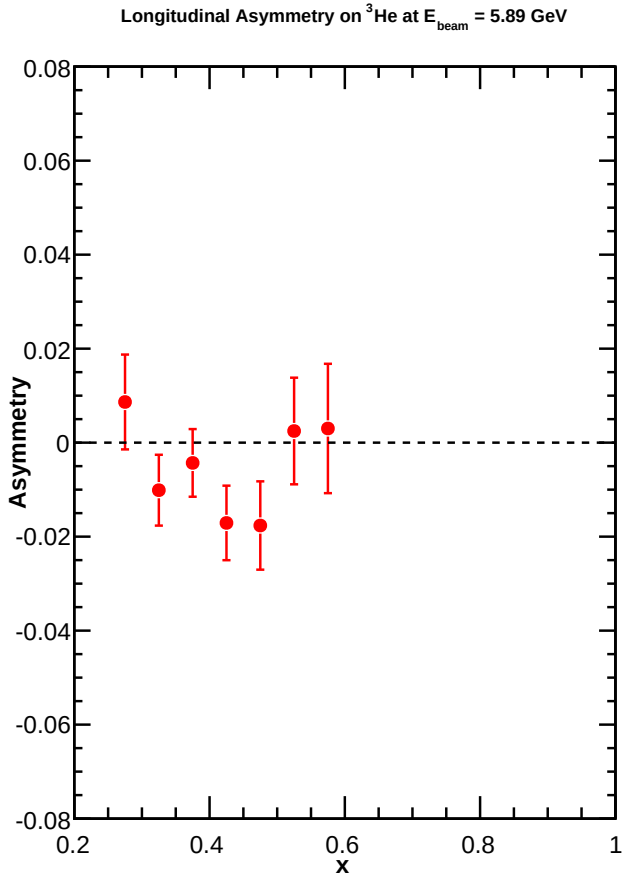
d_2^n can be measured through the unpolarized cross section and the asymmetries

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

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

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

Preliminary Electron Asymmetries



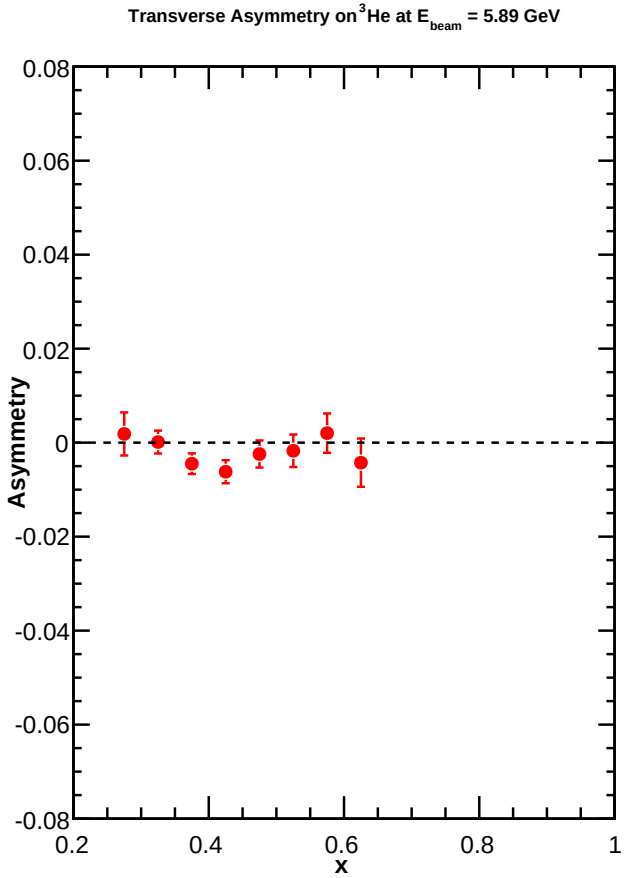


Figure: Preliminary electron asymmetries in the DIS region.

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Preliminary Electron Asymmetries

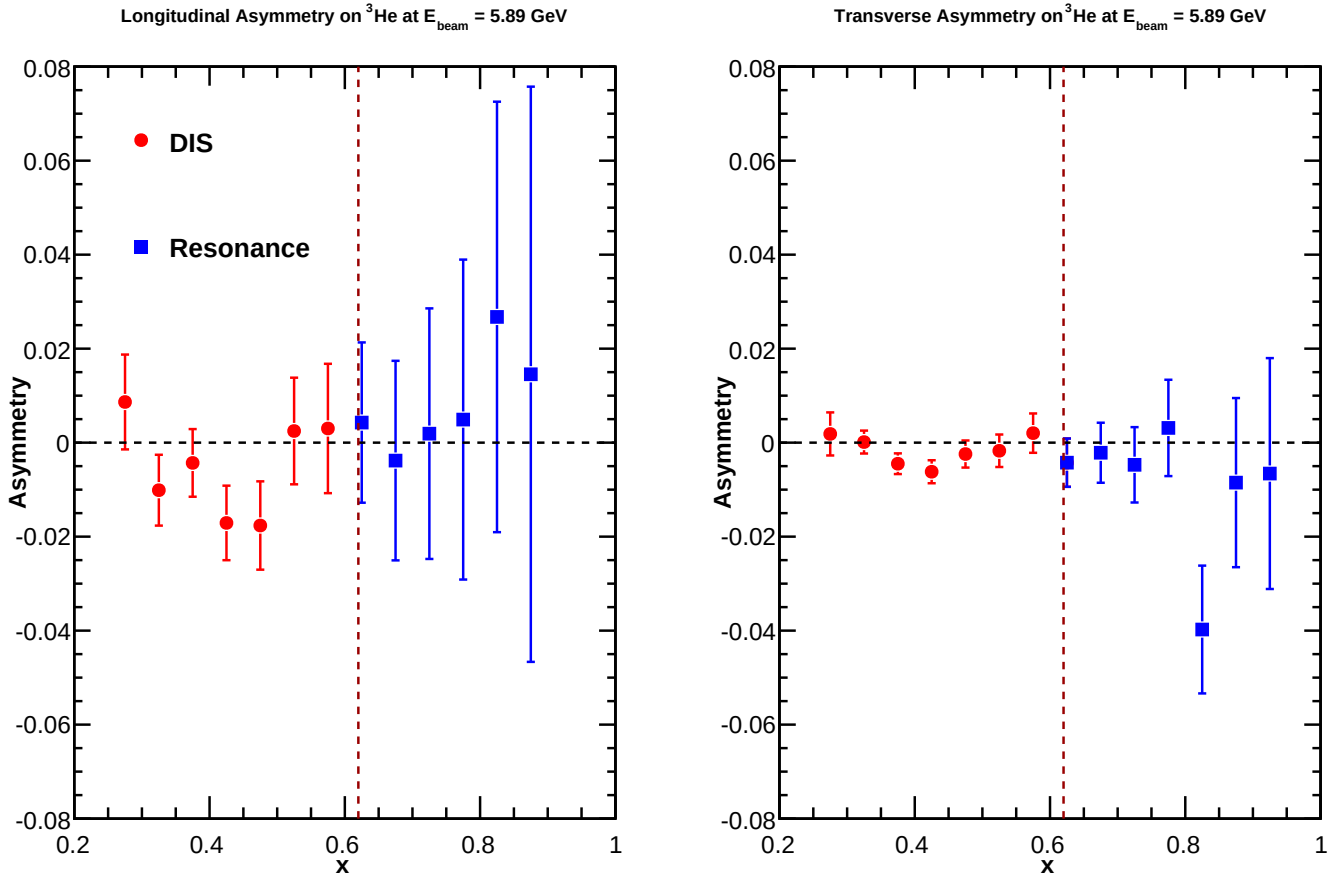
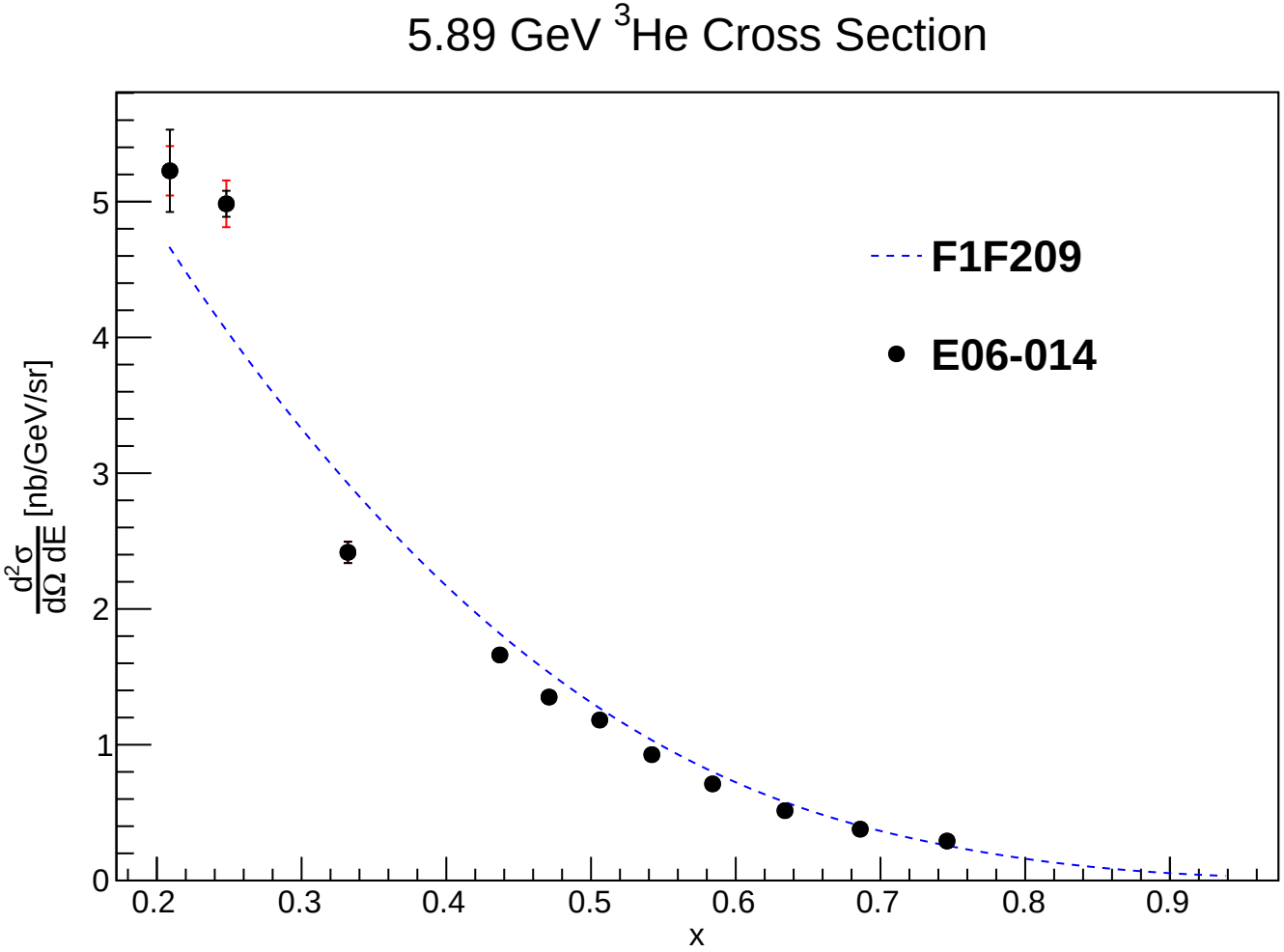


Figure: Preliminary electron asymmetries in the DIS and resonance regions.

Cross Sections



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Preliminary g_1 on ^{3}He

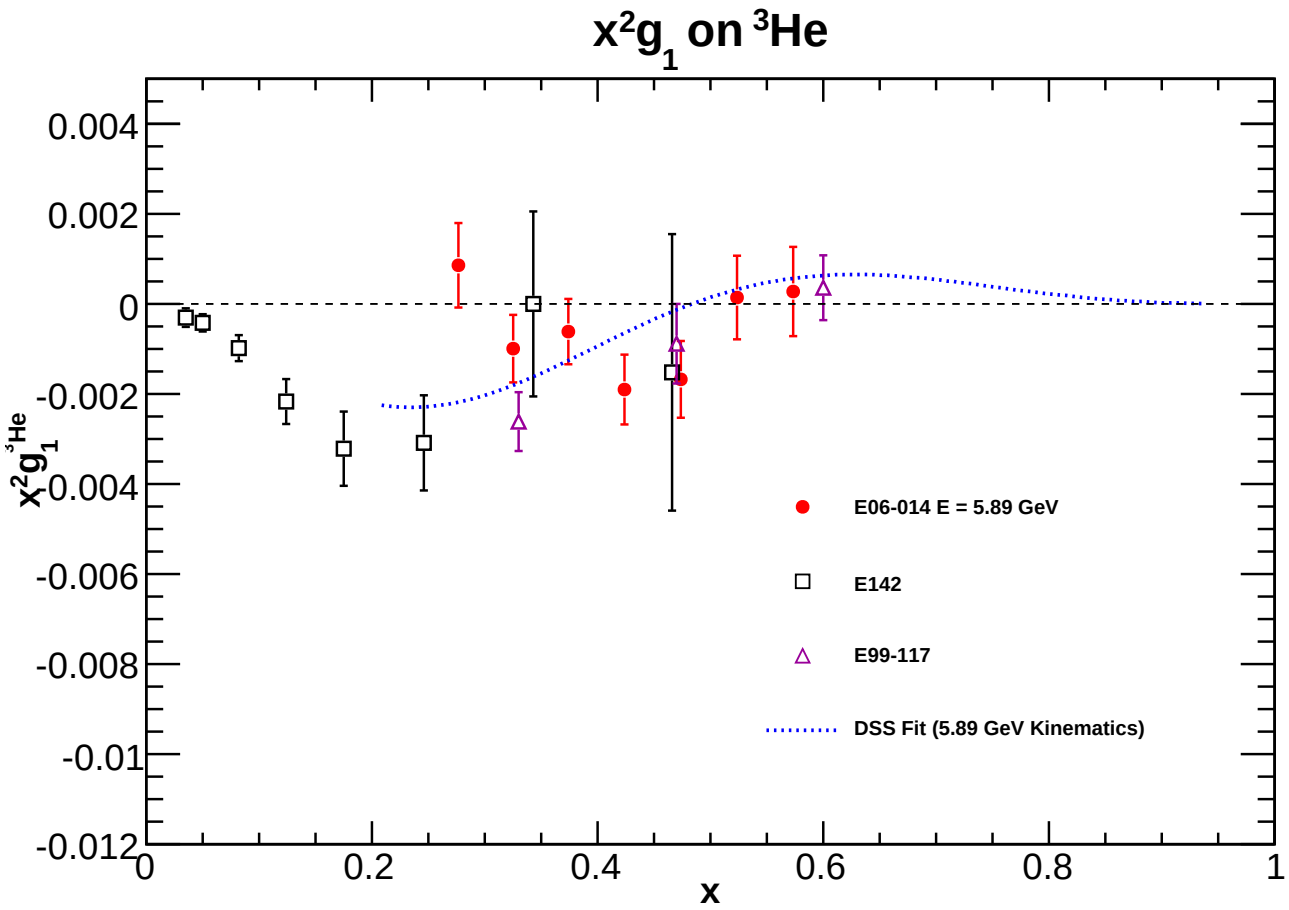


Figure: Preliminary $x^2 g_1$ structure function on ^{3}He

Preliminary g_2 on ^{3}He

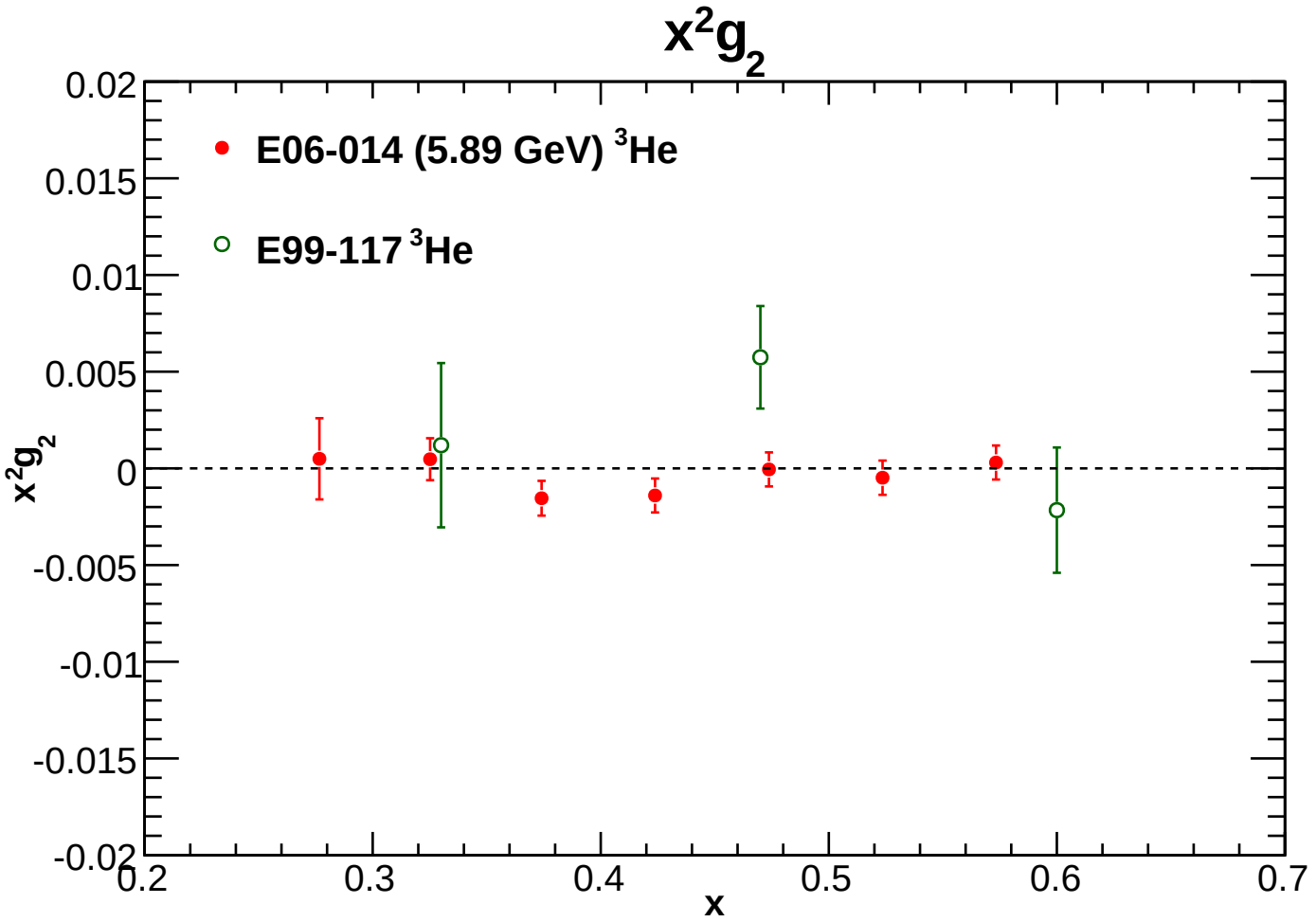
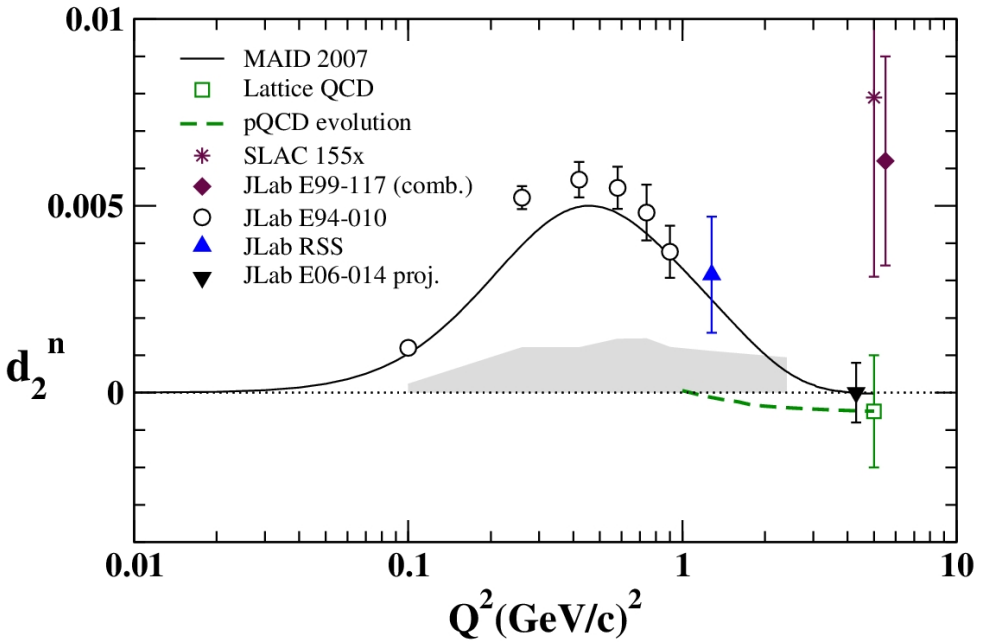


Figure: Preliminary $x^2 g_2$ structure function on ^{3}He

Current d_2 Uncertainty



Current statistical uncertainty on $d_2^{^3He}$ at 5.89 GeV $\approx 8 \times 10^{-4}$ (DIS + Resonance)

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 ...

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- 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:
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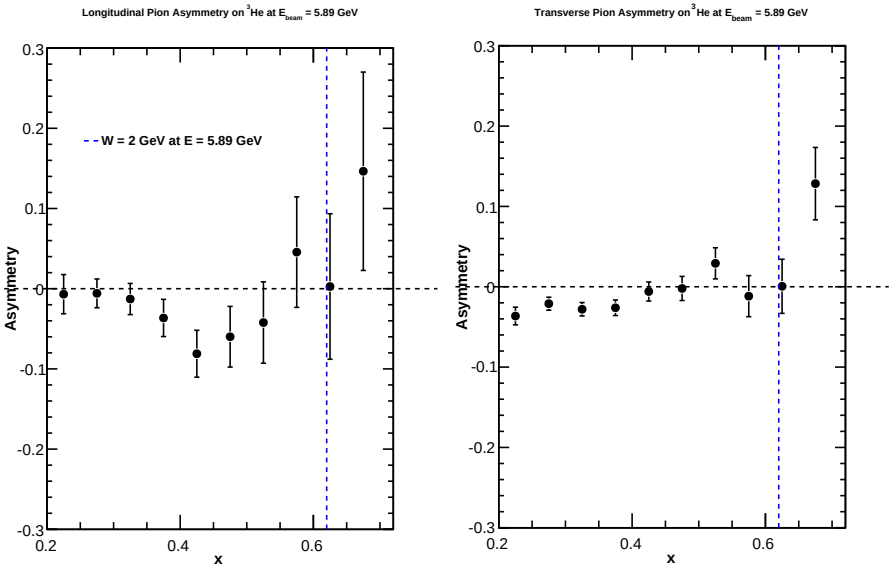
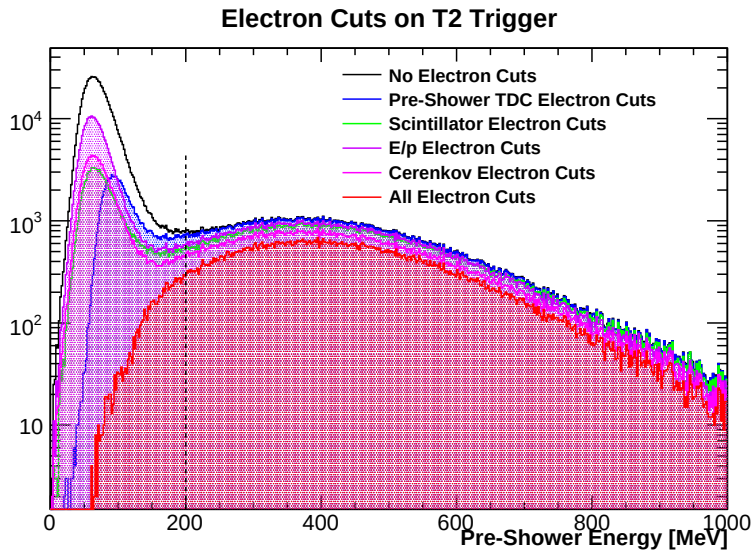
Pion Asymmetry Contamination





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

Positron to Electron Bend-Up Ratio

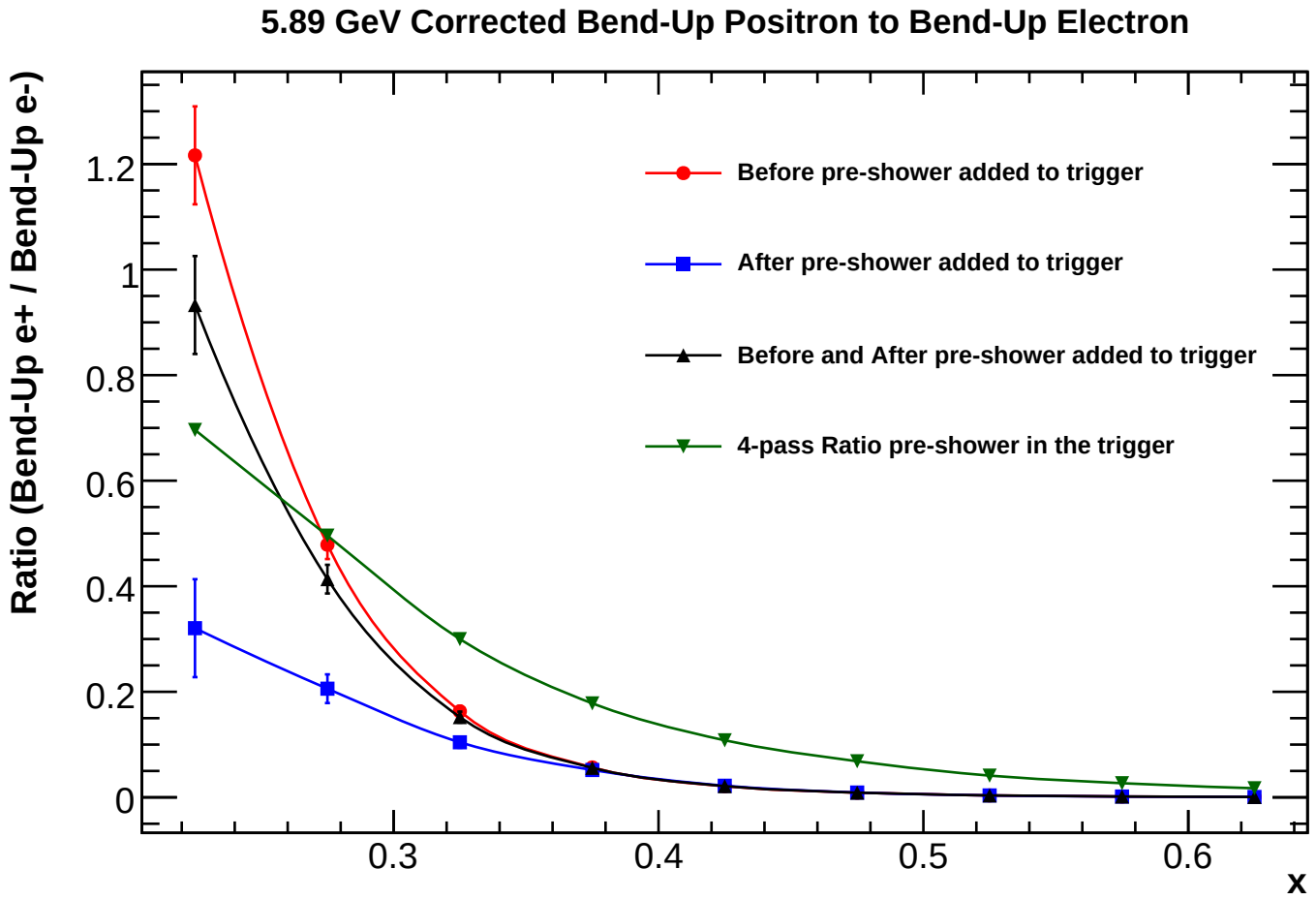


Figure: Ratio of bend-up positrons to bend-up electrons obtained by using κ factor.

Bend-Up and Bend-Down Positron Raw Asymmetries

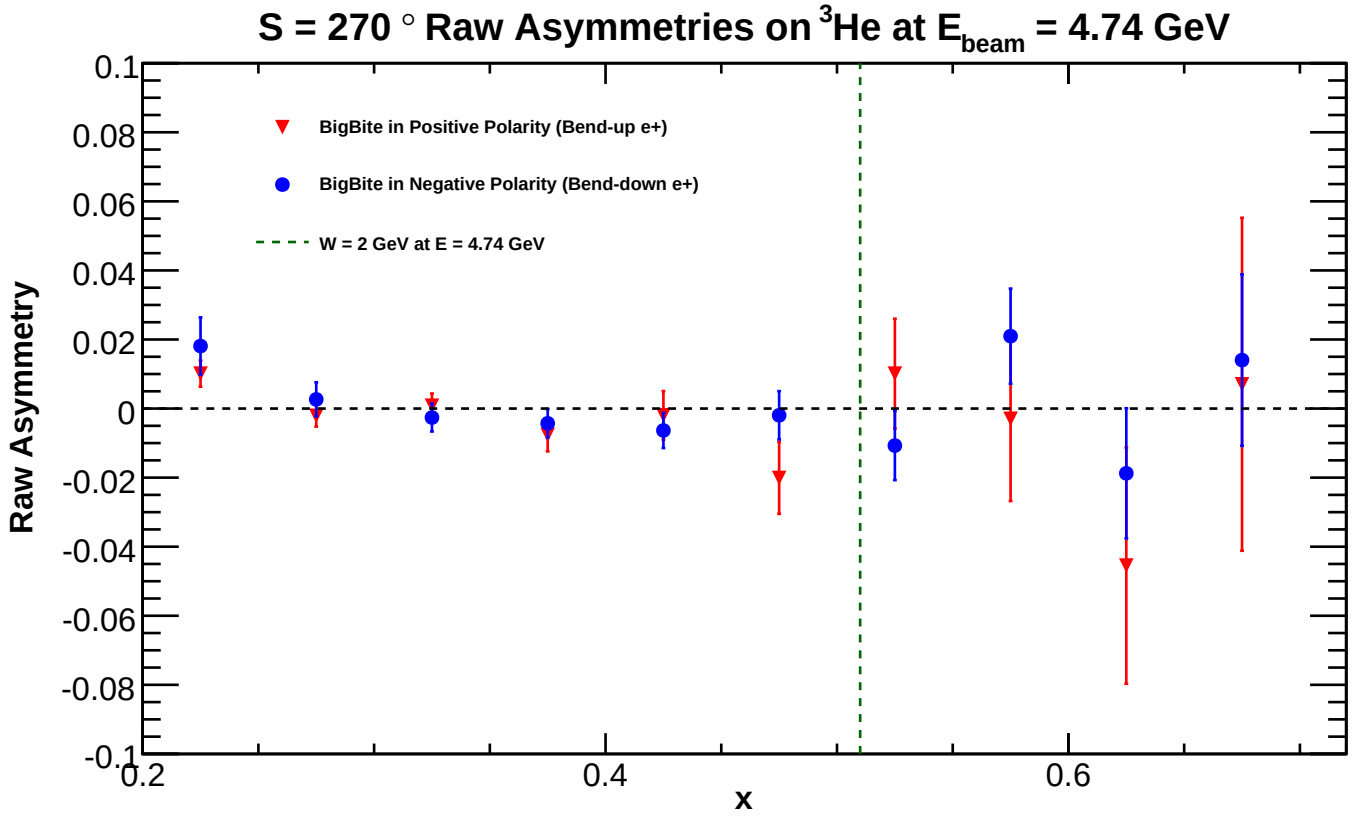


Figure: Comparison between bend-up and bend-down positron asymmetries.

Bend-Down Positron Asymmetries

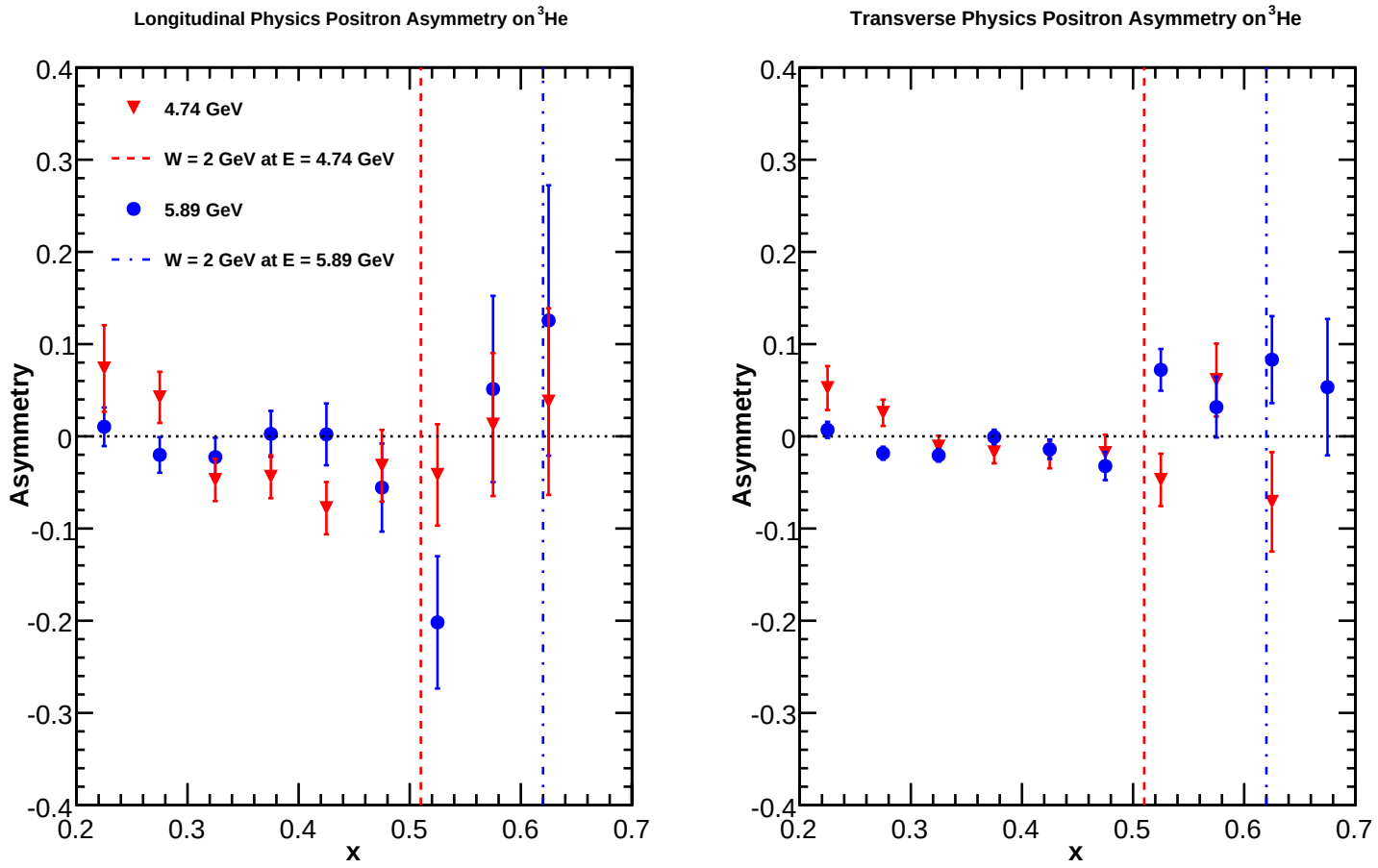
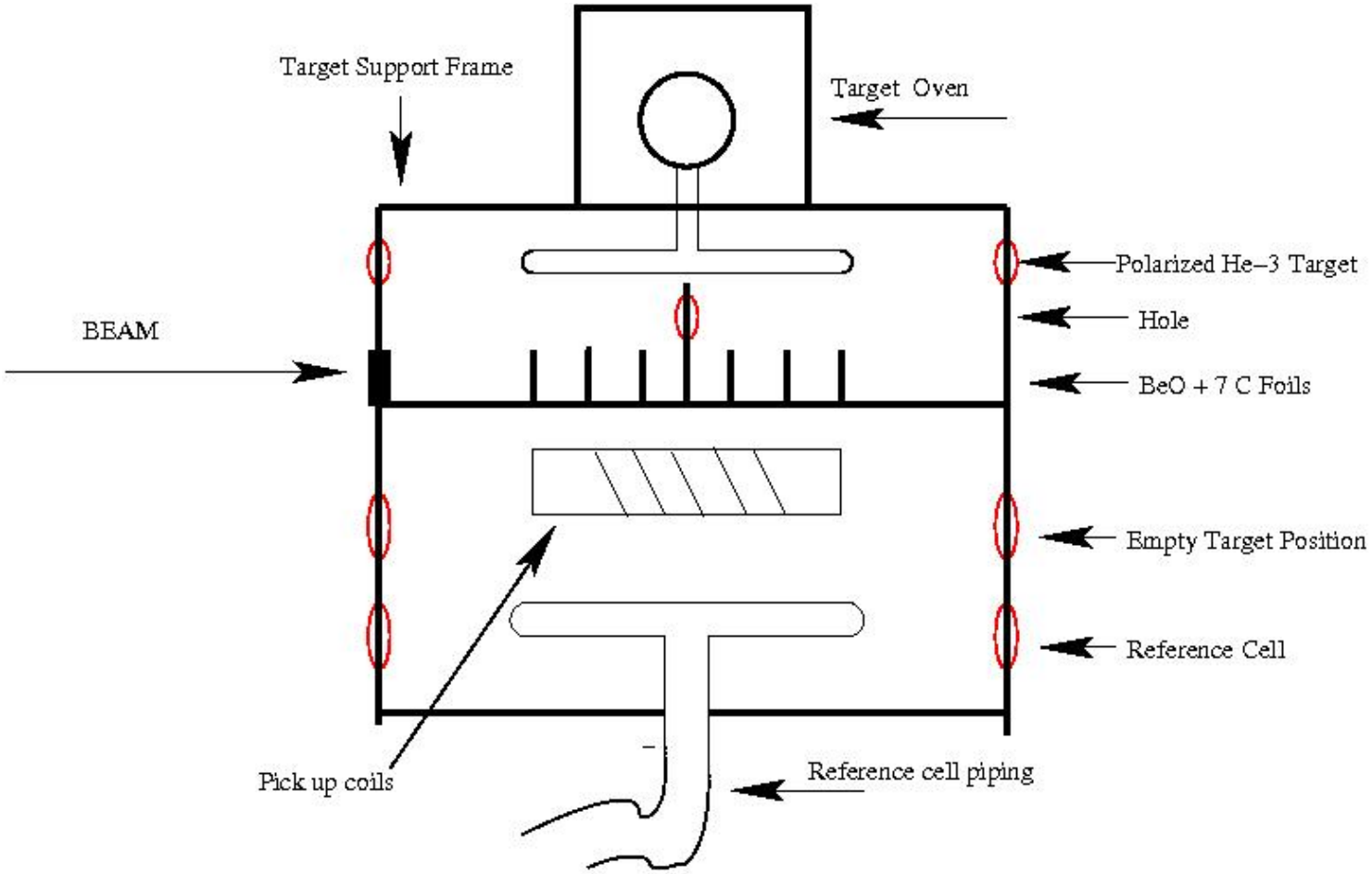


Figure: 4.74 and 5.89 GeV longitudinal and transverse positron asymmetries.

Target Ladder



Target Setup