An Overview of E03-004

Measurement of Single Target-Spin Asymmetry in Semi-Inclusive Pion Electroproduction on a Transversely Polarized ^{3}He Target

Argonne, CalState-LA, Duke, E. Kentucky, FIU, UIUC, JLab, Kentucky, Maryland, UMass,
MIT, ODU, Rutgers, Temple, UVa, W&M, USTC-China, CIAE-China, Glasgow-UK, INFN-Italy,
U. Ljubljana-Slovenia, St. Mary's-Canada, Tel Aviv-Israel, St. Petersburg-Russia.

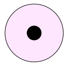
Transverse target single spin asymmetry $n^{\uparrow}(e, e'\pi^{-})X$.

- approved for 24 days of beam (PAC23, Jan. 2003) with a B$^+$ rating.
- BigBite at 30°, 1.5 m drift as e-arm. HRS$_L$ as h-arm @ 16°, 2.4 GeV/c.
- Better run Right After the Hall A G_{En} experiment to save BigBite installation and calliberation time.

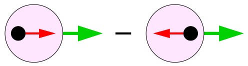
  The official start of the G_{En} installation is Dec. 1st 2005.

Transversity h_1: transverse spin at twist–2

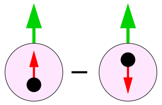
Three fundamental quark distributions at twist-2:



$f_1(x, Q^2)$: well known.



$g_1(x, Q^2)$: becoming known.



$h_1(x, Q^2)$: unknown.

h_1 is chiral–odd, inaccessible through inclusive DIS. $\Rightarrow$ Accessible in SIDIS $N^{\uparrow}(e, e'h)$ through chiral–odd quark fragmentation function $H_1^{\perp}$

J.C. Collins, NPB 396, 161(1993).

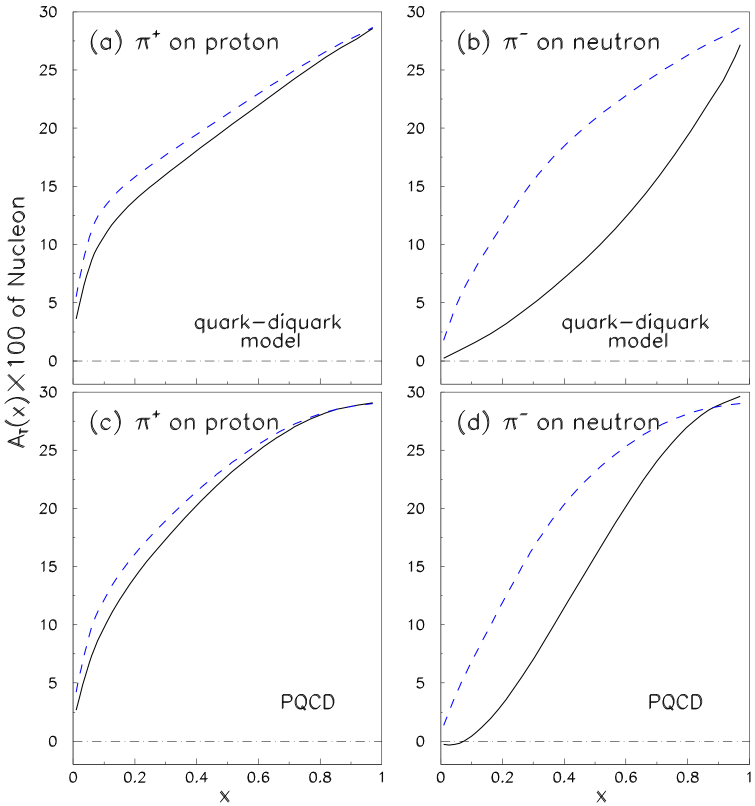
$$A_{UT}(x, z, P_{\perp}^2) \propto \frac{\sum_q e_q^2 \cdot h_1^q(x) \cdot H_{1q}^{\perp}(z, P_{\perp}^2)}{\sum_q e_q^2 \cdot f_1^q(x) \cdot D_{1q}(z, P_{\perp}^2)}.$$

Model Predicts Large A_{UT}^{π}

$h_1^q \Leftrightarrow \delta q$, B.-Q. Ma, I. Schimdt and J.-J. Yang, PRD 65, 034010 (2002)

Collins suggested ($\boldsymbol{k}_T = \boldsymbol{P}_\perp / z$ quark trans. momentum):

$$\frac{|\boldsymbol{k}_T| H_1^{\perp q}(z, \boldsymbol{P}_\perp^2)}{M_h D_1^q(z, \boldsymbol{P}_\perp^2)} = \frac{M_C |\boldsymbol{k}_T|}{M_C^2 + |\boldsymbol{k}_T^2|},$$



- Large asymmetries in A_{UT}, increases with x.
- $A_{UT}^{\pi^+}(p)$: u-quark dominates.
- $A_{UT}^{\pi^-}(n)$: both u-quark and d-quark contribute.

Sivers Effect is T-odd, allowed in SIDIS?

S. Brodsky, D.S.Hwang and I. Schimdt, PLB 530, 99(2002).

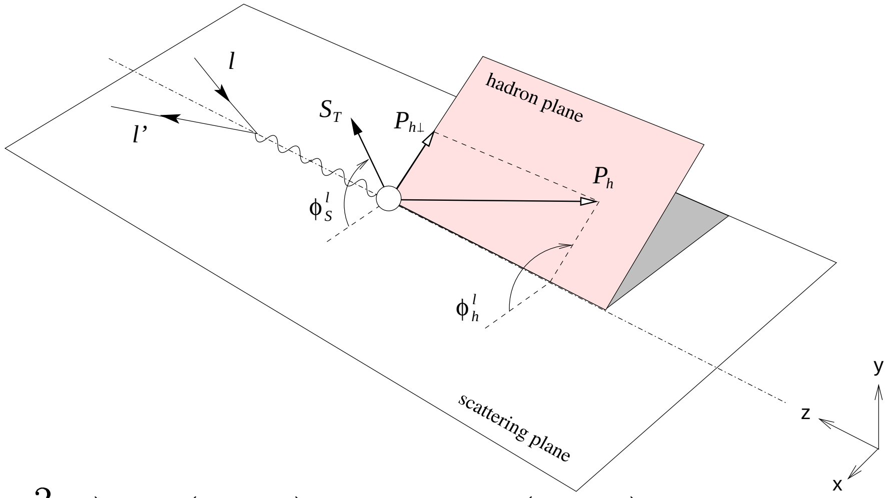
- Quark final state interactions $\Rightarrow$ a phase difference.
- T-odd Sivers distribution f_{1T} allowed at the leading order.

Confirmed by J. C. Collins, PLB 536, 43(2002).

Light cone gauge approach: X. Ji and F. Yuan, PLB 543, 66(2002).

SSA $A_{UT} \propto \kappa_N$ nucleon anomalous magnetic moment.
$A_{UT}^{\pi^+}(p)$ and $A_{UT}^{\pi^-}(n)$ similar in size, opposite in sign.

Collins effect vs Sivers effect



$$\sigma_{UT}(x, z, \boldsymbol{P}_{h\perp}^2) = (\sigma_{UT})_{Collins} + (\sigma_{UT})_{Sivers}$$

$$= \quad |\boldsymbol{S}_T|(1-y) \cdot \frac{P_{h\perp}}{zM_h} \sin(\phi_h^\ell + \phi_S^\ell) \cdot \sum e_q^2\, h_1^q(x) H_1^{\perp q}(z, \boldsymbol{P}_{h\perp}^2)$$

$$+ |\boldsymbol{S}_T|(1 - y + \frac{y^2}{2}) \frac{P_{h\perp}}{zM_N} \sin(\phi_h^\ell - \phi_S^\ell) \cdot \sum e_q^2\, f_{1T}^{\perp(1)q}(x) D_1^q(z, \boldsymbol{P}_{h\perp}^2)$$

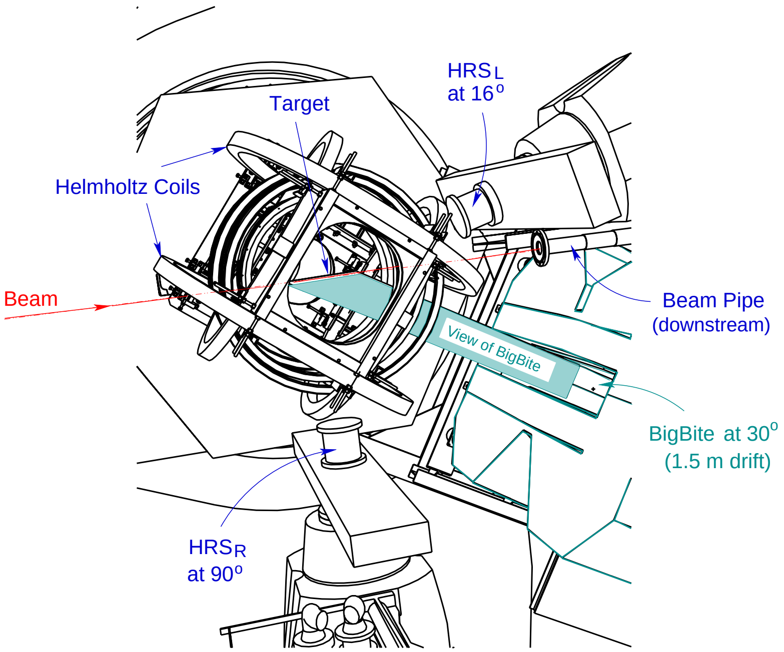
- Longitudinal target has $\phi_S^\ell = 0$. Need a transversely polarized target (Hermes run-II).
- Collins angle: $\phi_C = \phi_h^l + \phi_S^l$, $\Rightarrow$ target spin rotation $\approx$ out-of-plane detection.

What JLab E03-004 Can Offer ?

- Polarized ^{3}He target $\Rightarrow$ neutron transversity.
- Flexibility on target spin $\Rightarrow$ freedom of ϕ_S^l.

  Transverse target: large transversity effect, disentangle Collins/Sivers (???).
- High luminosity $\Rightarrow$ high statistics, access high Q^2.
- Access to the valence-x region.

E03-004 Layout : $n^{\uparrow}(e, e'\pi^{-})X$



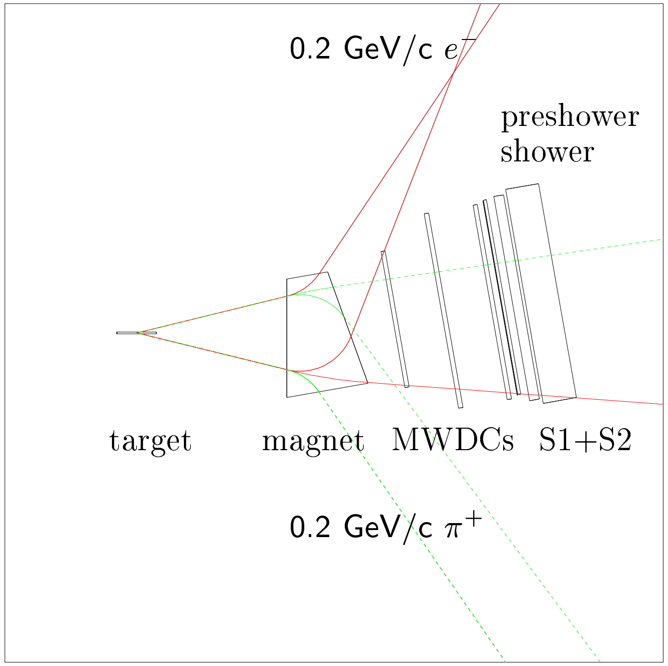
➡ BigBite as e-arm: at 30°, 1.5 m drift, $\Delta\Omega$ =64 msr.

e' : $0.8 \sim 1.8$ GeV, $\delta E'/E' \approx 2.0\%$. The same detector configuration as in the G_E^n experiment (E02013).

➡ HRS$_L$ as h-arm: at 16°.

➡ Hall A ^{3}He$^{\uparrow}$ target with modifications see J.-P.and Lingyan's list.

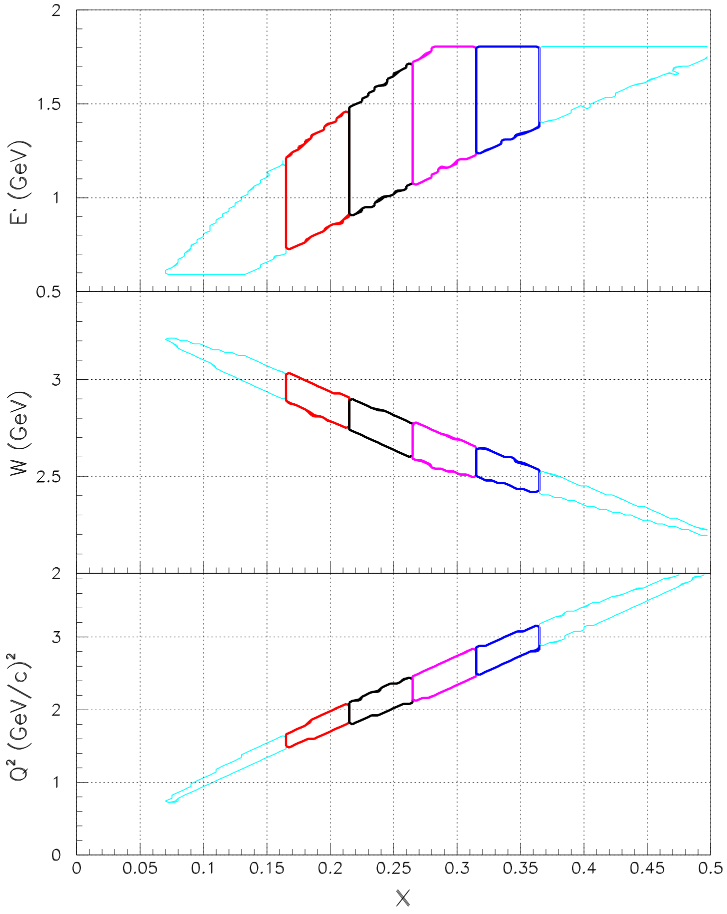
Issues on BigBite Common to G_E^n



- detectors and software.
- trigger and DAQ.
- background and shielding (more of an issue for Transversity).
- commissioning, caliberation and optics study.

Semi-Inclusive DIS Kinematics

One BigBite setting covers all x-bins.

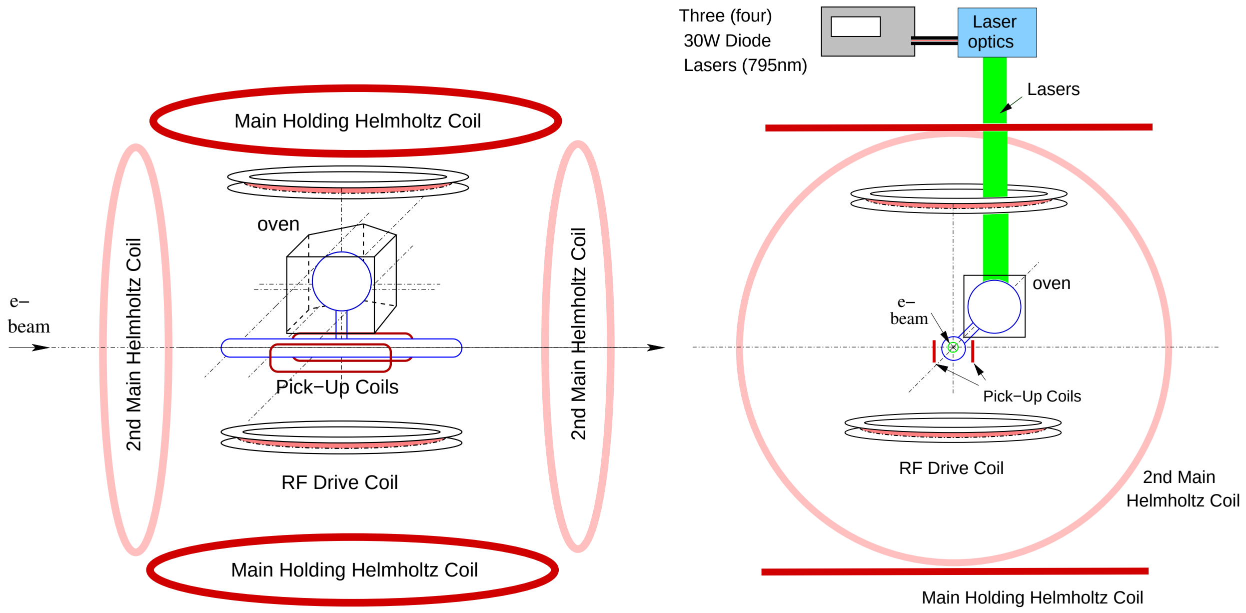


π^- arm: left side HRS

Standard HRS detectors for PID at 2.4 GeV/c:

- Gas Č + preshower/shower for π^-/e separation.
- Aerogel detectors A1/A2 separate π^-/K^-,
  by-product: $(e, e'K^-)$, issues with the RICH detector ?

The Polarized ^{3}He Target

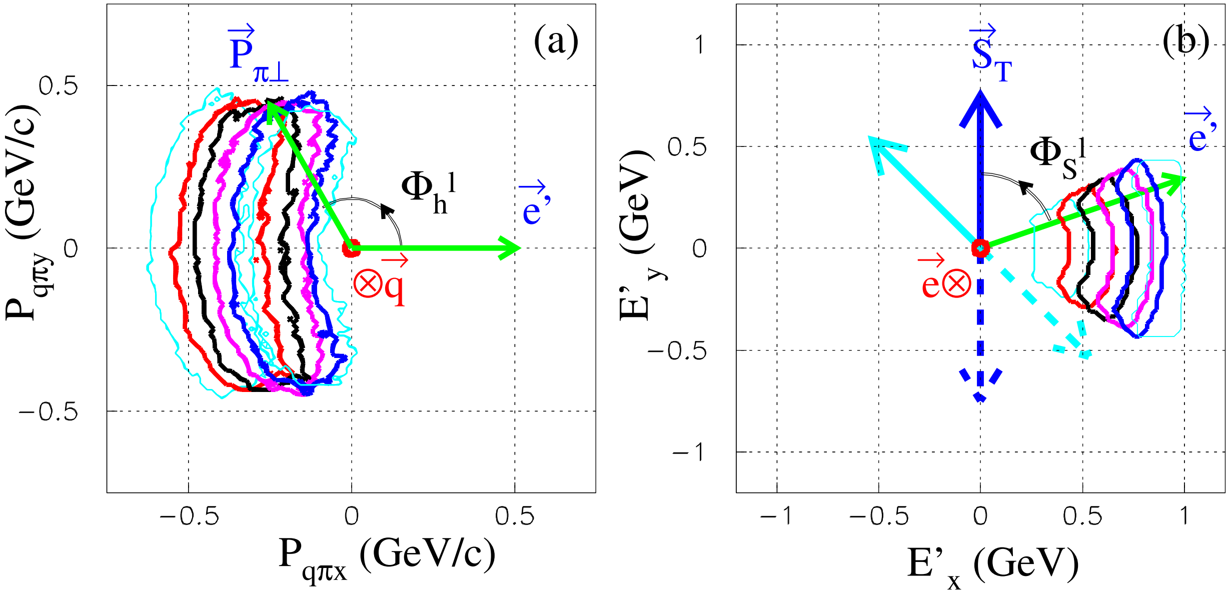


Issues similar to G_E^n:

- laser lines and optics.
- target cell development and polarimetry.
- reference cell, moving mechanism and control software.
- BigBite field clamps and field mapping.

Collins angle: $\phi_C = \phi_h^l + \phi_S^l$

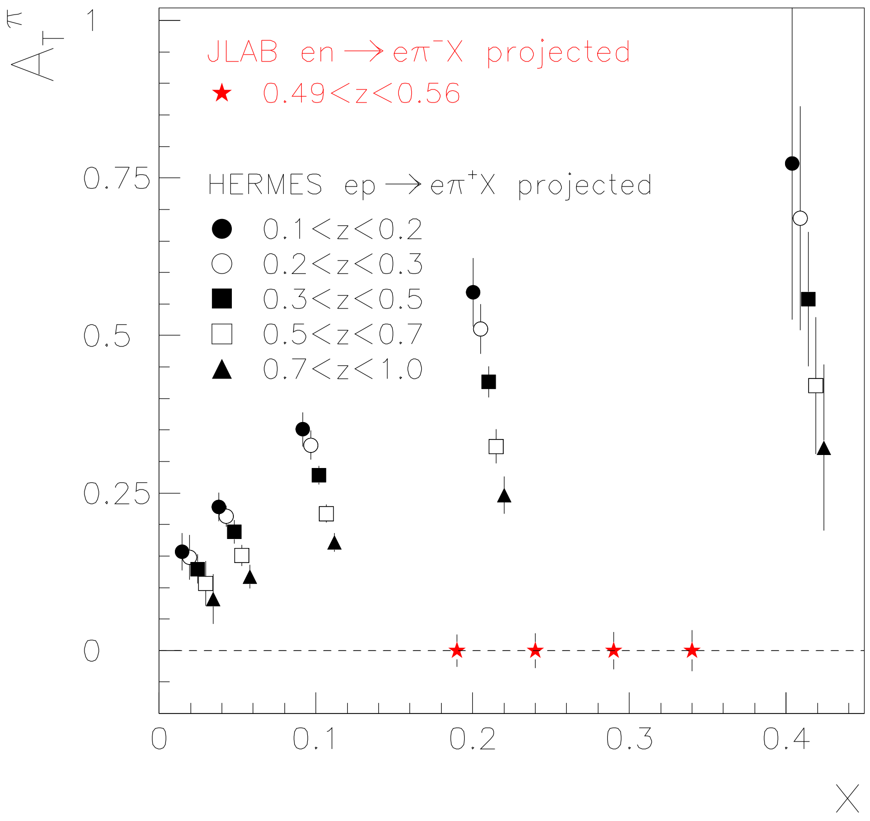
View along $\vec{q}$: $\Delta\phi_h^l \approx 126^\circ$ along $\vec{e}$: $\Delta\phi_S^l \approx 54^\circ$.



- two target spin: $\Delta\phi_C \approx 126^\circ + 54^\circ \times 2 \approx 234^\circ$.
- one target spin: $\Delta\phi_C \approx 126^\circ + 54^\circ \approx 180^\circ$.
- Should we add $\phi_S = 0^\circ$? Check systematics, cover a larger ϕ_C range.

$$A_{UT}(\phi_h^l, \phi_S^l) = \frac{N(\phi_h^l, \phi_S^l) - \frac{\mathcal{L}^\uparrow}{\mathcal{L}^\downarrow} N(\phi_h^l, \phi_S^l + \pi)}{N(\phi_h^l, \phi_S^l) + \frac{\mathcal{L}^\uparrow}{\mathcal{L}^\downarrow} N(\phi_h^l, \phi_S^l + \pi)}$$

Compared with the Projected Hermes Data



$$A_{UT}^{\pi^+}(p) \propto 4h_1^u \cdot H_1^{\perp +} + h_1^d \cdot H_1^{\perp -}$$

$$A_{UT}^{\pi^-}(n) \propto 4h_1^d \cdot H_1^{\perp -} + h_1^u \cdot H_1^{\perp +}$$

$A_{UT}^{\pi^+}(p)$ h_1^u dominates. $A_{UT}^{\pi^-}(n)$ access both h_1^u and h_1^d.

Summary

E03-004 measures $A_{UT}^{\pi^-}(n)$, a simple observable,

- Equipments: HRS+BigBite, many hardware and software overlaps with G_E^n.
- Out-of-plane polarized ^{3}He target. Need to be ready when G_{En} starts.

First neutron transversity measurement:

- Cover a large range of Collins angle ϕ_C.
- Transversity on both $h_1^u(x)$ and $h_1^d(x)$, complementary to the upcoming proton data of Hermes run-II.
- JLab physics in a new direction, in strong competition with Hermes, COMPASS, RHIC-spin.