New Results for Double Spin Asymmetry A_{LT} in DIS Pion production on ^3He

Jin Huang
MIT
For DIS2011
Apr 12, 2011 @ NPN, VA

Jefferson Lab

Transverse Momentum Dependent (TMD) Parton Distributions

- TMD PDFs link
  - Intrinsic motion of partons
  - Parton spin
  - Spin of the nucleon
- Multi-Dimension structure of nucleon
- A new phase of study, fast developing field
  - Great advance in theories (factorization, models, Lattice ...)
  - Not sys. studied until recent years
    - Semi-Inclusive DIS (SIDIS): HERMES, COMPASS, Jlab, ...
    - p-p(p_bar) process : FNAL, BNL, ...

Leading-Twist TMDs

Nucleon Spin

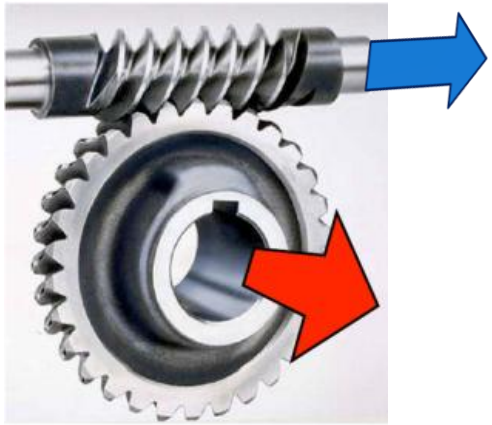
Quark Spin

Nucleon Polarization	Quark polarization: Un-Polarized	Longitudinally Polarized	Transversely Polarized
U	$f_1 =$		$h_1^\perp =$ – Boer-Mulder
L		$g_1 =$ – Helicity	$h_{1L}^\perp =$ –
T	$f_{1T}^\perp =$ – Sivers	$g_{1T} =$ –	$h_{1T} =$ – Transversity $h_{1T}^\perp =$ – Pretzelosity

: See K. Allada Talk on Thu

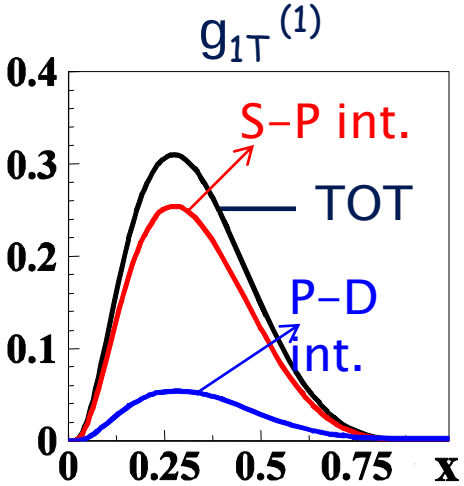
: This Talk

"Worm-Gear" Functions g_{1T}



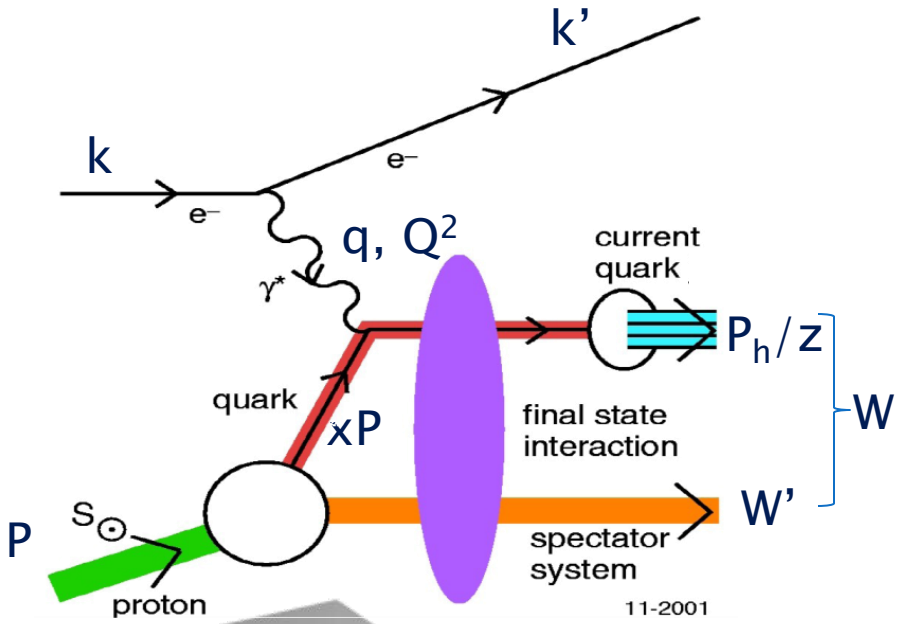
Worm Gear

- g_{1T} =
  - Leading twist TMD PDFs
  - T-even, Chiral-even
- Dominated by real part of interference between L=0 (S) and L=1 (P) states
  - Imaginary part -> Sivers effect
- No GPD correspondence
  - a genuine sign of intrinsic transverse motion
- First TMDs in Pioneer Lattice calculation
  - arXiv:0908.1283 [hep-lat], arXiv:1011.1213 [hep-lat]

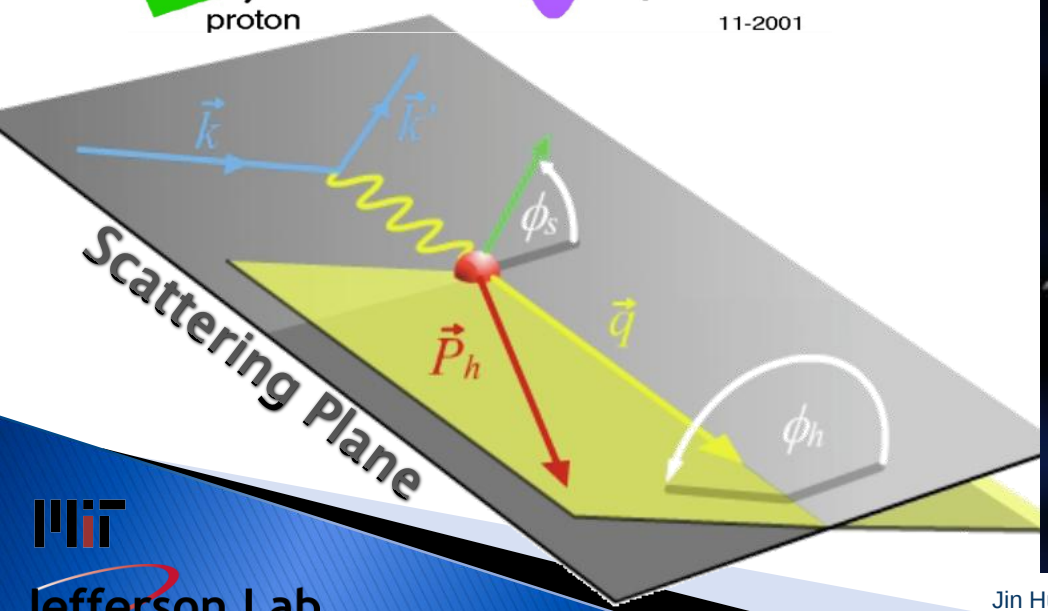


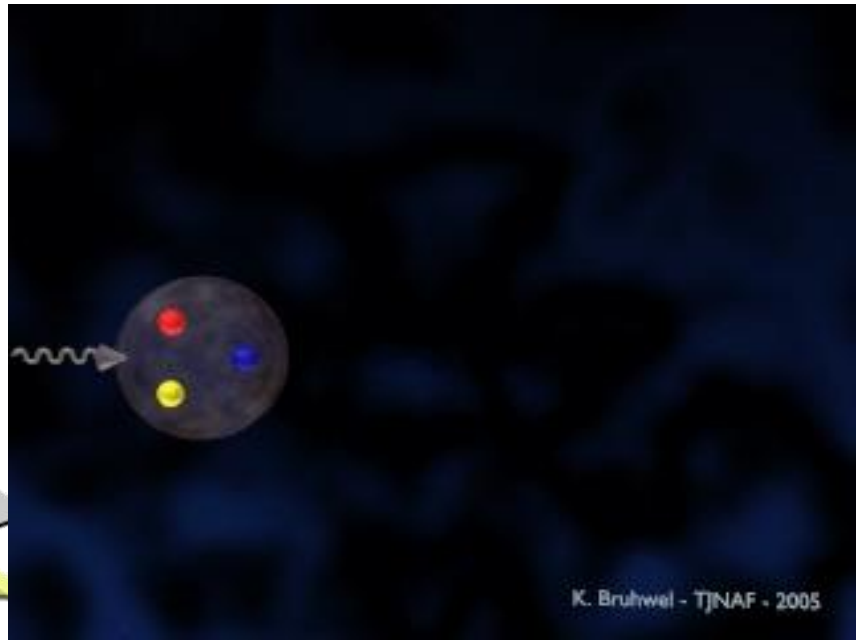
Light-Cone CQM by B. Pasquini
B.P., Cazzaniga, Boffi, PRD78, 2008

One Tool to Study TMDs: SIDIS



- Access new TMDs not accessible in inclusive DIS ($m_{quark}=0$)
- Variables: x, q, Q^2, z, W, W'





TMDs in SIDIS Cross Section

$$\frac{d\sigma}{dx\,dy\,d\phi_S\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\cdot$$

$$\{F_{UU,T} +$$

$$+\varepsilon\cos(2\phi_h)\cdot F_{UU}^{\cos(2\phi_h)} + \ldots$$

$$+ S_T\lambda_e[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)\cdot F_{LT}^{\cos(\phi_h-\phi_S)} + \ldots]$$

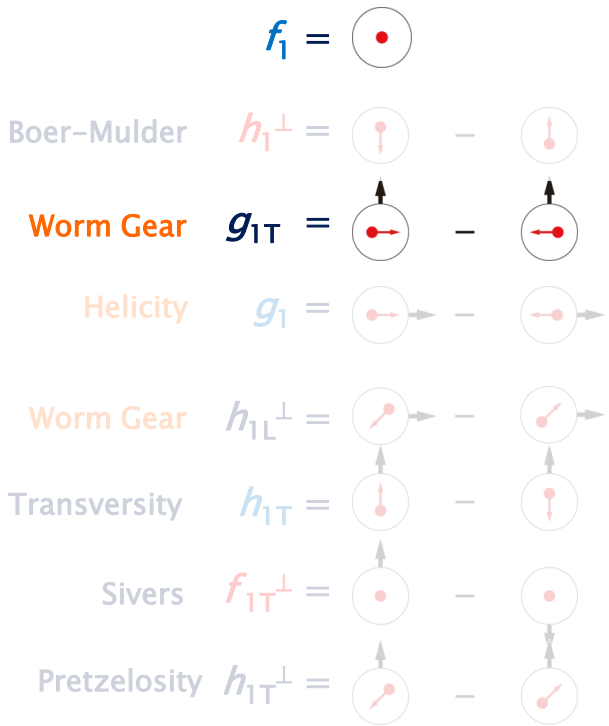
$$+ S_L\lambda_e[\sqrt{1-\varepsilon^2}\cdot F_{LL} + \ldots]$$

$$+ S_L[\varepsilon\sin(2\phi_h)\cdot F_{UL}^{\sin(2\phi_h)} + \ldots]$$

$$+ S_T[\varepsilon\sin(\phi_h+\phi_S)\cdot F_{UT}^{\sin(\phi_h+\phi_S)}$$

$$+\sin(\phi_h-\phi_S)\cdot(F_{UT}^{\sin(\phi_h-\phi_S)} + \ldots)$$

$$+\varepsilon\sin(3\phi_h-\phi_S)\cdot F_{UT}^{\sin(3\phi_h-\phi_S)} + \ldots]\}$$

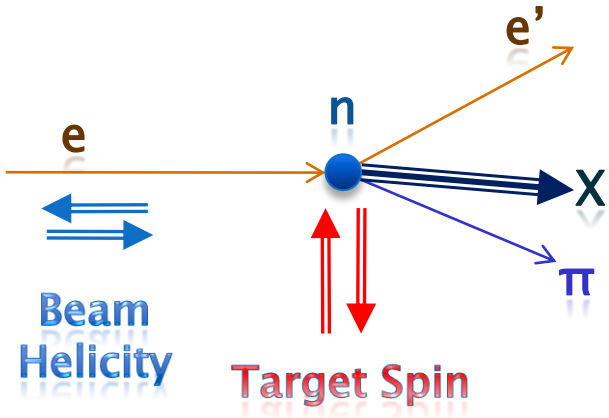


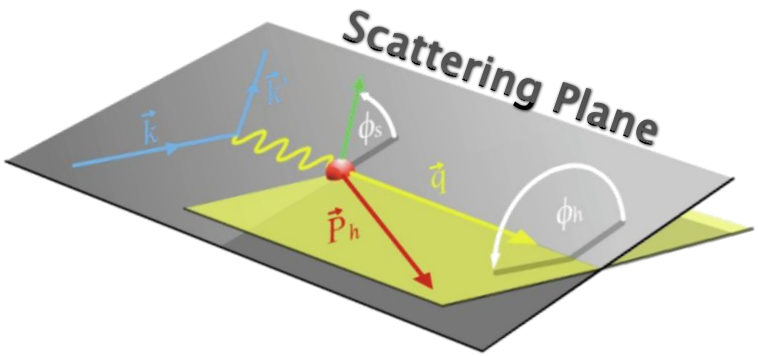
Clean measurement w/ helicity flips: Only one ST dep LT term left

S_L, S_T: Target Polarization; λ_e: Beam Polarization

Experimental Extraction of g_{1T}

- Extractable from
  Double Beam–Target Spin Asymmetry (DSA) in SIDIS
  with transversely polarized target: A_{LT}





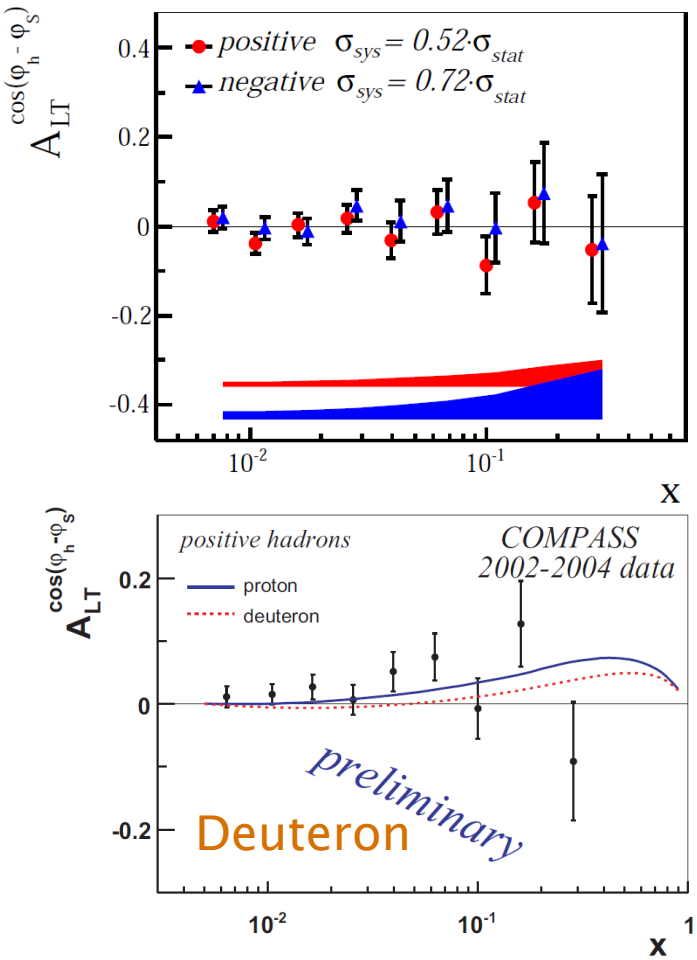
$$A_{LT}^{\cos(\phi_h-\phi_s)} \equiv 2\frac{\int d\phi_s^h\left(d\vec{\sigma}-d\overleftarrow{\sigma}\right)\cos(\phi_h-\phi_s)}{\int d\phi_s^h\left(d\vec{\sigma}+d\overleftarrow{\sigma}\right)} \propto g_{1T}^q \otimes D_{1q}^h$$

Existing A_{LT} Results

- COMPASS
  - Last Session, C. Schill
  - Proton , Deuteron
- HERMES
  - Last Session, L. Pappalardo
- Jlab E06-010
  - This talk
  - Pol. ^{3}He Target (eff. pol. n)
  - Fast beam helicity flips

COMPASS
Proton

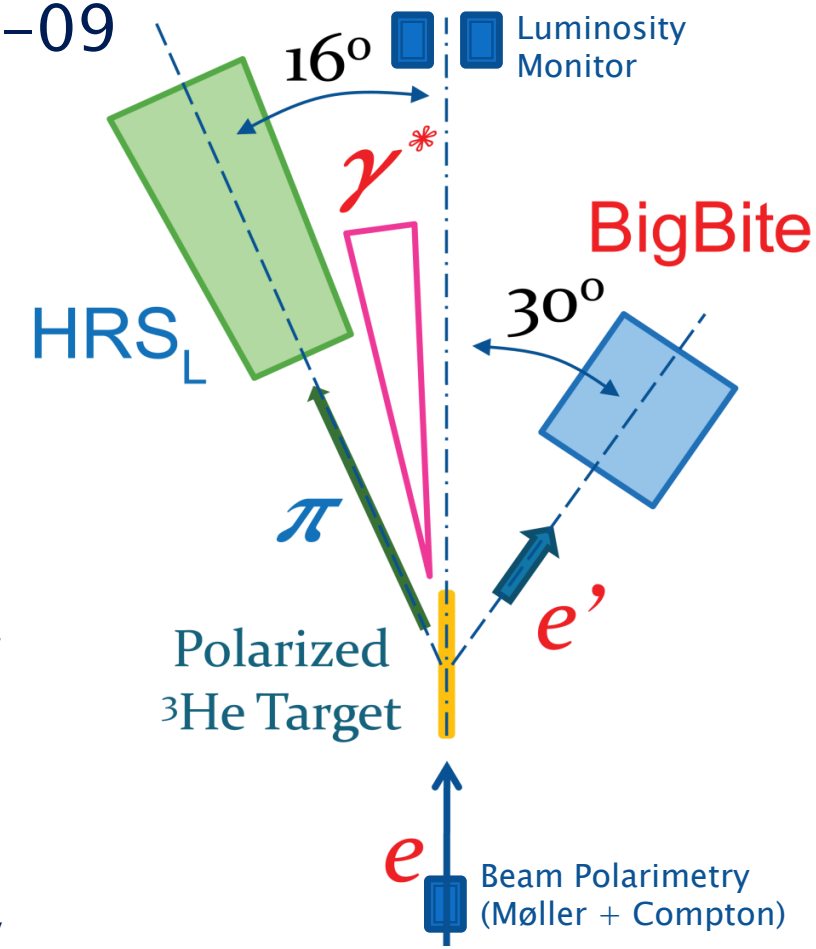
arXiv:1012.0155 [hep-ex]



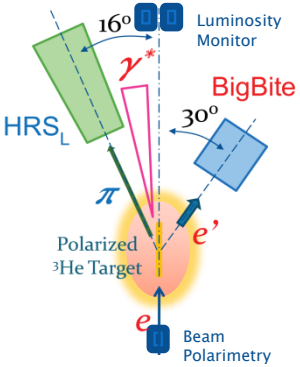
Eur. Phys. J. Special Topics **162**, 89–96 (2008)

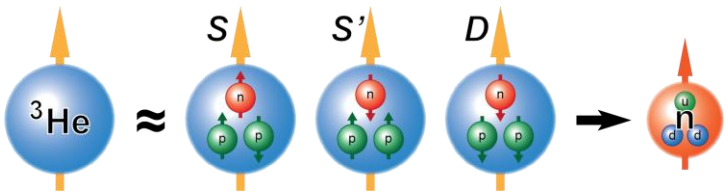
E06-010 Experiment Setup

- Success full data taking 2008-09
- Polarized electron beam
  - ~80% polarization
  - Fast Flipping at 30Hz
  - PPM level charge asymmetry controlled by online feed back
- Polarized ^{3}He target
- BigBite at 30° as electron arm
  - Dipole magnet, P_e = 0.7 ~ 2.2 GeV/c
  - MWDC/shower-preshow/scitillator
- HRS_L at 16° as hadron arm
  - QQDQ config, P_h = 2.35 GeV/c
  - Scintillator/drift chamber/Cherenkov



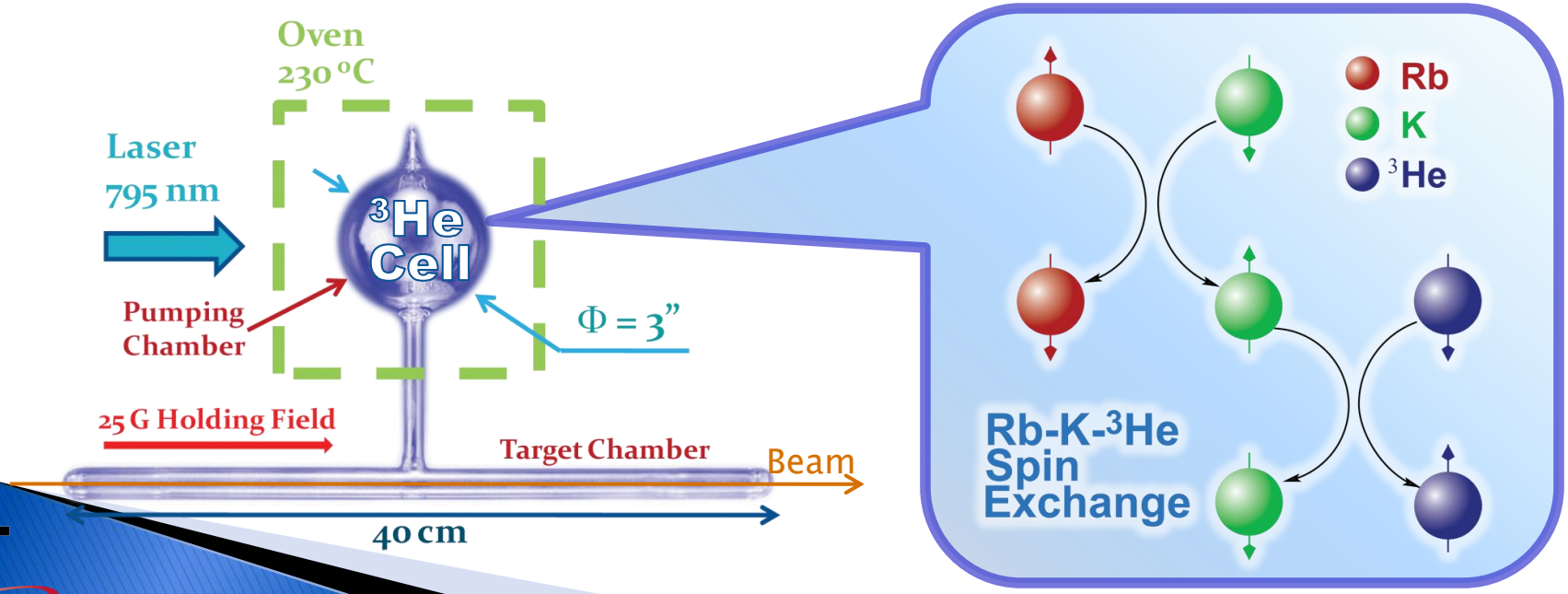
Polarized ^{3}He Target



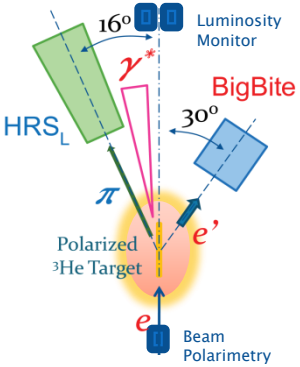
- 

  ~90% ~1.5% ~8%

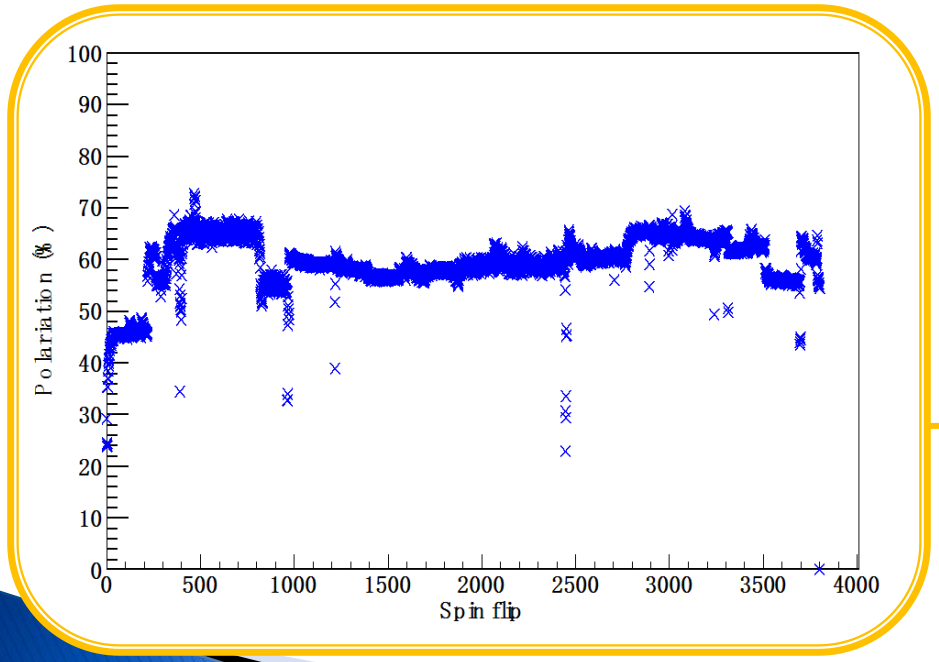
- Greater figure of merit than polarized deuteron target
  - Nuclear polarization: 40~60% vs 30~50%
  - Much higher beam current
- Compact size: No cryogenic support needed



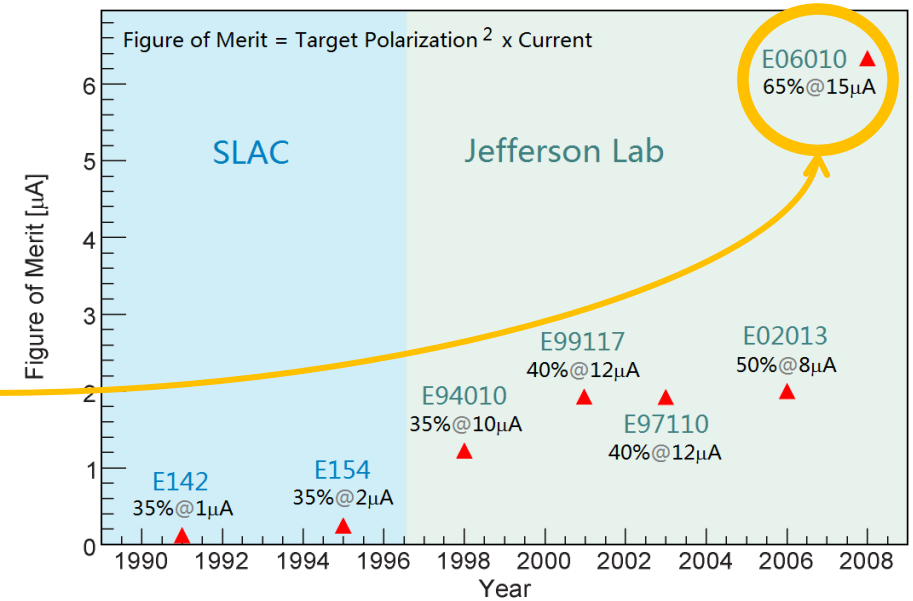
Performance of ^{3}He Target



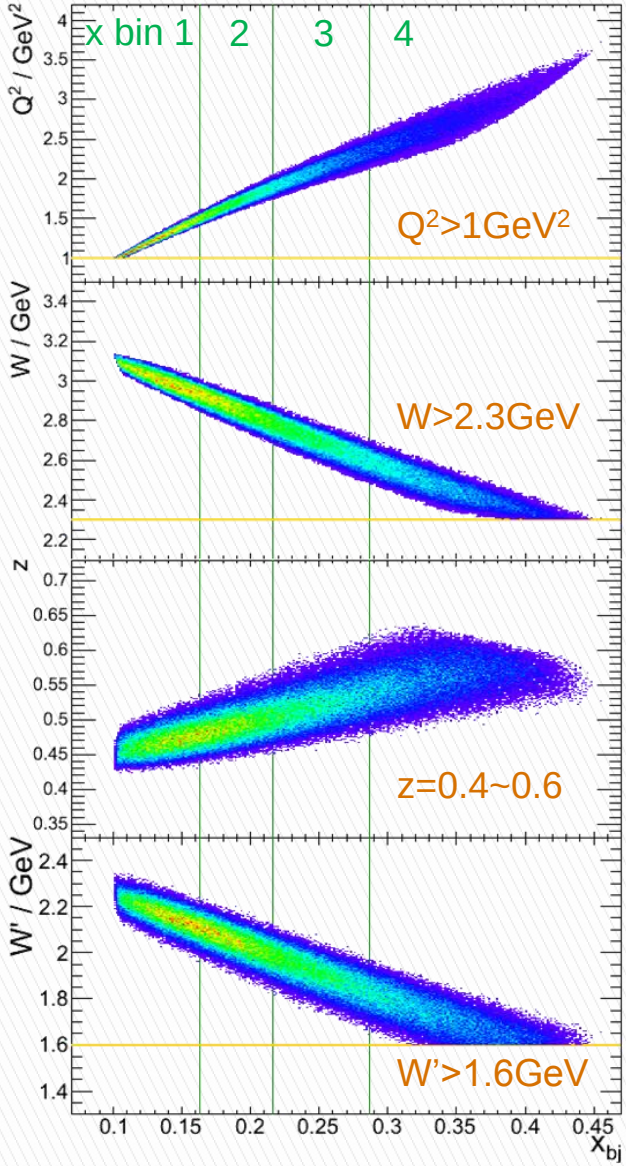
- High luminosity: $L(n) = 10^{36}$ cm^{-2} s^{-1}
- Record high 60~ 65% polarization in beam with automatic spin flip / 20min

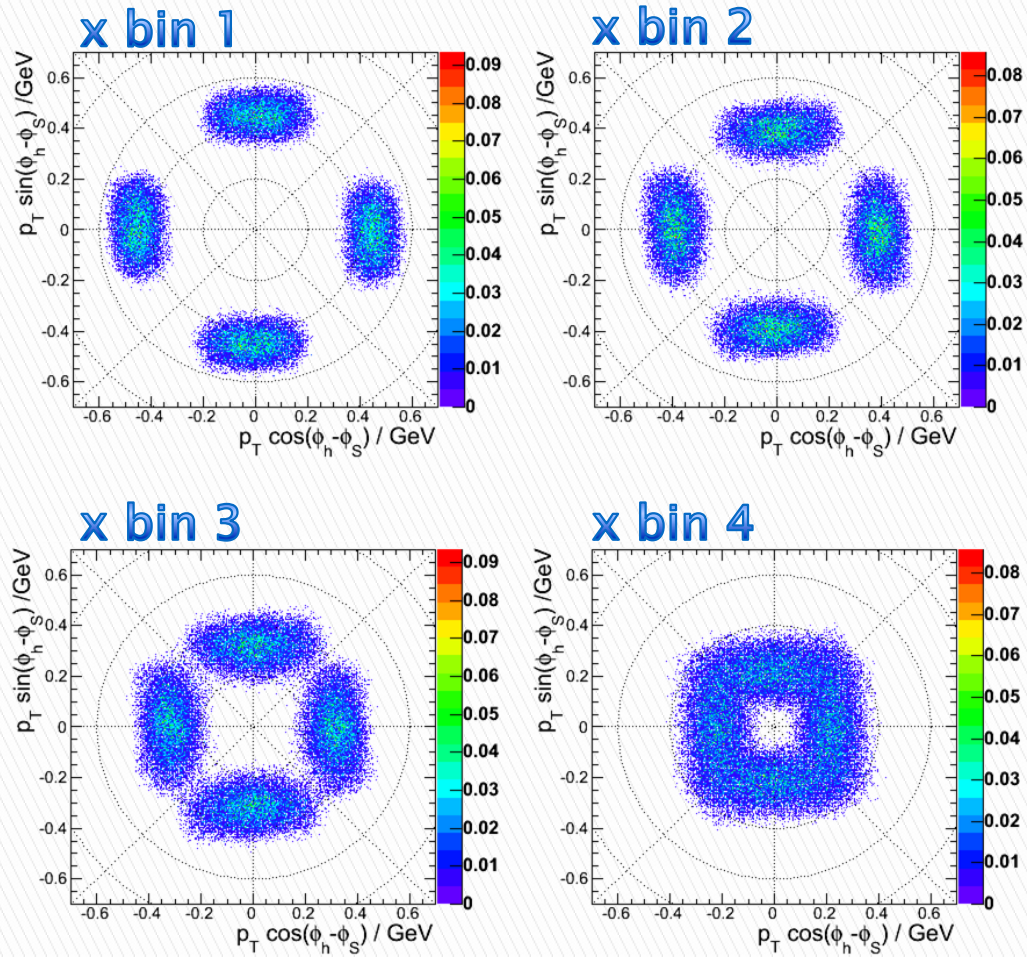


History of Figure of Merit of Polarized ^{3}He Target



Data Coverage



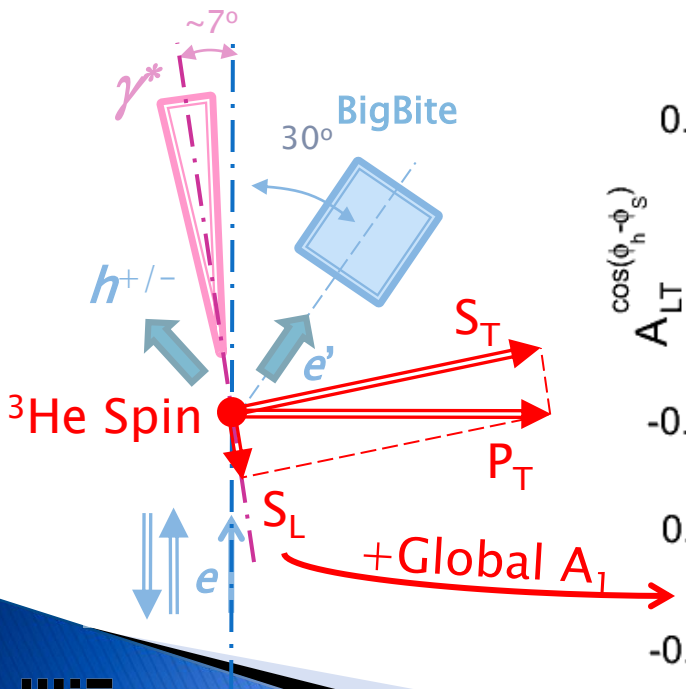


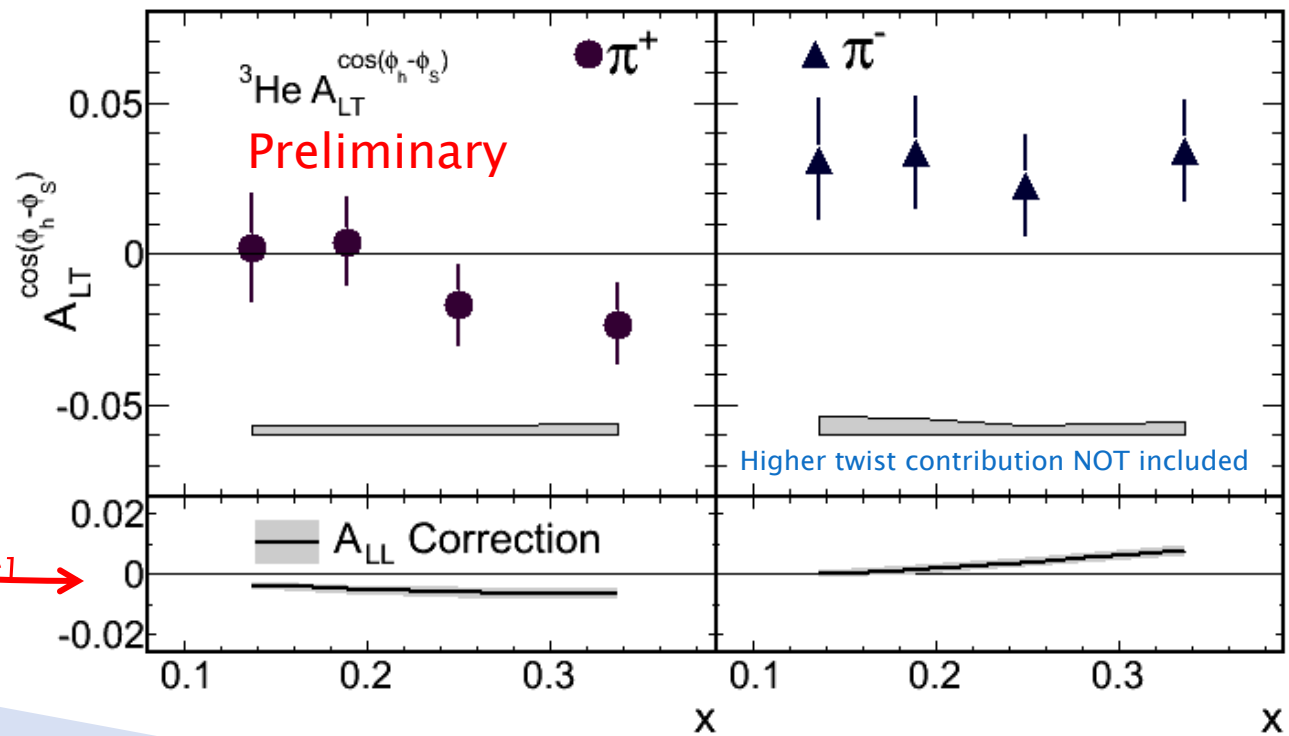
Kinematics Coverage

p_T & ϕ_h- ϕ_S Coverage

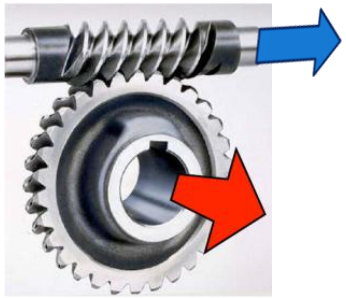
^{3}He A_{LT} Results

- First measurement with ^{3}He target
  - Fast beam helicity flips
  - Two analysis team, cross checks
  - Corrected for small component of long. target spin, S_L
- Data suggest non-zero SIDIS A_{LT}: π^-, $+2.8\sigma$ (sum all bins)

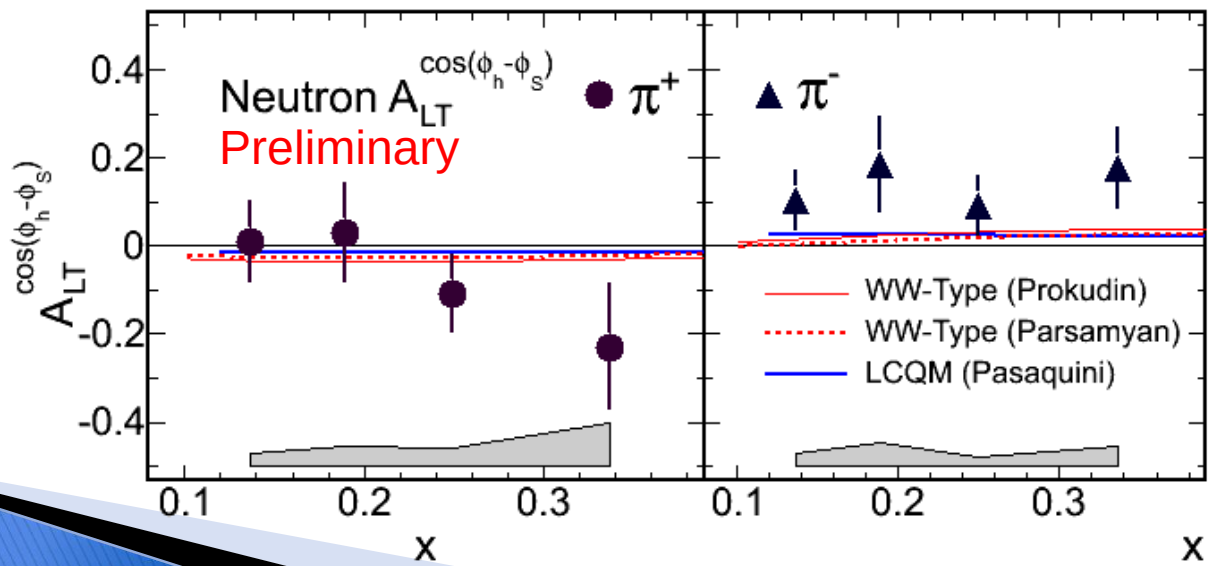




Extract Neutron A_{LT}

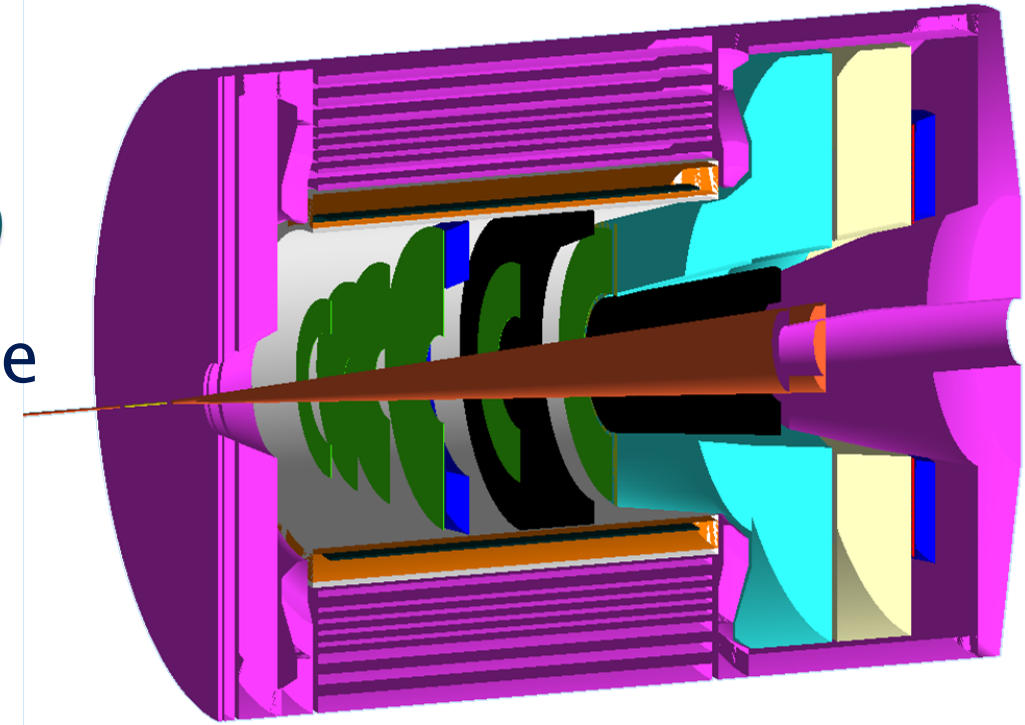


- $A_{LT}^{^3\mathrm{He}} = P_n \frac{\sigma_n}{\sigma_{^3\mathrm{He}}} A_{LT}^n + P_p \frac{2\sigma_p}{\sigma_{^3\mathrm{He}}} A_{LT}^p$ $\quad \begin{cases} P_n = 0.86^{+0.036}_{-0.02} \\ P_p = -0.028^{+0.009}_{-0.004} \end{cases}$
  - Corrected for proton dilution, f_p
  - Predicted proton asymmetry contribution <1.5% (π^+), 0.6% (π^-)
- $A_{\mathrm{LT}}^n \propto g_{1T}^q \otimes D_{1q}^h$, sensitive to *d* quark
  - Dominated by L=0 (S) and L=1 (P) interference
- Consist w/ model in signs, suggest larger asymmetry

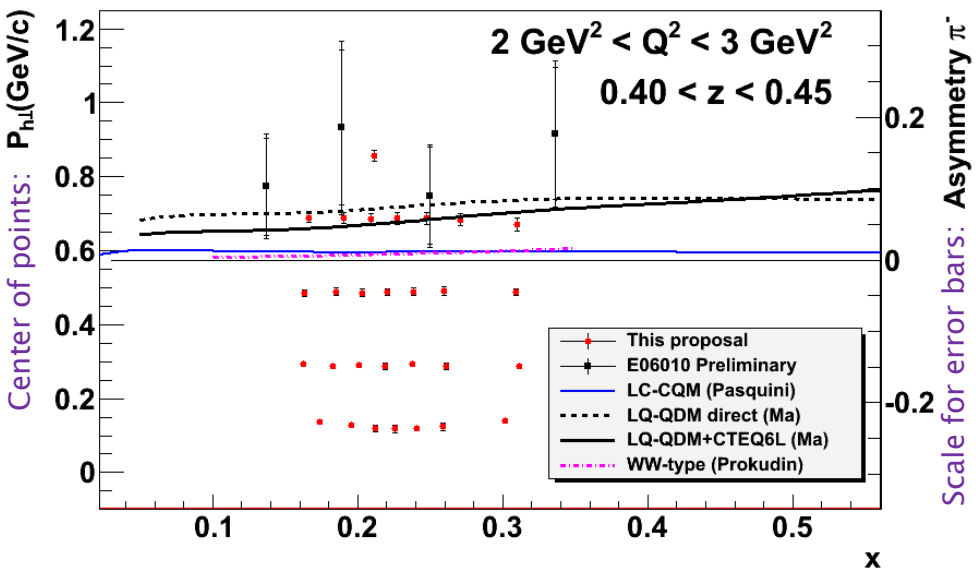


Future A_{LT} with 12 GeV & SoLID

- Jlab 12 GeV Upgrade
- Large acceptance spectrometer SoLID
- ^{3}He target
- High precision
- Multi-D mapping
- X. Qian's talk Session future DIS



Projection of 1 of 48 Q^2–z bin for π^-



Conclusion

- First measurement of neutron A_{LT} using polarized ^{3}He target, sensitive to d quark
- Systematic uncertainties is improved by fast beam helicity flip
- Indication of non-zero SIDIS A_{LT}
  - $^3He \rightarrow \pi^-$, $+2.8\sigma$ A_{LT} (sum all bins)
- Current progress
  - Extensive Internal review
  - Working on systematic uncertainties
- Foundation work for future studies
  - JLab 12 : 4D mapping of A_{LT} with ultimate precision