Tensor SIDIS Hall C Program Longitudinal Overview

David Ruth

Tensor SIDIS Workshop

6/5/26

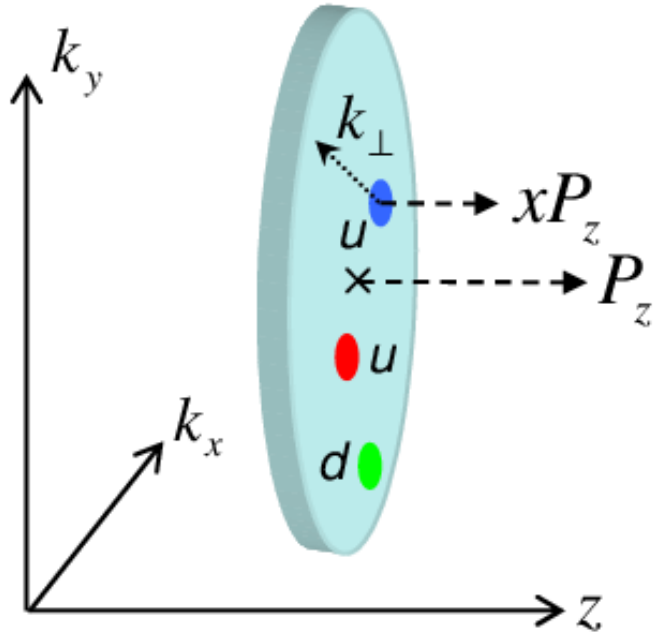
Transverse-Momentum Distributions (TMDs)

- Map the nucleon as a function of quark transverse momentum $\mathbf{k_T}$ and longitudinal momentum fraction **x**!

- Accessed with **Semi-Inclusive Deep Inelastic Scattering (SIDIS)**
- Unique Capabilities for:
  - Hadron Tomography
  - Color Degrees of Freedom
  - Understanding Transverse Momentum Structure

- Lots of research on nucleon TMDs, **but…**

- With a tensor-polarized deuteron target, **a class of never-before measured TMDs is revealed**



	$[\gamma^+]$		$[\gamma^+\gamma_5]$		$[i\sigma^{i+}\gamma_5]$	
	TR-even	TR-odd	TR-even	TR-odd	TR-even	TR-odd
U	f_1					$(h_1^\perp)$
L			g_{1L}		$h_{1L}^\perp$	
T		$(f_{1T}^\perp)$	g_{1T}		h_{1T} $h_{1T}^\perp$	
LL	f_{1LL}					$(h_{1LL}^\perp)$
LT	f_{1LT}			(g_{1LT})		$(h'_{1LT}$ $h_{1LT}^\perp)$
TT	f_{1TT}			(g_{1TT})		$(h'_{1TT}$ $h_{1TT}^\perp)$

Leading Twist Functions, Bacchetta + Mulders, 2000

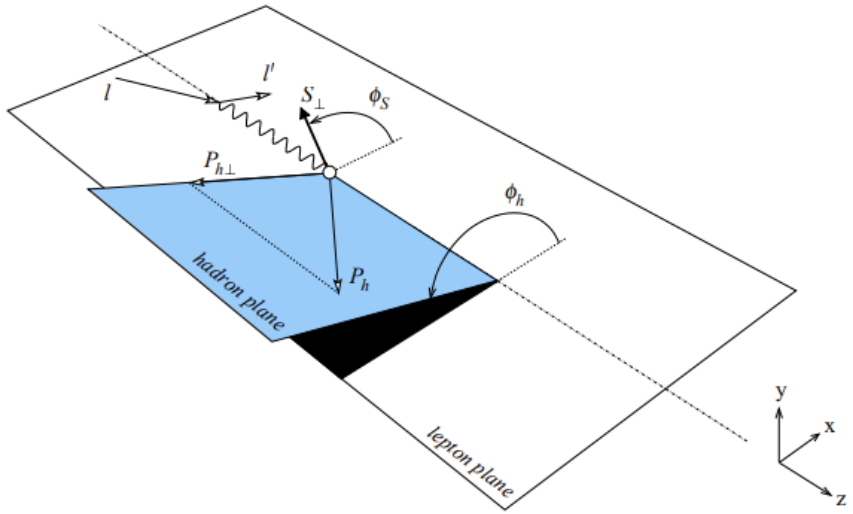
Deuteron SIDIS Cross Section

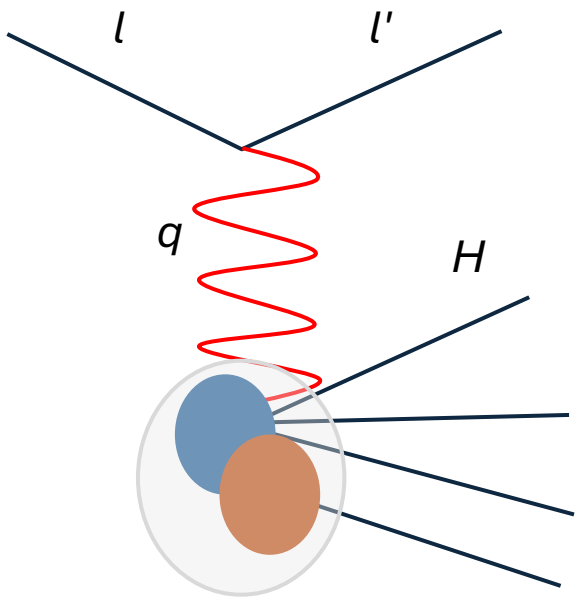
J. Poudel, A. Bacchetta et al. EPJA 2025

$$\frac{d\sigma}{dx\ dy\ d\psi\ dz\ d\phi_h\ dP_{h\perp}^2} = \frac{y^2\alpha^2}{2(1-\epsilon)xyQ^2}\left(1+\frac{\gamma^2}{2x}\right)\Bigg[F_{UU,T} + \epsilon F_{UU,L} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_h\ F_{UU}^{\cos\phi_h}$$
$$+ \epsilon\cos(2\phi_h)\ F_{UU}^{\cos(2\phi_h)} + \lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h\ F_{LU}^{\sin\phi_h}$$

Vector polarization:
$$+ S_\parallel\Big\{\sqrt{2\epsilon(1+\epsilon)}\sin\phi_h\ F_{UL}^{\sin\phi_h} + \epsilon\sin(2\phi_h)\ F_{UL}^{\sin 2\phi_h}\Big\}$$
$$+ S_\parallel\lambda_e\Big\{\sqrt{1-\epsilon^2}\ F_{LL} + \sqrt{2\epsilon(1-\epsilon)}\cos\phi_h\ F_{LL}^{\cos\phi_h}\Big\}$$

Tensor Polarization:
$$+ T_{\parallel\parallel}\Big\{F_{U(LL),T} + \epsilon\ F_{U(LL),L} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_h\ F_{U(LL)}^{\cos\phi_h}$$
$$+ \epsilon\cos(2\phi_h)\ F_{U(LL)}^{\cos 2\phi_h} + \lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h\ F_{L(LL)}^{\sin\phi_h}\Big\}\Bigg] \qquad (9)$$

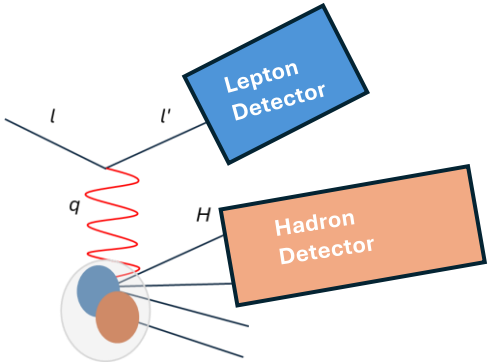




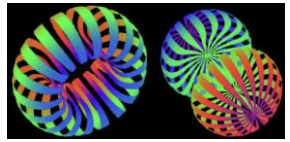
- F structure functions are linked to TMDs and Fragmentation Functions:

$$F_{U(LL),T} = C[f_{1LL}D_1]$$

Experimental Requirements

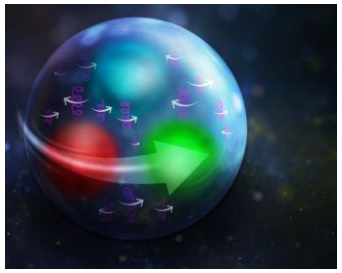


- SIDIS Measurement ➔ High precision lepton and hadron detectors



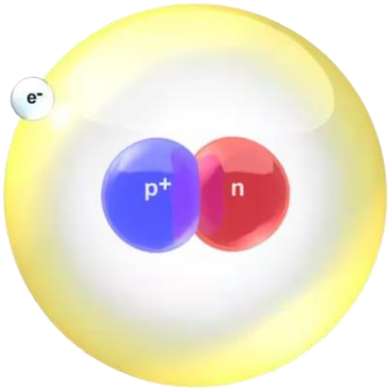
- Tensor Polarization ➔ Spin-1 Polarized Deuteron Target

- Decoupling XS Terms ➔ Need a variety of unpolarized and vector polarized states for const. tensor polarization



- Standard JLab Physics Beamline Requirements ➔ precise knowledge of beam position, energy, and polarization, beam raster, etc.

Tensor Polarized Target



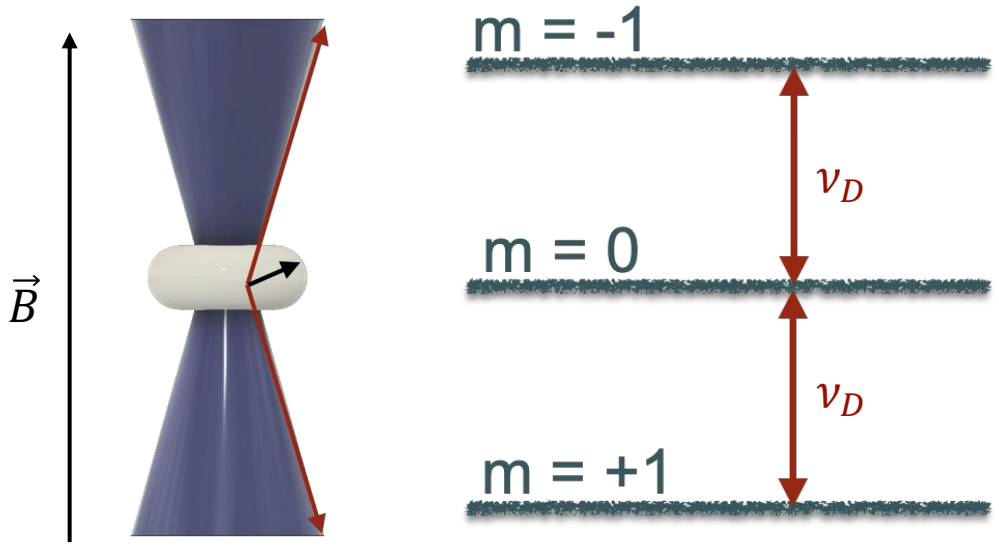
- Need to manipulate spin states to enhance deuteron tensor polarization
- Frozen ND_3
- Dynamic Nuclear Polarization
- Tensor Enhancement Techniques

- Technology has recently reached maturity (UNH/UVA)
- Can access different S.F. with different polarization angles

Transverse Angle:
See I. Fernando Talk next!

Vector Polarization:
$P = N_+ - N_-$
$-1 < P < +1$

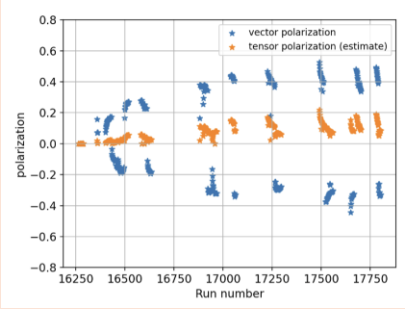
Tensor Polarization:
$Q = N_+ + N_- - 2N_0$
$-2 < Q < +1$



Dual-Pronged Approach to extracting the Tensor S.F.

Can we use existing polarized deuteron data?

- Run Group C in Hall B: Polarized ND_3



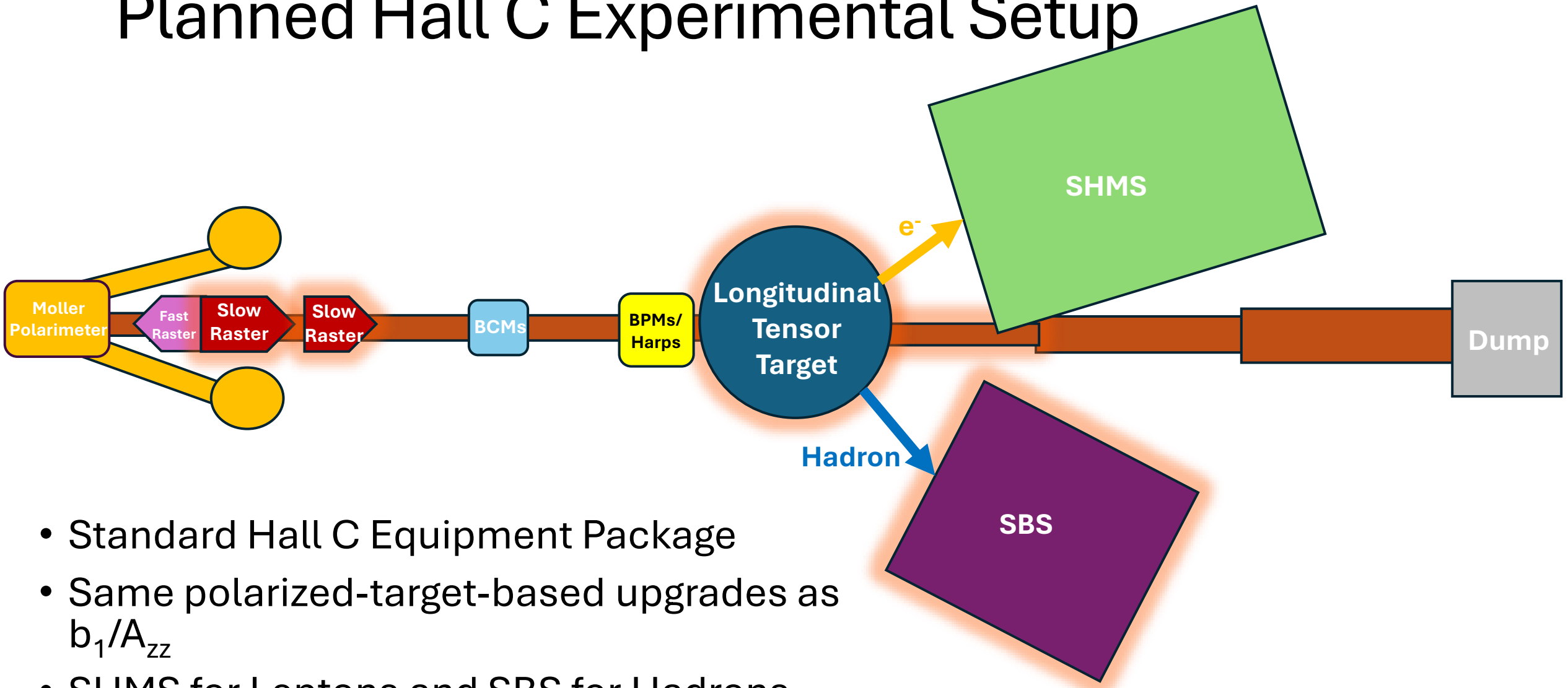
- Enough passive tensor polarization to try an extraction!
- CAA Approved in 2025
- Work is in progress for a first extraction

CAA Progress: See J. Poudel talk this morning!

Can we create a focused experiment to measure them?

- Use Tensor enhancement techniques
- Much better statistics than using the equilibrium Tensor pol.
- Target the kinematics most interesting for the TMDs
- Simplest longitudinal S.F.: $F_{U(LL),T}$
- ***Excellent place to start!***
- Tensor Target will be deployed in Hall C for b_1/A_{zz} experiments = **<u>natural synergy</u>**

Planned Hall C Experimental Setup



- Standard Hall C Equipment Package
- Same polarized-target-based upgrades as b_1/A_{zz}
- SHMS for Leptons and SBS for Hadrons

Letter of Intent

- LOI12-24-002 Submitted to PAC52 in 2024
- **Encouraged** to submit full proposal
- PAC Charges:

"The complexity of the measurement suggests expanding the collaboration and strengthening the connection with theoreticians"

✅ i.e. this workshop, hi y'all

"Conduct an exploratory measurement using deuteron data recently collected in Hall-B by the CLAS12 Run Group C"

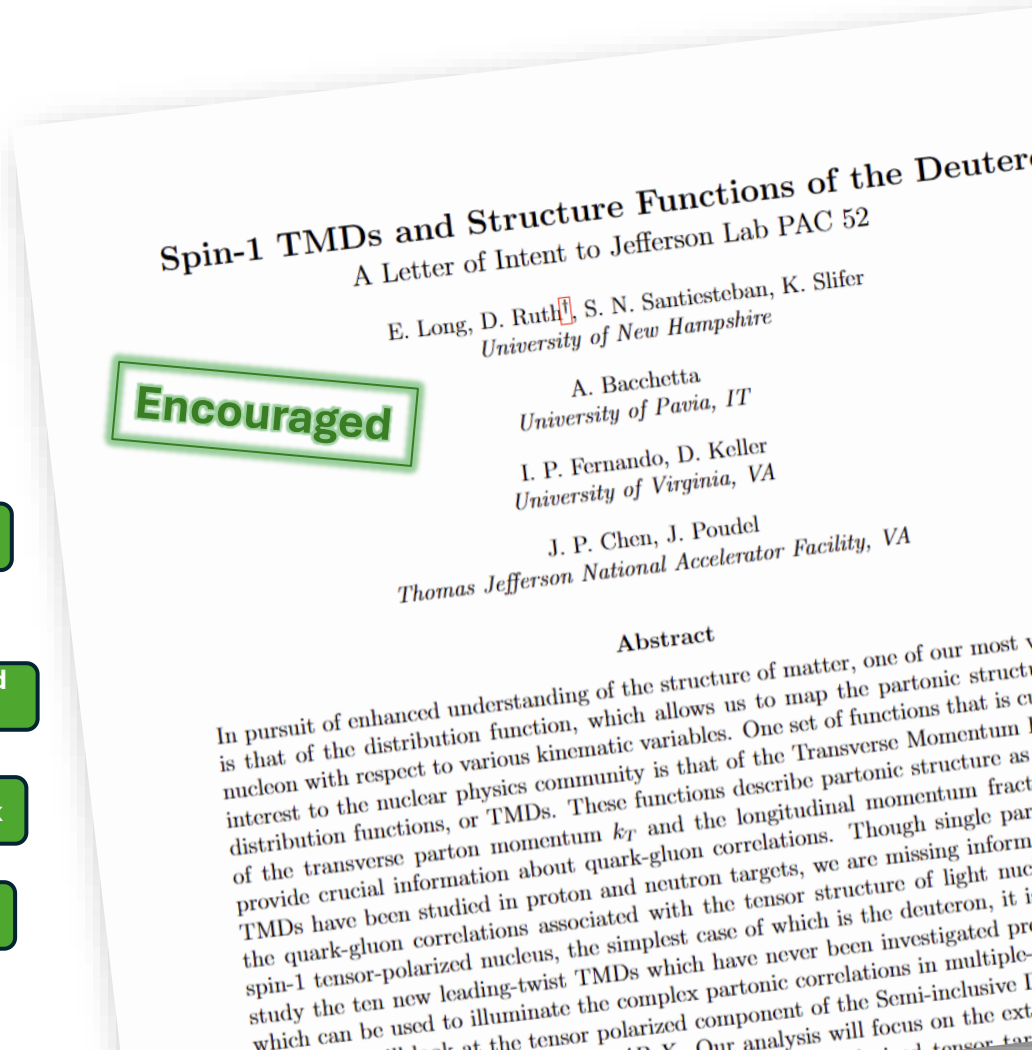
✅ See J. Poudel and H. Chinchay talks

"Refine the projections for the structure function FU(LL),T"

✅ See J. Vanek talk

"Provide a detailed description of the ssRF+AFP method"

✅ See b_1/A_{zz} talks



Spin-1 TMDs and Structure Functions of the Deuter

A Letter of Intent to Jefferson Lab PAC 52

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University of New Hampshire

A. Bacchetta
University of Pavia, IT

I. P. Fernando, D. Keller
University of Virginia, VA

J. P. Chen, J. Poudel
Thomas Jefferson National Accelerator Facility, VA

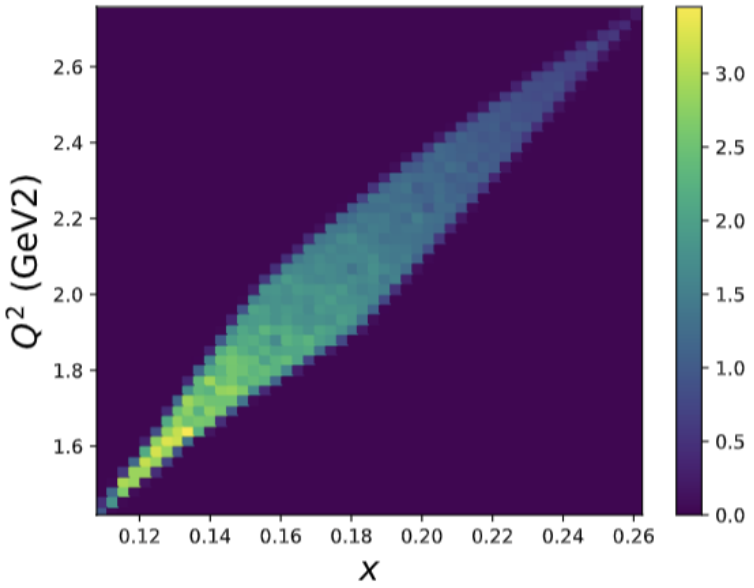
Encouraged

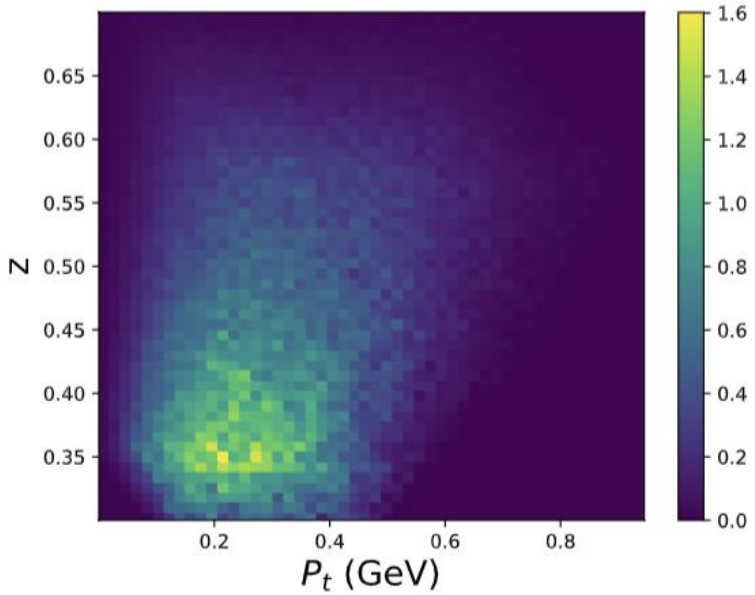
Abstract

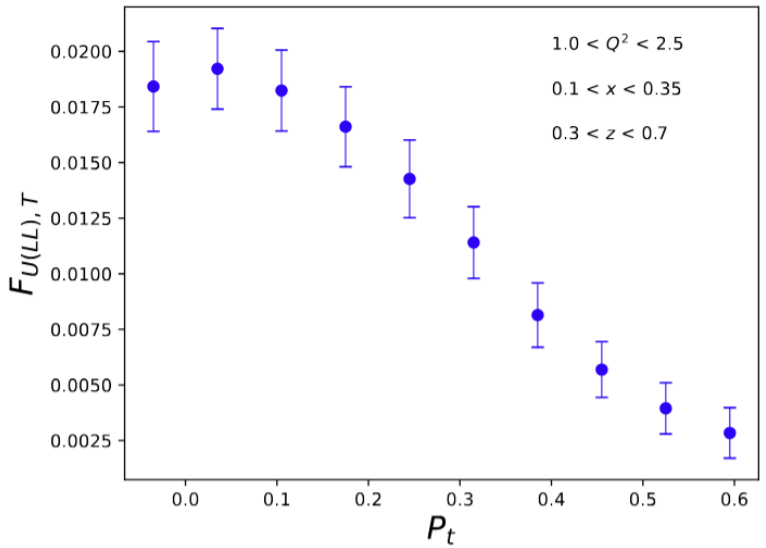
In pursuit of enhanced understanding of the structure of matter, one of our most
is that of the distribution function, which allows us to map the partonic structu
nucleon with respect to various kinematic variables. One set of functions that is c
interest to the nuclear physics community is that of the Transverse Momentum
distribution functions, or TMDs. These functions describe partonic structure as
of the transverse parton momentum k_T and the longitudinal momentum fract
provide crucial information about quark-gluon correlations. Though single par
TMDs have been studied in proton and neutron targets, we are missing inform
the quark-gluon correlations associated with the tensor structure of light nuc
spin-1 tensor-polarized nucleus, the simplest case of which is the deuteron, it i
study the ten new leading-twist TMDs which have never been investigated pr
which can be used to illuminate the complex partonic correlations in multiple-
look at the tensor polarized component of the Semi-inclusive

Simulation Overview

- Early simulations using LiuSIDIS model w/ Hall C acceptances done for LOI:







Projected rate for 5 days @ 80 nA

- Updated simulations in progress – the above may be optimistic…

Modern simulations: See J. Vanek talk tomorrow!

Planned Proposal

- SHMS for Lepton detection
- SBS for Hadron detection
- Standard equipment package + tensor target
- Beam Energy: 11 GeV
- Construct an asymmetry between tensor pol. and unpol. data

Analysis calculations: See N. Santiesteban talk this morning!

- Rates and detector angles calculation in progress ⏳

Planned Proposal Timeline + Distribution

- Originally planned to submit in 2026, but…
  - Integrating SBS and Hall C simulations turned out to be a very complex task
  - Need to include modern and realistic plan for the Tensor Target
  - Systematics are also complicated, needing standard SIDIS background and polarized target contributions
- Now targeting **PAC55 in 2027**
- Transverse Tensor SIDIS LOI in progress by UVA this year, likely to join in full proposal in 2027 (See I. Fernando talk)
- **If approved, we hope these SIDIS experiments could join the growing suite of early-2030s polarized target experiments in Hall C!**

JLab Tensor SIDIS Collaboration

- Meetings every Monday at 10:30 AM EST
- Open to all: Join tensor-sidis@jlab.org !
- Please join us!


N. Santiesteban


J. Poudel


D. Ruth


J.P. Chen


K. Slifer


E. Long


I. Fernando


F. Hossain


H. Chinchay


C. Lama


M. Farooq


O. Kehinde


A. Arora

Conclusion & Next Steps

- Full proposal following up on LOI12-24-002 in progress for 2027 PAC submission
- Simulations integrating SBS and SHMS will be completed (J. Vanek)
- CAA Analysis is underway

- **Tensor TMDs and structure functions provide a unique mechanism to understand nuclear structure**
- **World first measurements are coming soon!**