Spin-1 TMDs and Structure Functions of the Deuteron

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On Behalf of the Tensor Collaboration

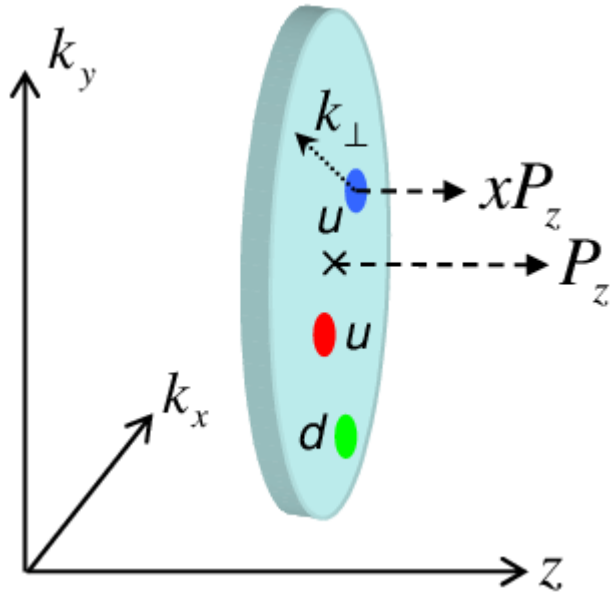
Hall C Winter 2025 Meeting

University of New Hampshire

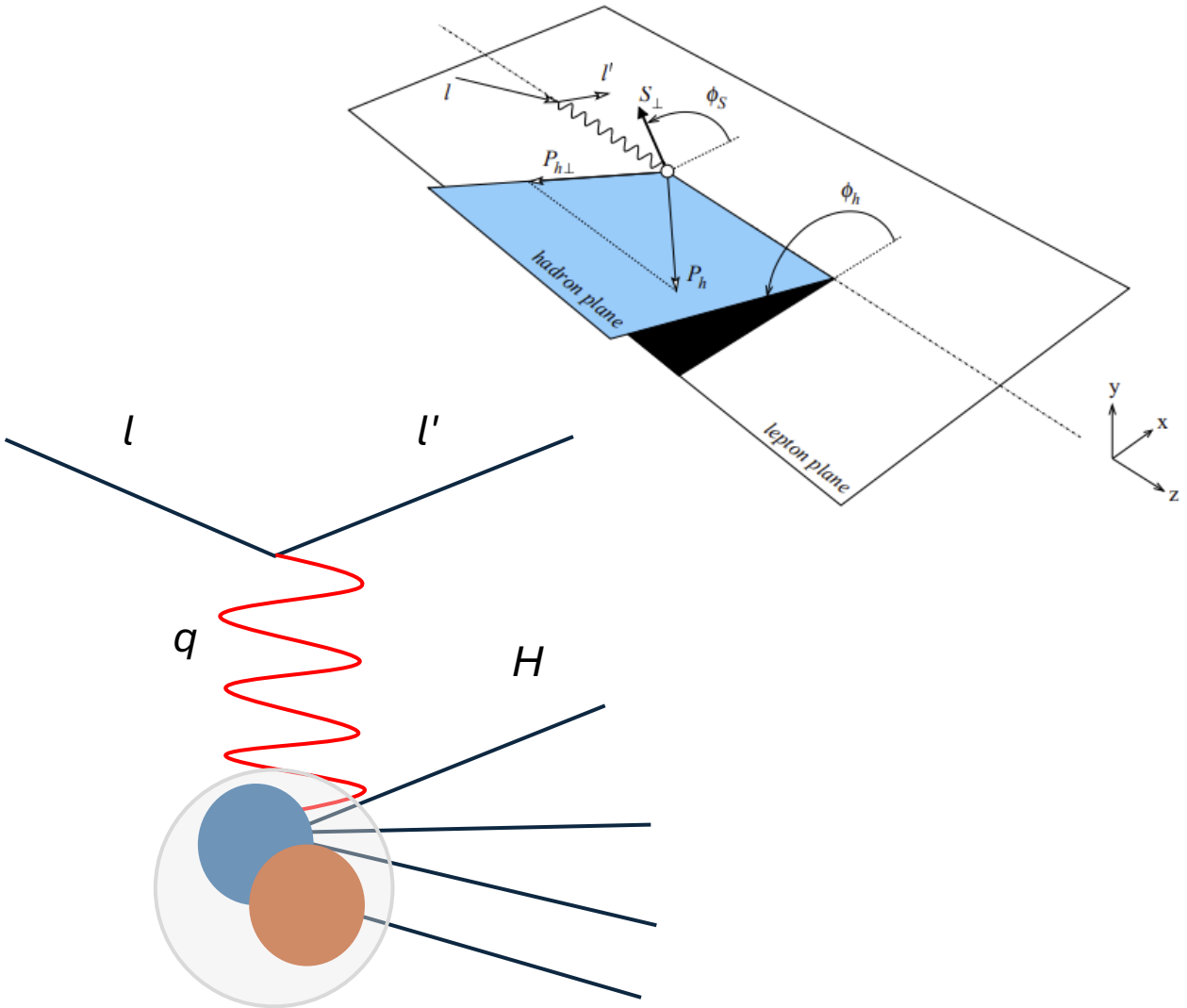
Jefferson Lab

TMDs are essential for investigating nuclear structure

- **Transverse-Momentum-Dependent** distribution functions: parton structure in terms of **x** and k_T (transverse momentum)
- Unique Capabilities for:
  - Hadron Tomography
  - Color Degrees of Freedom
  - Understanding Transverse Momentum Structure
- Extensive past and current studies on spin $\frac{1}{2}$ nucleon TMDs



Spin-1 Deuteron TMDs Never Before Measured!



- Suite of Tensor TMDs never before measured:

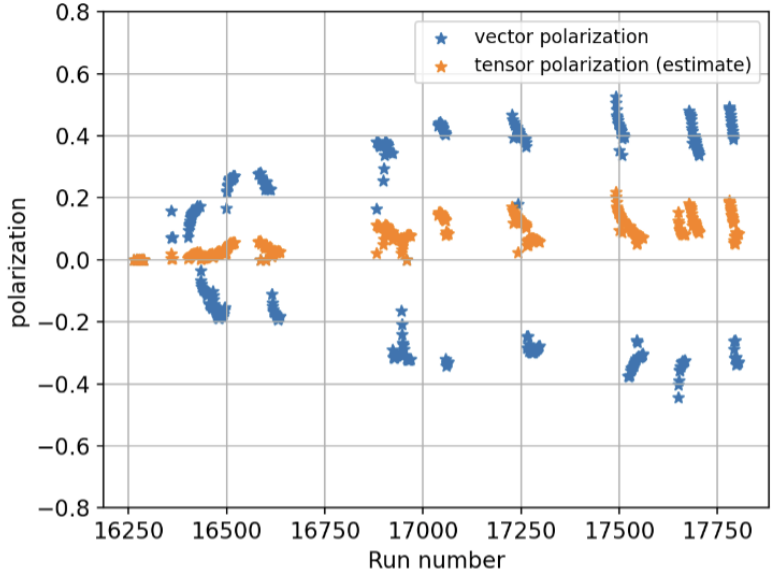
	$[\gamma^+]$		$[\gamma^+\gamma_5]$		$[i\sigma^{i+}\gamma_5]$	
	TR-even	TR-odd	TR-even	TR-odd	TR-even	TR-odd
U	f_1					$(h_1^\perp)$
L			g_{1L}		$h_{1L}^\perp$	
T		$(f_{1T}^\perp)$	g_{1T}		h_{1T} $h_{1T}^\perp$	
LL	f_{1LL}					$(h_{1LL}^\perp)$
LT	f_{1LT}			(g_{1LT})		$(h'_{1LT}$ $h_{1LT}^\perp)$
TT	f_{1TT}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

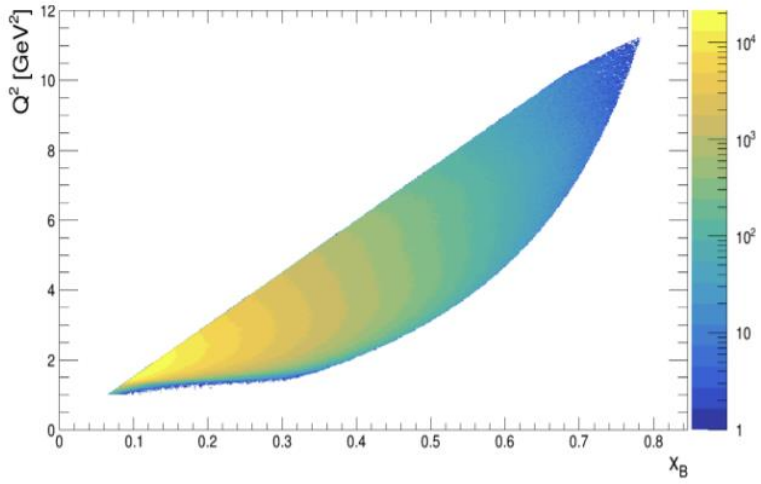
- Needs Semi-Inclusive Deep-Inelastic Scattering (SIDIS)
- Needs tensor polarized target:

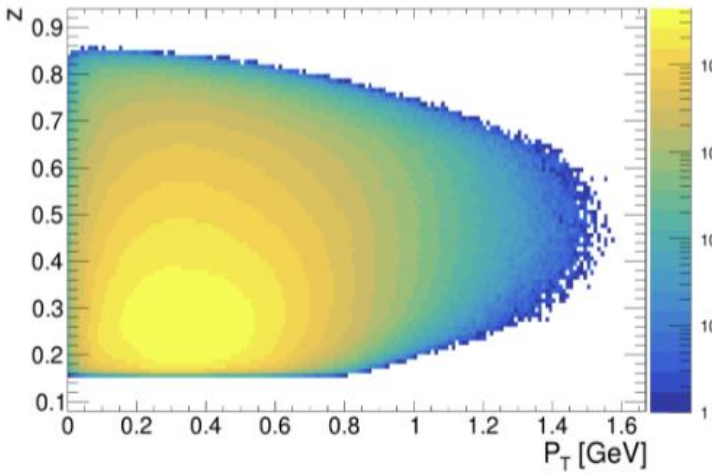
$$P_{zz} = \frac{N_1 + N_{-1} - 2N_0}{N_{tot}}$$

First, can we use any existing data?

- Recently approved **CLAS-Approved-Analysis (CAA)** to use RG-C data from Hall B
- Equilibrium tensor polarization (~10%) sufficient for a first extraction
- Analysis is just getting going!
- But we will get **much better statistics** from a dedicated measurement







Hall C Proposed Setup + LOI

- Use SBS (Hadron) and SHMS (Lepton) to do a SIDIS measurement in Hall C
- Collect data over a range of vector polarization magnitudes and directions to isolate tensor part of XS
- LOI12-24-002 Submitted to PAC52

- **Encouraged to submit a full proposal!**

Spin-1 TMDs and Structure Functions of the Deuteron

A Letter of Intent to Jefferson Lab PAC 52

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University of New Hampshire

A. Bacchetta
University of Pavia, IT

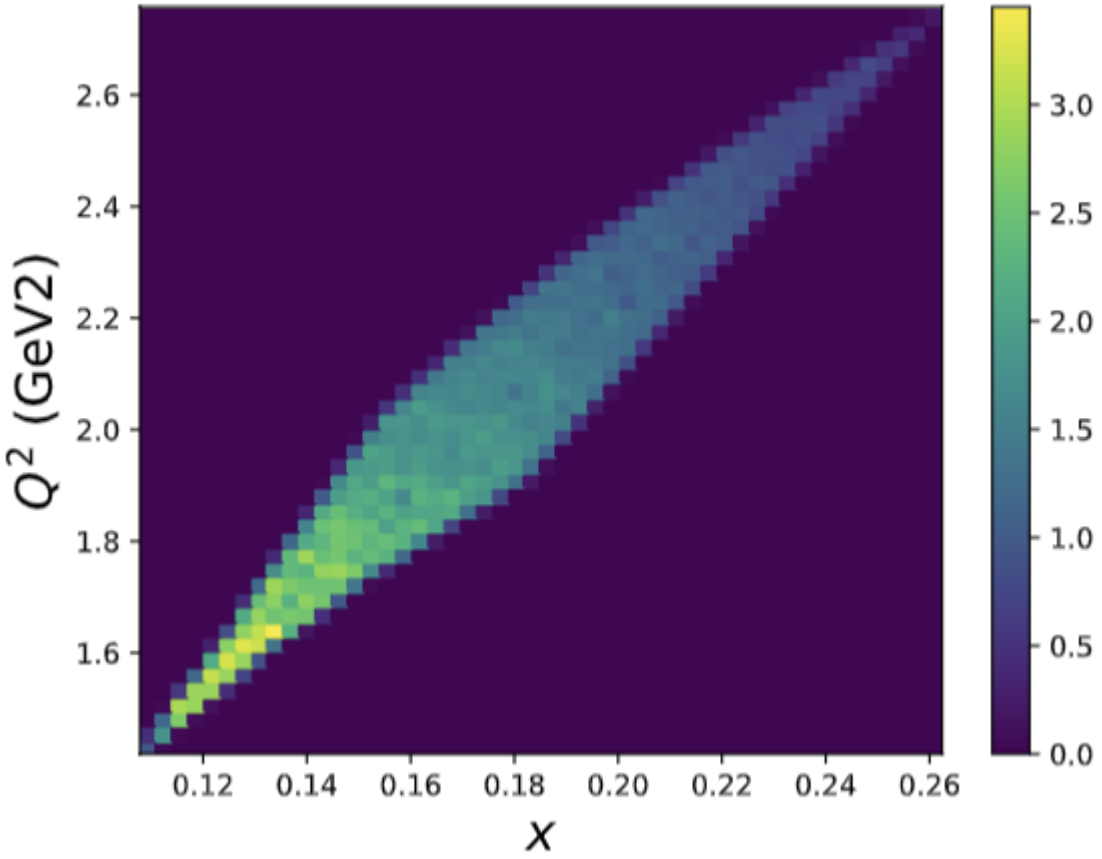
I. P. Fernando, D. Keller
University of Virginia, VA

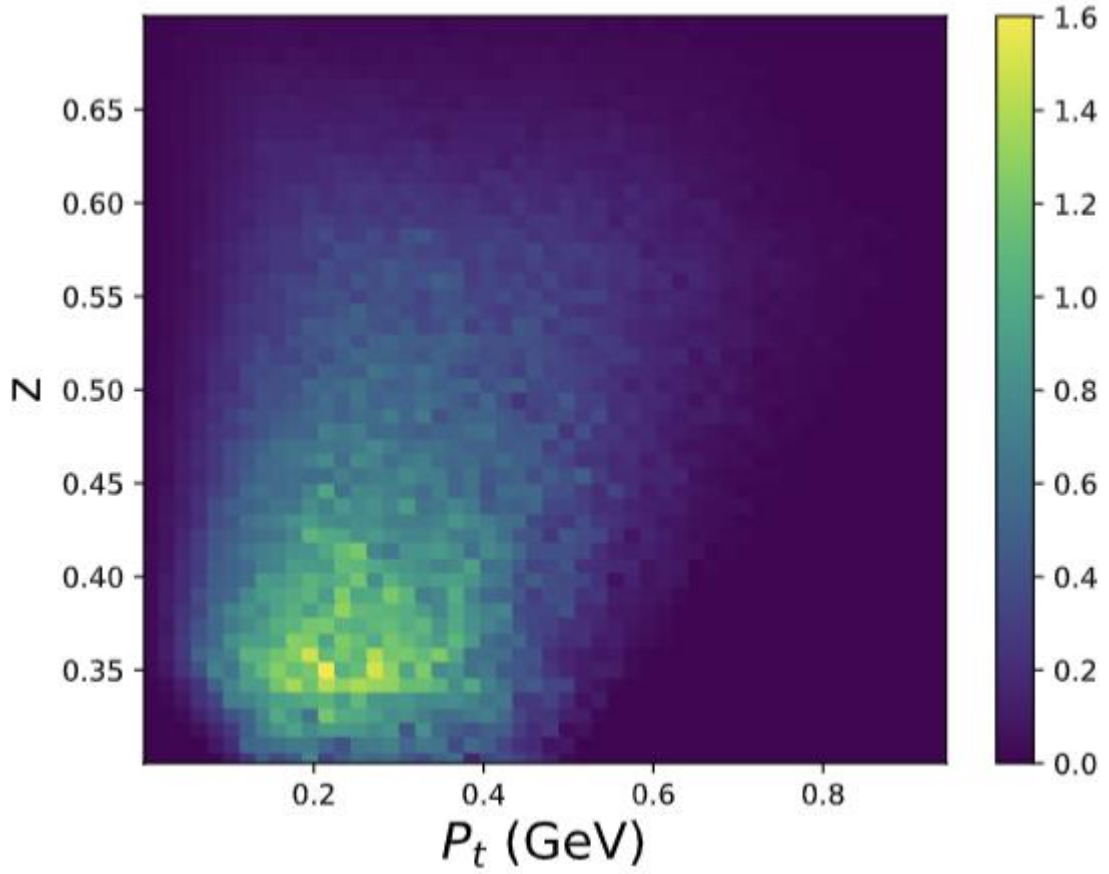
J. P. Chen, J. Poudel
Thomas Jefferson National Accelerator Facility, VA

Abstract

In pursuit of enhanced understanding of the structure of matter, one of our most vital tools is that of the distribution function, which allows us to map the partonic structure of the nucleon with respect to various kinematic variables. One set of functions that is currently of interest to the nuclear physics community is that of the Transverse Momentum Dependent distribution functions, or TMDs. These functions describe partonic structure as a function of transverse parton momentum k_T and the longitudinal momentum fraction x, and information about quark-gluon correlations. Though single particle spin-$\frac{1}{2}$ in proton and neutron targets, we are missing information about ciated with the tensor structure of light nuclei. With a st case of which is the deuteron, it is possible to never been investigated previously, and lations in multiple-nucleon light inclusive Deep Inelastic straction of the through

Expected Acceptances





Structure Functions

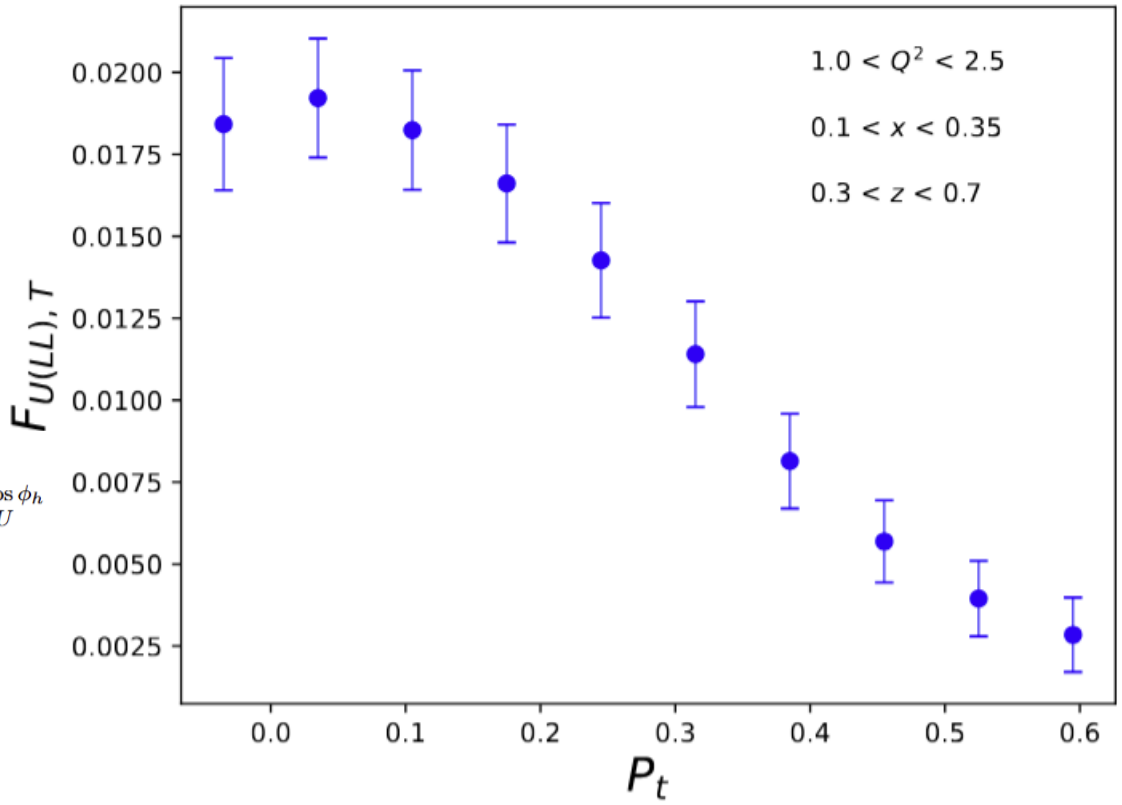
- TMDs are linked to set of tensor structure functions

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

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

A. Baccheta



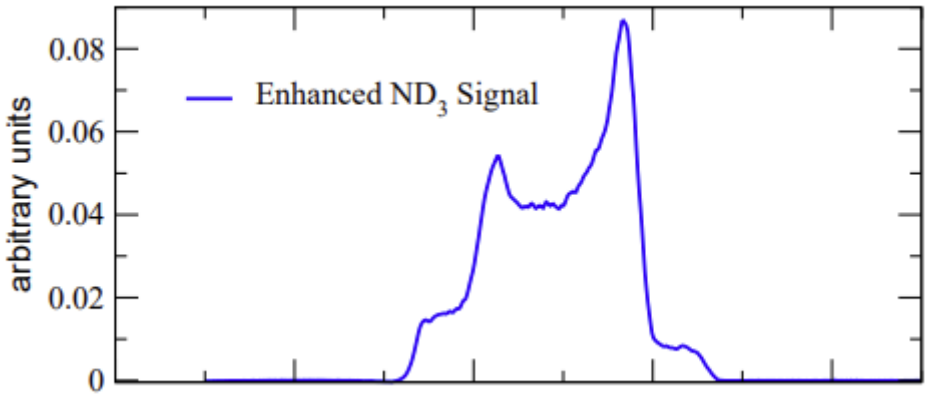
Projected rate for 5 days @ 80 nA

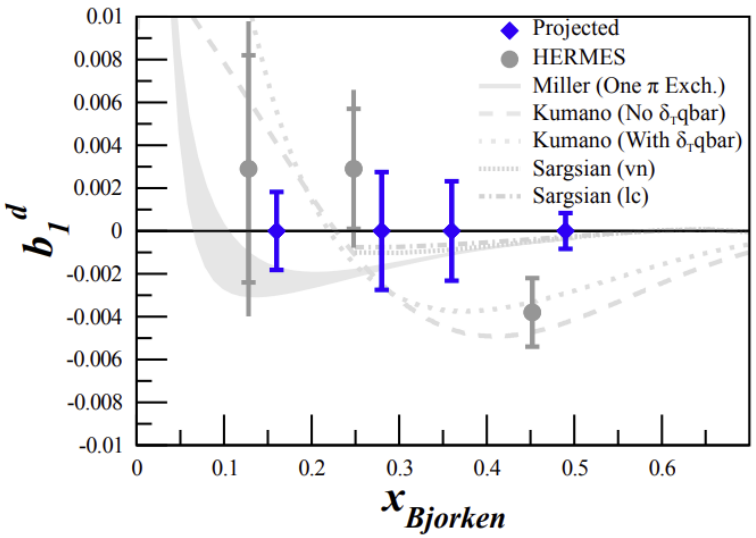
Current Open Tasks

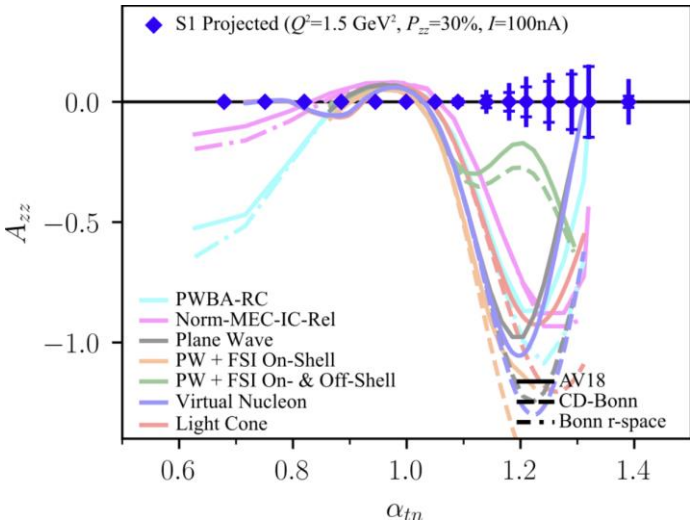
- Theory support to better understand **relation between $F_{U(LL),T}$ and $F_{UU,T}$** (A. Baccheta, I. Cloet)
- **Full simulation including SBS**
- **Tensor-enhanced polarized target**
- **CAA Analysis to better understand tensor contribution**

Other Tensor Experiments

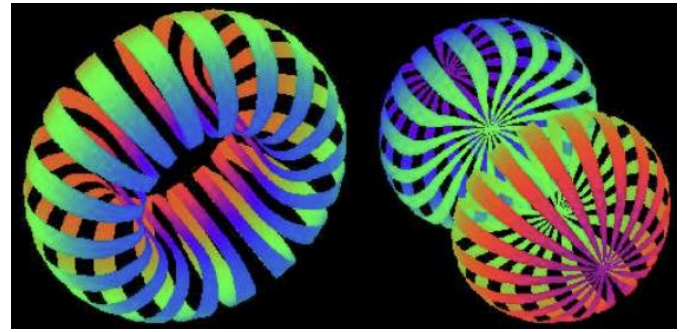
- This new SIDIS program joins 2 approved DIS experiments using tensor polarization
- b_1 and A_{zz} collaborations preparing to run in Hall C, **currently we are working on an ERR**
- Look for an update from these experiments at another meeting soon







Meetings & Tensor Group



- SIDIS Meetings: Thursdays at 2PM (TBD)
- General Tensor Meetings: Every-other Friday at 1:30 PM

Spokespeople:

- Nathaly Santiesteban
- Jian-Ping Chen
- Karl Slifer†
- Elena Long†
- Dustin Keller
- Oscar Rondon Aramayo
- Narbe Kalantarians
- Donal Day
- Doug Higinbotham

Postdocs:

- David Ruth†
- Jiwan Poudel
- Ishara Fernando
- Allison Zec

Grad Students:

- Anchit Arora
- Hector Chinchay
- Muhammad Farooq
- Chhetra Lama
- Michael McClellan

†: Contact († b_1, † A_{zz}, † SIDIS LOI)

- Large and **growing** group (DIS, SIDIS… See previous talk by C. Yero on Exclusive too!)
- All are welcome! Let us know if you are interested in Tensor spin physics and please join us!

Next Steps + Full Proposal

- Full Hall C SIDIS Proposal currently targeted for **Summer 2026**
- CLAS-Approved Analysis underway, with preliminary results targeted for **2025**
- DIS Experiments preparing for an ERR

- **More Tensor physics is coming soon to Hall C!**