Spin 1 SIDIS Observables from Transversely Tensor Polarized Targets

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Tensor Collaboration Meeting

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Jefferson Lab, Virginia

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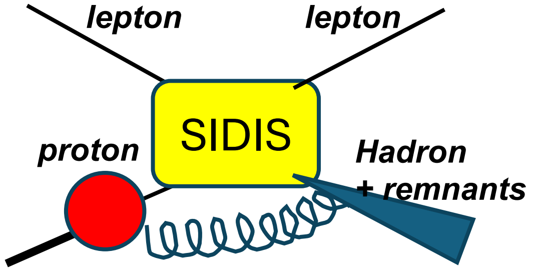
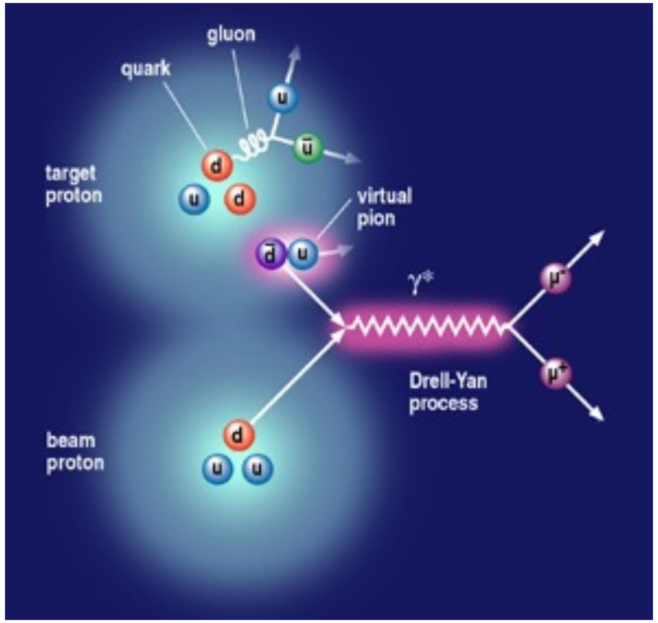
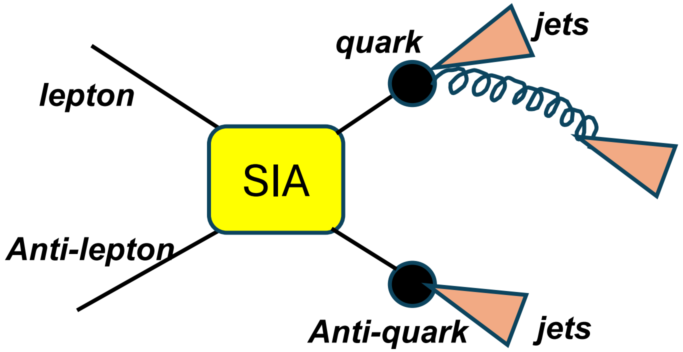
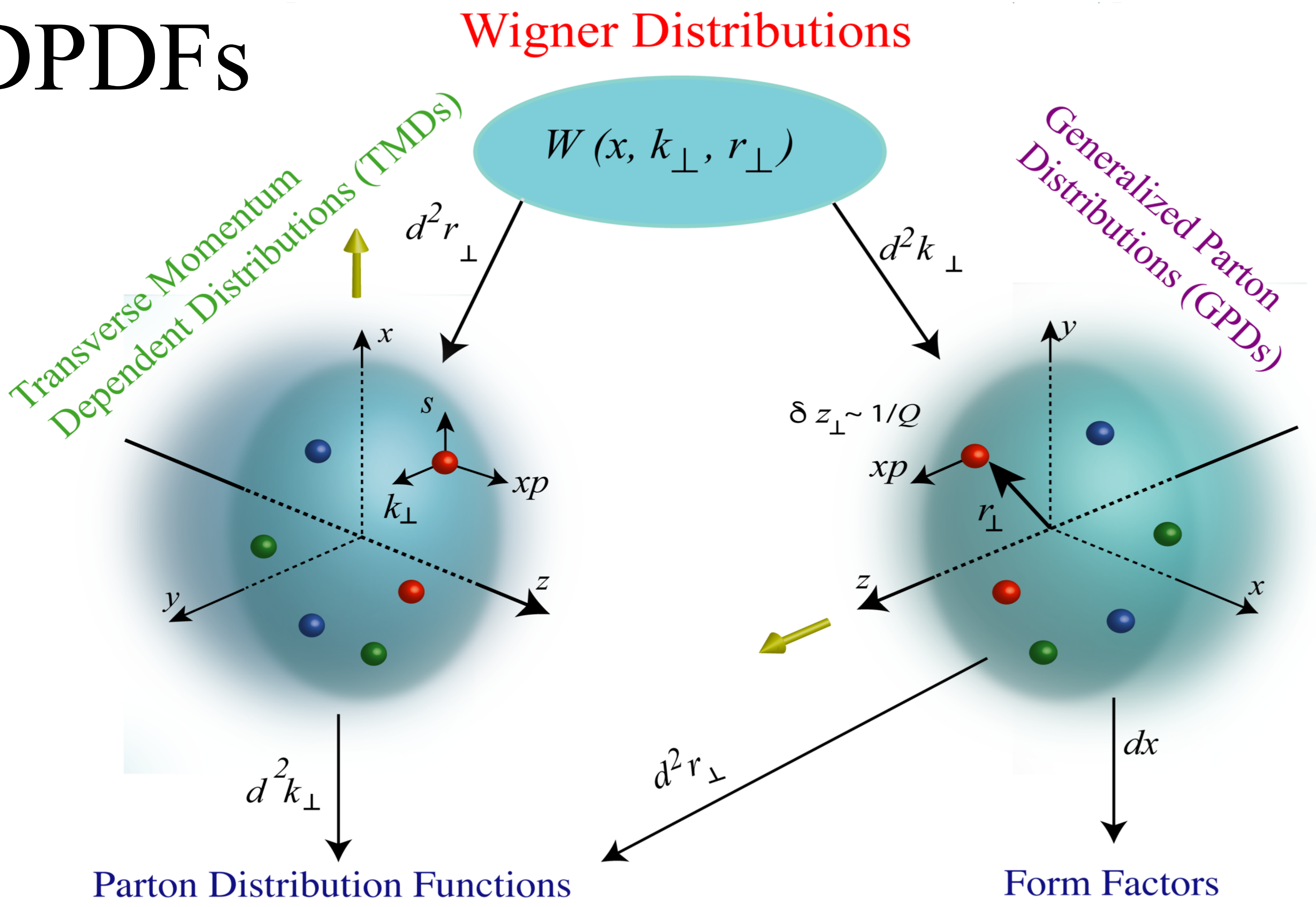
TMDPDFs



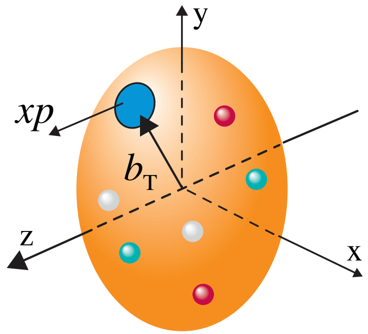






$$\Phi(x, k_T; S) = \int \frac{d\xi^- d\xi_T}{(2\pi)^3} e^{ik.\xi} \langle P, S|\bar{\psi}(0)\, \mathcal{U}_{[0,\xi]}\ \psi(\xi)|P, S\rangle|_{\xi^+=0}$$

Spin 1 TMDPDFs



Leading Twist		Quark Polarization		
		Unpolarized [U]	Longitudinal [L]	Transverse [T]
Target Polarization	U	f_1 Unpolarized		$h_1^\perp$ Boer-Mulders
	L		g_1 Helicity	$h_{1L}^\perp$ Worm-gear 1
	T	$f_{1T}^\perp$ Sivers	g_{1T} Worm-gear 2	h_1 Transversity $h_{1T}^\perp$ Pretzelosity
	TENSOR	$f_{1LL}(x,\boldsymbol{k}_T^2)$ $f_{1TT}(x,\boldsymbol{k}_T^2)$ $f_{1LT}(x,\boldsymbol{k}_T^2)$	$g_{1TT}(x,\boldsymbol{k}_T^2)$ $g_{1LT}(x,\boldsymbol{k}_T^2)$	$h_{1LL}^\perp(x,\boldsymbol{k}_T^2)$ $h_{1TT}(x,\boldsymbol{k}_T^2)$ $h_{1TT}^\perp(x,\boldsymbol{k}_T^2)$ $h_{1LT}(x,\boldsymbol{k}_T^2)$ $h_{1LT}^\perp(x,\boldsymbol{k}_T^2)$

Leading Twist			Gluon Polarization		
			Unpolarized	Circular	Linear
Target Polarization	Vector Polarized	U	f_1		$h_1^\perp$
		L		g_1	$h_{1L}^\perp$
		T	$f_{1T}^\perp$	g_{1T}	h_{1T} $h_{1T}^\perp$
	Tensor Polarized	LL	f_{1LL}		$h_{1LL}^\perp$
		LT	f_{1LT}	g_{1LT}	h_{1LT} $h_{1LT}^\perp$
		TT	f_{1TT}	g_{1TT}	h_{1TT} $h_{1TT}^\perp$ $h_{1TT}^{\perp\perp}$

$$\Phi = \Phi_U + \Phi_L + \Phi_T + \Phi_{LL} + \Phi_{LT} + \Phi_{TT}$$

$$\Gamma^{ij} = \Gamma_U^{ij} + \Gamma_L^{ij} + \Gamma_T^{ij} + \Gamma_{LL}^{ij} + \Gamma_{LT}^{ij} + \Gamma_{TT}^{ij}$$

The collinear correlators after integrating over the momentum,

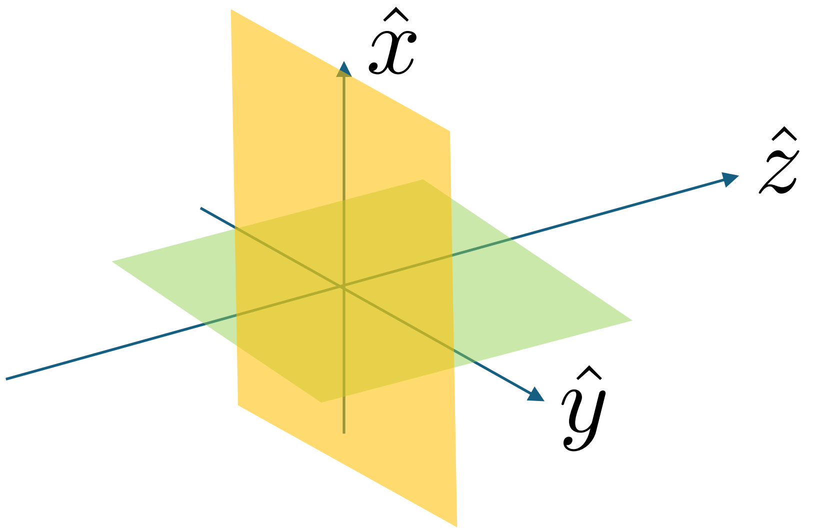
$$\Phi(x;P,S,T) = \frac{1}{2}\left[\not{P} f_1(x) + S_L\gamma_5 \not{P} g_1(x) + \frac{[\not{S}_T,\not{P}]\gamma_5}{2} h_1(x) + S_{LL}\not{P} f_{1LL}(x) + \frac{[\not{S}_{LT},\not{P}]}{2} i h_{1LT}(x,k_T^2)\right].$$

$$\Phi_g^{\alpha\beta}(x) \equiv \int d^2p_T \Phi_g^{\alpha\beta}(x,\vec{p}_T)$$

$$= \frac{1}{2}\left[-g_T^{\alpha\beta} f_1^g(x) + i\epsilon_T^{\alpha\beta} S_L g_1^g(x) - g_T^{\alpha\beta} S_{LL} f_{1LL}^g(x + S_{TT}^{\alpha\beta} h_{1TT}^g(x)\right]$$

Kumano et al (2020)

Deuteron Polarizations



The deuteron polarization density matrix

$$\rho(S,T) = \frac{1}{3}\left(I + \frac{3}{2}S^i\Sigma^i + 3T^{ij}\Sigma^{ij}\right)$$

$\boldsymbol{\Sigma_i}$ are 3×3 spin matrices for the deuteron

$$\boldsymbol{\Sigma_x} = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \quad \boldsymbol{\Sigma_y} = \frac{i}{\sqrt{2}}\begin{pmatrix} 0 & -1 & 0 \\ 1 & 0 & -1 \\ 0 & 1 & 0 \end{pmatrix} \quad \boldsymbol{\Sigma_z} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{pmatrix}$$

$\boldsymbol{\Sigma}_{ij}$ are spin tensors

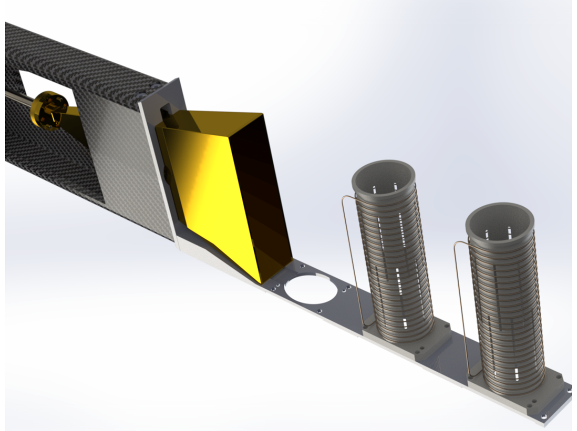
$$\boldsymbol{\Sigma}_{ij} = \frac{1}{2}\left(\boldsymbol{\Sigma_i}\boldsymbol{\Sigma_j} + \boldsymbol{\Sigma_j}\boldsymbol{\Sigma_i}\right) - \frac{2}{3}\boldsymbol{I}\delta_{ij}$$

$$\boldsymbol{S} = (S_T^x, S_T^y, S_L)$$

$$\boldsymbol{T} = \frac{1}{2}\begin{pmatrix} -\frac{2}{3}S_{LL} + S_{\mathrm{TT}}^{xx} & S_{\mathrm{TT}}^{xy} & S_{LT}^x \\ S_{\mathrm{TT}}^{xy} & -\frac{2}{3}S_{LL} - S_{\mathrm{TT}}^{xx} & S_{LT}^y \\ S_{LT}^x & S_{LT}^y & \frac{4}{3}S_{LL} \end{pmatrix}$$

$$\rho(S,T) = \begin{pmatrix} \frac{1}{3} + \frac{S_L}{2} + \frac{S_{LL}}{3} & \frac{S_T^x - iS_T^y}{2\sqrt{2}} + \frac{S_{LT}^x - iS_{LT}^y}{2\sqrt{2}} & \frac{S_{TT}^{xx} - iS_{TT}^{xy}}{2} \\ \frac{S_T^{x+iS_T^y}}{2\sqrt{2}} + \frac{S_{LT}^x + iS_{LT}^y}{2\sqrt{2}} & \frac{1}{3} - \frac{2S_{LL}}{3} & \frac{S_T^x - iS_T^y}{2\sqrt{2}} - \frac{S_{LT}^x - iS_{LT}^y}{2\sqrt{2}} \\ \frac{S_{TT}^{xx} + iS_{TT}^{xy}}{2} & \frac{S_T^x + iS_T^y}{2\sqrt{2}} - \frac{S_{LT}^x + iS_{LT}^y}{2\sqrt{2}} & \frac{1}{3} - \frac{S_L}{2} + \frac{S_{LL}}{3} \end{pmatrix}$$

Tensor Polarization Enhancement

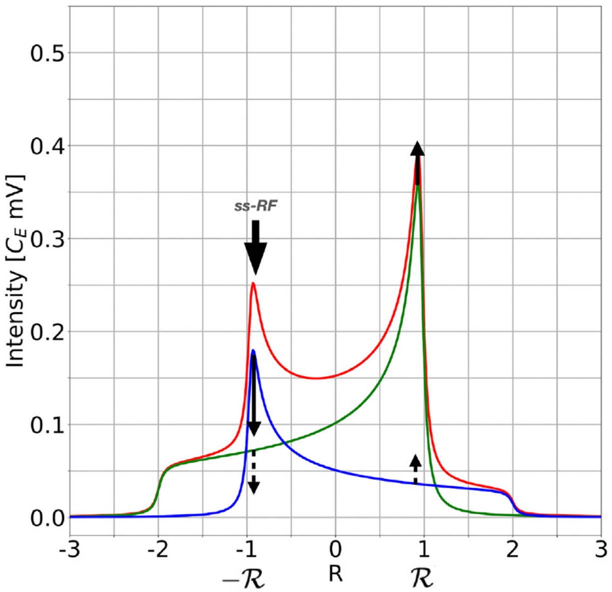


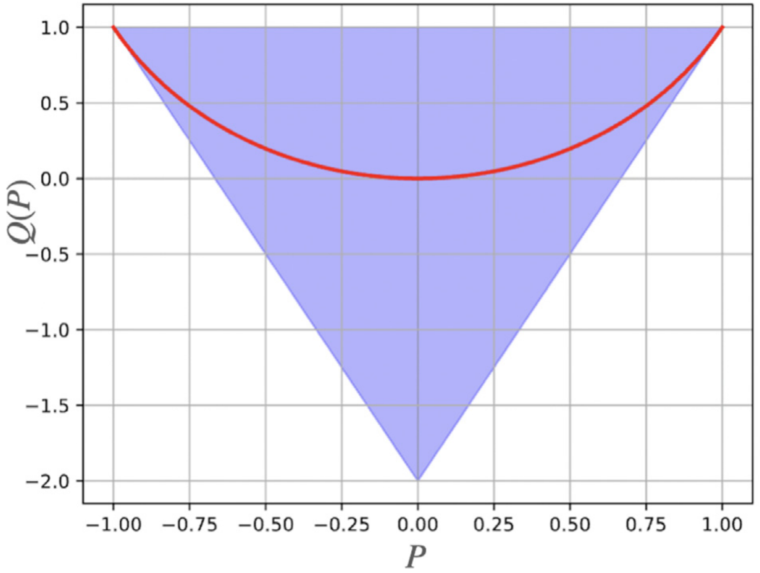
- ✓ DNP microwaves
- ✓ Additional RF: Semi-Saturating RF (ss-RF) irradiation → to maximize Tensor polarization
- ✓ Continuous Wave NMR (CW-NMR)
- ✓ The rate depends on the intensity level and the applied magnetic field strength of the RF power.

J. Clement and D. Keller (2023) [https://doi.org/10.1016/j.nima.2023.168177]

Under normal DNP-enhancement, conditions, the system is in Boltzmann equilibrium and Q_n can be calculated directly from P_n

$$Q_n = 2 - \sqrt{4 - 3P_n^2}$$





<u>Three Principles for Enhanced Tensor Polarization</u>

- ❖ Differential Binning
- ❖ Spin Temperature Consistency
- ❖ Rate Response

See Talks by Dustin, Forhad, Devin for more details

SIDIS Cross-Section for Deuteron Target

$$\frac{d\sigma_{\text{Tens}}}{dx_d dy dz d\phi_h d\psi dP_{h\perp}^2} = \frac{\alpha^2}{x_d y Q^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x_d}\right)\Bigg\{S_{LL}\Big[F_{U(LL),T}+\varepsilon F_{U(LL),L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\,\cos\phi_h\,F_{U(LL)}^{\cos\phi_h}$$

$$+\,\varepsilon\cos(2\phi_h)\,F_{U(LL)}^{\cos 2\phi_h}+\lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\,\sin\phi_h\,F_{L(LL)}^{\sin\phi_h}\Big]$$

$$+\,|S_{LT}|\Big[\cos(\phi_h-\phi_{LT})\Big(F_{U(LT),T}^{\cos(\phi_h-\phi_{LT})}+\varepsilon F_{U(LT),L}^{\cos(\phi_h-\phi_{LT})}\Big)$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\Big(\cos\phi_{LT}F_{U(LT)}^{\cos\phi_{LT}}+\cos(2\phi_h-\phi_{LT})F_{U(LT)}^{\cos(2\phi_h-\phi_{LT})}\Big)$$

$$+\,\varepsilon\Big(\cos(\phi_h+\phi_{LT})F_{U(LT)}^{\cos(\phi_h+\phi_{LT})}+\cos(3\phi_h-\phi_{LT})F_{U(LT)}^{\cos(3\phi_h-\phi_{LT})}\Big)$$

$$+\,\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\Big(\sin\phi_{LT}F_{L(LT)}^{\sin\phi_{LT}}+\sin(2\phi_h-\phi_{LT})F_{L(LT)}^{\sin(2\phi_h-\phi_{LT})}\Big)$$

$$+\,\lambda_e\sqrt{1-\varepsilon^2}\sin(\phi_h-\phi_{LT})F_{L(LT)}^{\sin(\phi_h-\phi_{LT})}\Big]$$

$$+\,|S_{TT}|\Big[\cos(2\phi_h-2\phi_{TT})\Big(F_{U(TT),T}^{\cos(2\phi_h-2\phi_{TT})}+\varepsilon F_{U(TT),L}^{\cos(2\phi_h-2\phi_{TT})}\Big)$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\Big(\cos(\phi_h-2\phi_{TT})F_{U(TT)}^{\cos(\phi_h-2\phi_{TT})}+\cos(3\phi_h-2\phi_{TT})F_{U(TT)}^{\cos(3\phi_h-2\phi_{TT})}\Big)$$

$$+\,\varepsilon\Big(\cos(2\phi_{TT})F_{U(TT)}^{\cos(2\phi_{TT})}+\cos(4\phi_h-2\phi_{TT})F_{U(TT)}^{\cos(4\phi_h-2\phi_{TT})}\Big)$$

$$+\,\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\Big(\sin(\phi_h-2\phi_{TT})F_{L(TT)}^{\sin(\phi_h-2\phi_{TT})}+\sin(3\phi_h-2\phi_{TT})F_{L(TT)}^{\sin(3\phi_h-2\phi_{TT})}\Big)$$

$$+\,\lambda_e\sqrt{1-\varepsilon^2}\sin(2\phi_h-2\phi_{TT})F_{L(TT)}^{\sin(2\phi_h-2\phi_{TT})}\Big]\Bigg\},$$

With Transversely Tensor Polarized Target

J. Zhao, A. Bacchetta, S. Kumano, T. Liu, Y.-J. Zhuo, arXiv: 2058.06134

Structure functions related to Transversely Tensor Polarized Targets

With Unpolarized Beam

$$F_{U(TT),T}^{\cos(2\phi_h-2\phi_{LT})} = \mathcal{C}\Big[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2-\boldsymbol{p}_T^2}{M^2}f_{1TT}D_1\Big],$$

$$F_{U(TT),L}^{\cos(2\phi_h-2\phi_{LT})} = 0,$$

$$\begin{aligned}F_{U(TT)}^{\cos(\phi_h-2\phi_{TT})} &= \frac{2M}{Q}\mathcal{C}\Big\{\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T}{M}\big(xf_{TT}D_1-\frac{M_h}{M}h_{1TT}\frac{\tilde{H}}{z}\big)\\ &+\frac{(\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_T)\boldsymbol{p}_T^2-2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)(\boldsymbol{k}_T\cdot\boldsymbol{p}_T)}{2M^2M_h}\Big[\Big(xh_{TT}H_1^\perp-\frac{M_h}{M}g_{1TT}\frac{\tilde{G}^\perp}{z}\Big)\\ &+\Big(xh_{TT}^\perp H_1^\perp-\frac{M_h}{M}f_{1TT}\frac{\tilde{D}^\perp}{z}\Big)\Big]\Big\},\end{aligned}$$

$$\begin{aligned}F_{U(TT)}^{\cos(3\phi_h-2\phi_{TT})} &= \frac{2M}{Q}\mathcal{C}\Big\{\frac{3(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)\big(2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2-\boldsymbol{p}_T^2\big)}{2M^3}\Big(xf_{TT}^\perp D_1+\frac{M_h}{M}h_{1TT}^\perp\frac{\tilde{H}^\perp}{z}\Big)\\ &+\frac{4(\boldsymbol{h}\cdot\boldsymbol{k}_T)(\boldsymbol{h}\cdot\boldsymbol{p}_T)^2-2(\boldsymbol{h}\cdot\boldsymbol{p}_T)(\boldsymbol{k}_T\cdot\boldsymbol{p}_T)-(\boldsymbol{h}\cdot\boldsymbol{k}_T)\boldsymbol{p}_T^2}{2M^2M_h}\\ &\times\Big[\Big(xh_{TT}^\perp H_1^\perp+\frac{M_h}{M}f_{1TT}\frac{\tilde{D}^\perp}{z}\Big)-\Big(xh_{TT}H_1^\perp+\frac{M_h}{M}g_{1TT}\frac{\tilde{G}^\perp}{z}\Big)\Big]\Big\}\end{aligned}$$

$$F_{U(TT)}^{\cos(2\phi_{TT})} = \mathcal{C}\Big[\frac{\boldsymbol{k}_T\cdot\boldsymbol{p}_T}{MM_h}h_{1TT}H_1^\perp\Big],$$

$$\begin{aligned}F_{U(TT)}^{\cos(4\phi_h-2\phi_{TT})} &= \mathcal{C}\Big[-\Big(\frac{4(\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_T)(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)\boldsymbol{p}_T^2-8(\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_T)(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^3}{2M^3M_h}\\ &+\frac{4(\boldsymbol{k}_T\cdot\boldsymbol{p}_T)(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2-(\boldsymbol{k}_T\cdot\boldsymbol{p}_T)\boldsymbol{p}_T^2}{2M^3M_h}\Big)h_{1TT}^\perp H_1^\perp\Big],\end{aligned}$$

With Longitudinally Polarized Beam

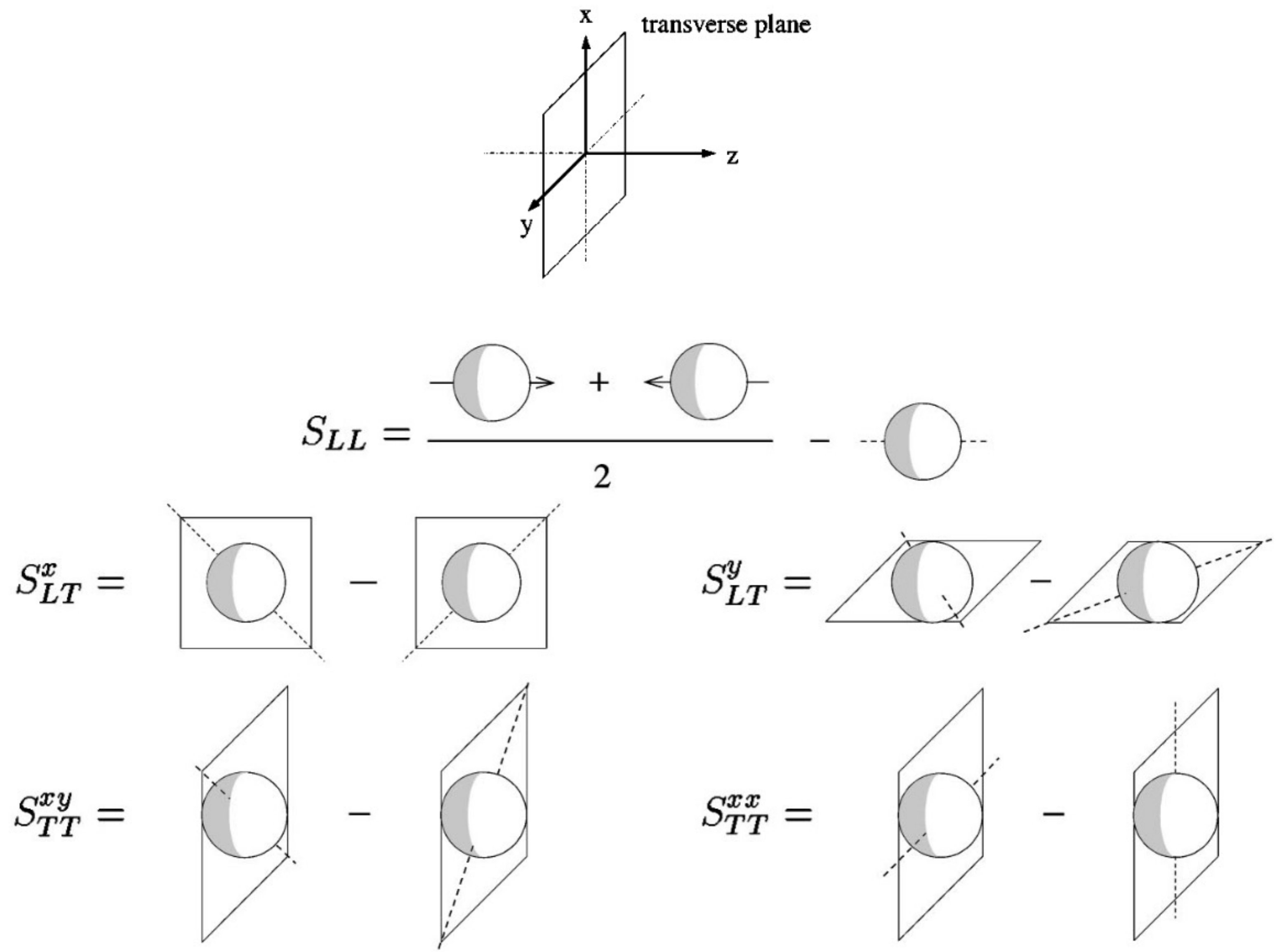
$$\begin{aligned}F_{L(TT)}^{\sin(\phi_h-2\phi_{TT})} &= \frac{2M}{Q}\mathcal{C}\Big\{\frac{\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T}{M}\Big(xg_{TT}D_1+\frac{M_h}{M}h_{1TT}\frac{\tilde{E}}{z}\Big)\\ &-\frac{(\hat{\boldsymbol{h}}\cdot\boldsymbol{k}_T)\boldsymbol{p}_T^2-2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)(\boldsymbol{k}_T\cdot\boldsymbol{p}_T)}{2M^2M_h}\Big[\Big(xe_{TT}H_1^\perp-\frac{M_h}{M}f_{1TT}\frac{\tilde{G}^\perp}{z}\Big)\\ &-\Big(xe_{TT}^\perp H_1^\perp-\frac{M_h}{M}g_{1TT}\frac{\tilde{D}^\perp}{z}\Big)\Big]\Big\},\end{aligned}$$

$$\begin{aligned}F_{L(TT)}^{\sin(3\phi_h-2\phi_{TT})} &= \frac{2M}{Q}\mathcal{C}\Big\{-\frac{3(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)\big(2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2-\boldsymbol{p}_T^2\big)}{2M^3}\Big(xg_{TT}^\perp D_1+\frac{M_h}{M}h_{1TT}^\perp\frac{\tilde{E}}{z}\Big)\\ &+\frac{4(\boldsymbol{h}\cdot\boldsymbol{k}_T)(\boldsymbol{h}\cdot\boldsymbol{p}_T)^2-2(\boldsymbol{h}\cdot\boldsymbol{p}_T)(\boldsymbol{k}_T\cdot\boldsymbol{p}_T)-(\boldsymbol{h}\cdot\boldsymbol{k}_T)\boldsymbol{p}_T^2}{2M^2M_h}\\ &\times\Big[\Big(xe_{TT}H_1^\perp+\frac{M_h}{M}f_{1TT}\frac{\tilde{G}^\perp}{z}\Big)+\Big(xe_{TT}^\perp H_1^\perp+\frac{M_h}{M}g_{1TT}\frac{\tilde{D}^\perp}{z}\Big)\Big]\Big\},\end{aligned}$$

$$F_{L(TT)}^{\sin(2\phi_h-2\phi_{TT})} = \mathcal{C}\Big[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2-\boldsymbol{p}_T^2}{M^2}g_{1TT}D_1\Big],$$

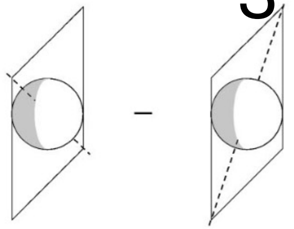
J. Zhao, A. Bacchetta, S. Kumano, T. Liu, Y.-J. Zhuo, arXiv: 2058.06134

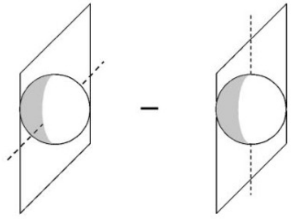
Deuteron Polarization Orientations



A. BACCHETTA AND P. J. MULDERS PHYSICAL REVIEW D **62** 114004

The prospective (tentative) plan with transversely tensor polarized ND_3 target

$S_{TT}^{xy} =$ 

$S_{TT}^{xx} =$ 

$$\frac{d\sigma_{(TT)}(l + d \to l' + h + X)}{dx\,dy\,d\phi_h\,d^2\mathbf{P}_{h\perp}} = \frac{y\alpha^2}{2(1-\epsilon)xQ^2}\left(1 + \frac{\gamma^2}{2x}\right)$$

$$\times \left[\underbrace{\left(\boxed{F_{U(TT)}^{\cos(2\phi_h - 2\phi_{TT})}} + F_{U(TT)}^{\cos(\phi_h - 2\phi_{TT})} + F_{U(TT)}^{\cos(3\phi_h - 2\phi_{TT})} + \boxed{F_{U(TT)}^{\cos(2\phi_{TT})}} + F_{U(TT)}^{\cos(4\phi_h - 2\phi_{TT})} \right)}_{\text{with unpolarized lepton beam}} \right.$$

$$\left. + \underbrace{\left(F_{L(TT)}^{\sin(\phi_h - 2\phi_{TT})} + F_{L(TT)}^{\sin(3\phi_h - 2\phi_{TT})} + \boxed{F_{L(TT)}^{\sin(2\phi_h - 2\phi_{TT})}} \right)}_{\text{with longitudinally polarized lepton beam}} \right]$$

The dominant/leading contribution
Will be from this Structure function
Where as the other terms suppressed
By the higher twist and order 1/Mn

$$F_{U(TT),T}^{\cos(2\phi_h - 2\phi_{LT})} = \mathcal{C}\left[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2 - \boldsymbol{p}_T^2}{M^2} f_{1TT} D_1 \right]$$

Tensor-Cahn like quadrupole

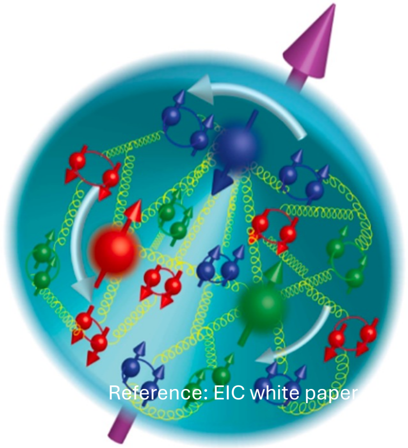
$$F_{U(TT)}^{\cos(2\phi_{TT})} = \mathcal{C}\left[\frac{\boldsymbol{k}_T\cdot\boldsymbol{p}_T}{M M_h} h_{1TT} H_1^{\perp} \right]$$

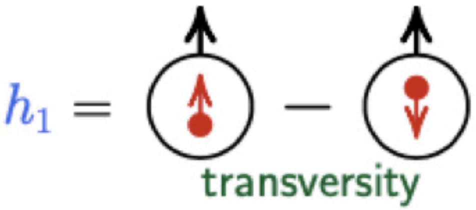
Tensor Transversity

$$F_{L(TT)}^{\sin(2\phi_h - 2\phi_{TT})} = \mathcal{C}\left[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2 - \boldsymbol{p}_T^2}{M^2} g_{1TT} D_1 \right]$$

Worm gear type / helicity counter-part

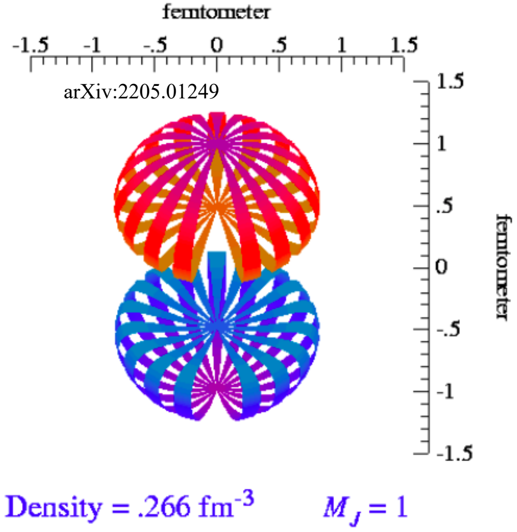
Transversity PDF distributions



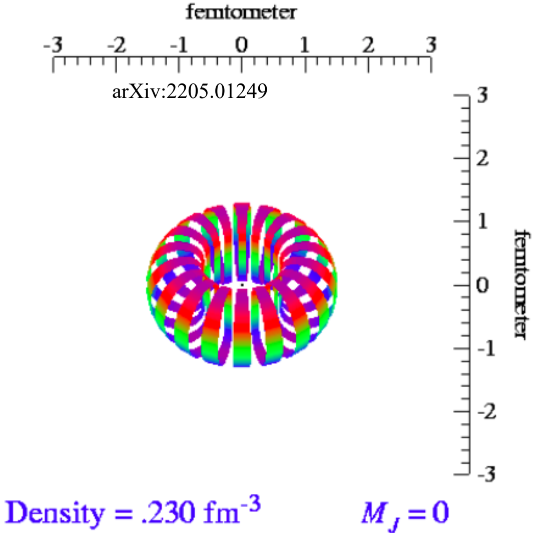


Distribution of transversely polarized quarks (or gluons) in a transversely polarized nucleon.

Sea-quark Transversity in the Deuteron



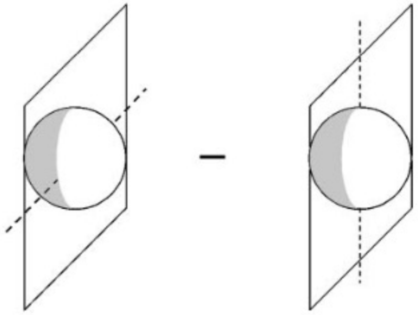
Gluon Transversity in the Deuteron



- The deuteron is the simplest spin-1 system and offers a vast array of observables to explore as we begin to build the composite spin picture of nuclei.
- We proposed the first ever Spin-1 TMD measurements using a polarized deuteron target, including a direct measurement of gluon transversity, while also for the first time measuring the sea-quark transversity distribution of the deuteron/neutron (at FNAL).
- We are going to propose a complementary measurement with SIDIS process at JLab, and a follow up series of experiments as a collaborative effort of this Tensor Collaboration!

Gluon Transversity

$S_{TT}^{xx} =$



$$\frac{2\pi d\sigma\left(lH^{\uparrow} \rightarrow l'hX\right)}{d\phi dx_B dz_h dy}(E_x - E_y) = \frac{2\alpha^2(1-y)}{Q^2 y}\cos(2\phi_h) h_{1TT}^{g}(x_B, Q^2) H_1^{\perp}(z_h)$$

The differential cross-section from the longitudinal tensor polarized contribution is assumed to be negligible compared to the transversely tensor polarized contribution

The generalized experimental gluon transversity asymmetry can then be written as,

$$A_{E_{xy}} = \frac{1}{f P_{zz}} \frac{\sigma^{E_x}_{ed\rightarrow e'\pi X} - \sigma^{E_y}_{ed\rightarrow e'\pi X}}{\sigma^{E_x}_{ed\rightarrow e'\pi X} + \sigma^{E_y}_{ed\rightarrow e'\pi X}},$$

$$\frac{1}{P_{zz}} N^{E_x} = \frac{1}{P'} N^{E_\pm, E_x} - \frac{1}{P} N^{E_\pm}.$$

where P_{zz} is the target ensemble tensor polarization pertaining to the tensor polarized cross-section events N^{E_x}

- There are several ways to build a gluon transversity asymmetry using different quantization axes and polarized target configurations
- σ^{E_x} can be measured with either a purely tensor polarized target or as the difference between a enhanced tensor polarized target and a purely vector polarized target.
- A purely vector polarized target is significantly easier to make compared to a purely tensor polarized target, so this is our preferred method: access to sea-quark transversity as well.

RGH Status

Run Group H

PAC39 2012

Experiment	Contact	Title	Rating	PAC days
C12-11-111	M. Contalbrigo	Transverse spin effect in SIDIS at 11 GeV with a transversely polarized target using CLAS12	A	110
C12-12-009	H. Avakian	Measurement of transversity with di-hadron production in SIDIS with a transversely polarized target	A	110
C12-12-010	L. Elouadrhiri	Deeply Virtual Compton scattering at 11 GeV with transversely polarized target using the CLAS12 detector	A	110

Access to unique observables in

- SIDIS hadron
- SIDIS Di-hadron
- DVCS

All RGH experiments selected among the high impact JLab measurements PAC42 [2014]

RGH experiment status (with HDice) confirmed at PAC48 in 2020 (during jeopardy process) with C1 condition on target performance

RGH status modified to C2 in 2024 (during jeopardy process) to properly evaluate the target change
✓ GEANT simulations ✓ Impact study ✓ Systematics

Gather unprecedented information on

- Transversity
- Tensor charge
- Sivers, $h_{1T}^{\perp}$, $g_{1T}^{\perp}$, $H_1^{\perp}$
- GPD E
- quark OAM

From Marco's slides:
https://www.fe.infn.it/~mcontalb/JLAB12/TALKs/PAC53/rgh_250723.pdf

RGH Status

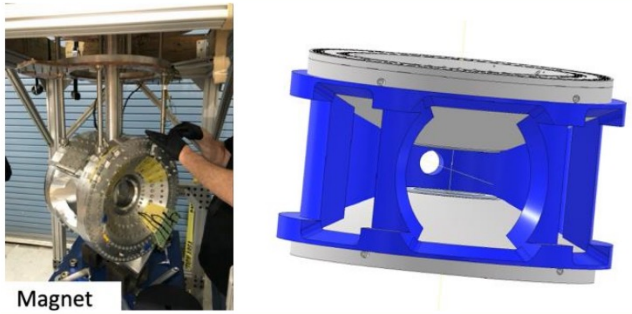
RGH Target & Magnet

Most viable solution to prioritize physics

Consolidated dynamically polarized NH_3 technology

Designed based on already successful realizations

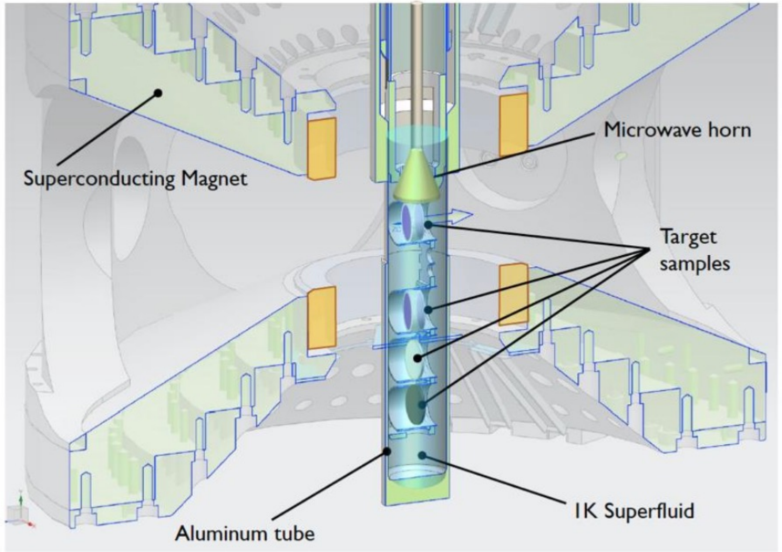
Hall-A G2p-Gep target (replica optimized for HTCC)
Hall-C E12-15-005 magnet (replica optimized for recoil detection)

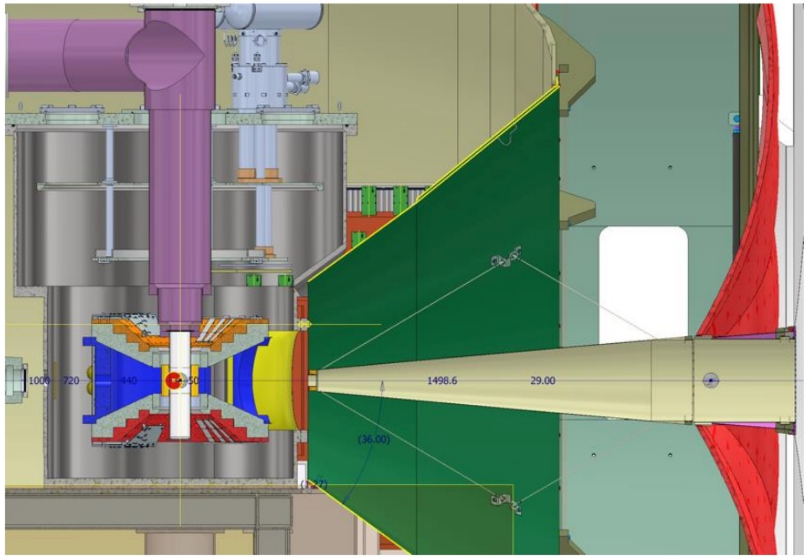


5T dipole acceptance:

$\pm$ 25° vertical

$\pm$ 65° horizontal





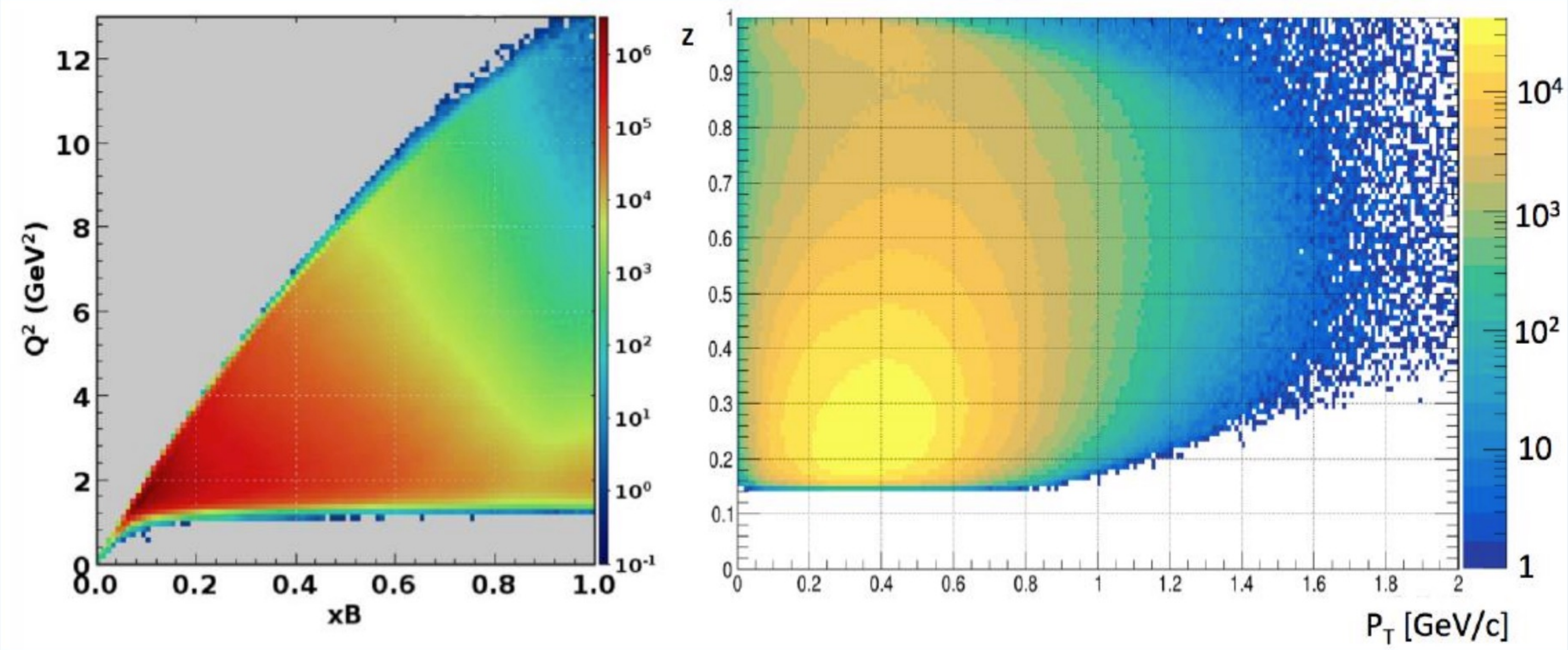
From Marco's slides:
https://www.fe.infn.it/~mcontalb/JLAB12/TALKs/PAC53/rgh_250723.pdf

RGH Status

CLAS12 Kinematic Reach

Features: wide phase space cover, excellent PID and statistics optimized for a multi-D analysis

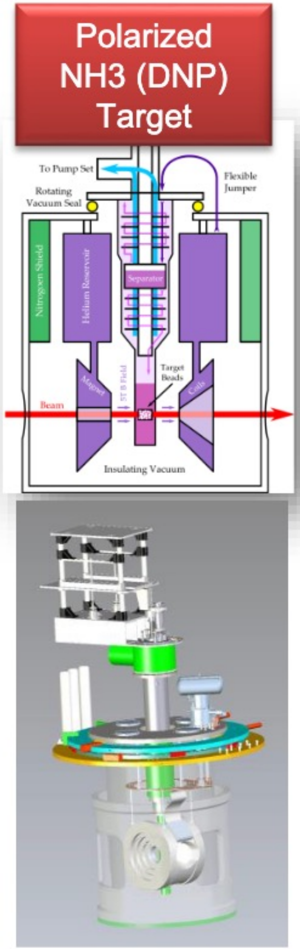
- disentangle kinematical correlations
- verify expected dependences (e.g. in Q^2) and isolate peculiar regimes (e.g. in z)
- study transition regions (e.g. in P_T)

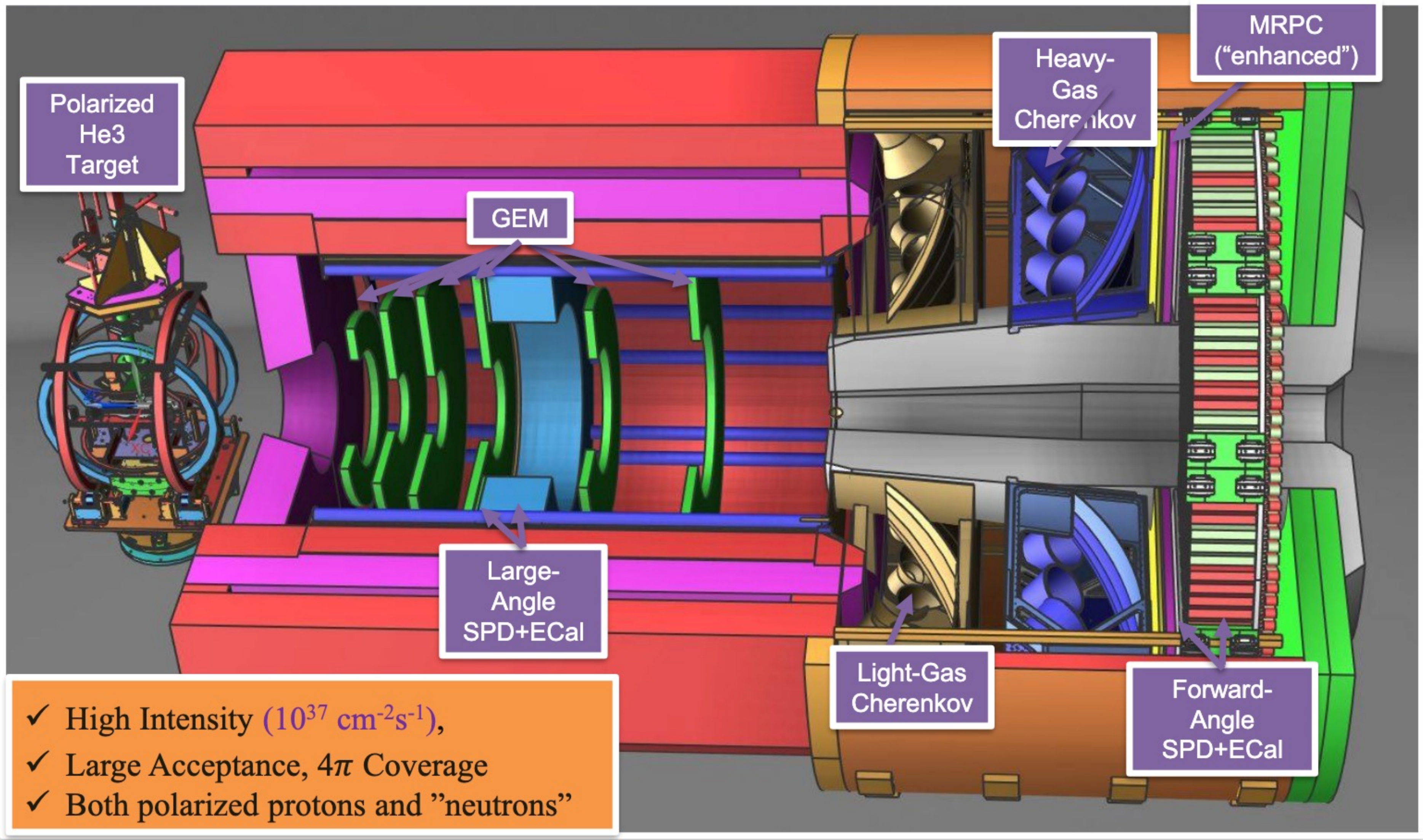


M. Contalbrigo JLab PAC53 Meeting – 23rd July 2025 9

From Marco's slides:
https://www.fe.infn.it/~mcontalb/JLAB12/TALKs/PAC53/rgh_250723.pdf

Prospective Plans with SoLID (Hall A)





- ✓ High Intensity (10^{37} cm^{-2}s^{-1}),
- ✓ Large Acceptance, 4π Coverage
- ✓ Both polarized protons and "neutrons"

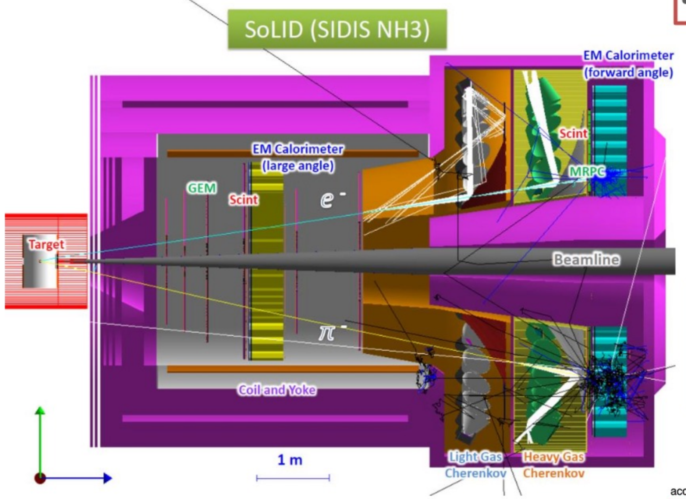
From the slides by Haiyan Gao and Zhiwen Zhao:
https://indico.phy.anl.gov/event/51/sessions/89/#20240619

+ Tensor Polarized ND3

Prospective Plans with SoLID (Hall A)

SoLID SIDIS NH3 Setup

- E12-10-008: SIDIS pion on transversely polarized proton (NH_3), 120 days, **rated A**
- SIDIS kaon and dihadron as run groups



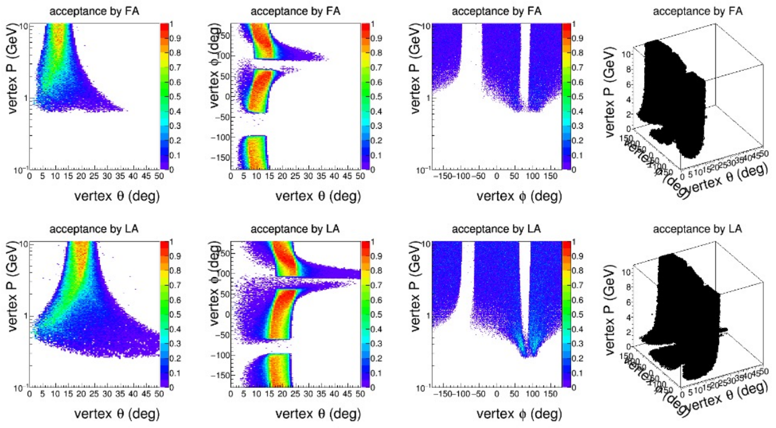
Detection is similar to He3 setup

Coverage is similar to He3 setup except some distortion from the target field

5T transverse target field
High radiation sheet of flame areas need to be cut away or shielded

Polarized lumi ~$1e^{35}$/cm^2/s
Unpolarized lumi ~$6e^{35}$/cm^2/s

e- acceptance shown
π^- acceptance is similar
π^+ acceptance is reversed along phi=0 plane

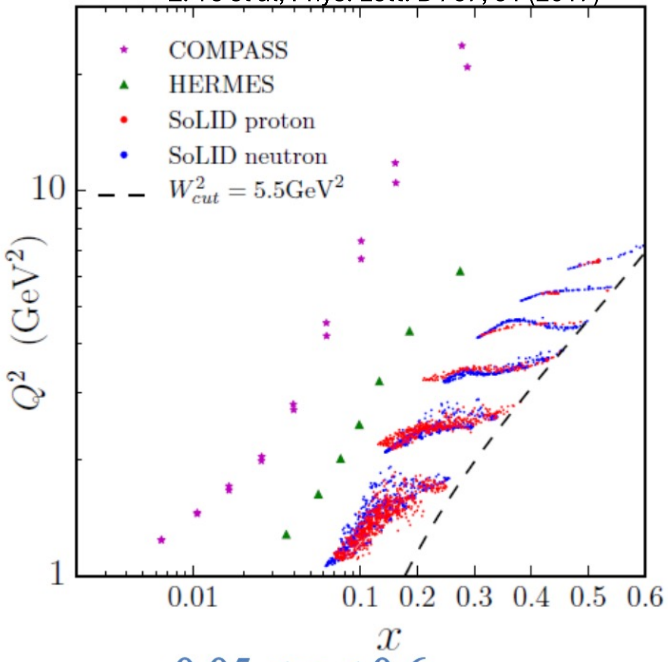


SoLID Jefferson Lab 13

+ ND3 Setup

Kinematic Coverage

Z. Ye et al, Phys. Lett. B 767, 91 (2017)

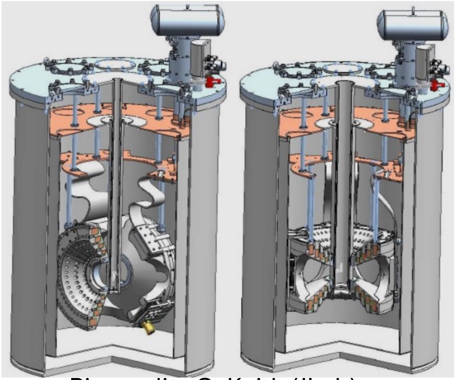


$0.05 < x < 0.6$
$1\text{GeV}^2 < Q^2 < 8\text{GeV}^2$
$0.3 < z < 0.7$
$0 < P_T < 1.6\text{GeV}$

From the slides by Haiyan Gao and Zhiwen Zhao: https://indico.phy.anl.gov/event/51/sessions/89/#20240619

The prospective (tentative) plan with transversely tensor polarized ND_3 target

- Proposals for JLab PAC (2026)



Pic credits C. Keith (JLab)

$$F_{U(TT),T}^{\cos(2\phi_h - 2\phi_{LT})} = \mathcal{C}\left[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2 - \boldsymbol{p}_T^2}{M^2} f_{1TT} D_1 \right]$$

$$F_{L(TT)}^{\sin(2\phi_h - 2\phi_{TT})} = \mathcal{C}\left[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2 - \boldsymbol{p}_T^2}{M^2} g_{1TT} D_1 \right]$$

$$F_{U(TT)}^{\cos(2\phi_{TT})} = \mathcal{C}\left[\frac{\boldsymbol{k}_T\cdot\boldsymbol{p}_T}{M M_h} h_{1TT} H_1^{\perp} \right]$$

Exploring
(needs to be discussed with JLab Target group

First Generation Tensor Experiments

Using lower temps and lower intensity: 1K and 5T

To run sequentially after the data taking for $F_{U,(LL)}$ @ Hall C (see Nathaly's talk)

- Proposals (2027<)

  * An addition to RGH (Hall B) program: Gluon Transversity in SIDIS

  Note: Complementary to the measurement with DY (FNAL)
  [Stage 1 Approval (March 2025) https://pac.fnal.gov/wp-content/uploads/2025/04/PAC_Report_March_2025_Public.pdf

  Needs to be discussed with RGH

  * Hall A (SoLID)

  With high statistics

  Needs to be discussed with SoLID Collaboration

$$F_{U(TT),T}^{\cos(2\phi_h - 2\phi_{LT})} = \mathcal{C}\left[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2 - \boldsymbol{p}_T^2}{M^2} f_{1TT} D_1 \right]$$

$$F_{L(TT)}^{\sin(2\phi_h - 2\phi_{TT})} = \mathcal{C}\left[-\frac{2(\hat{\boldsymbol{h}}\cdot\boldsymbol{p}_T)^2 - \boldsymbol{p}_T^2}{M^2} g_{1TT} D_1 \right]$$

Thank you

This work is supported by DOE contract DE-FG02-96ER40950