Probing Gluon TMDs at EIC

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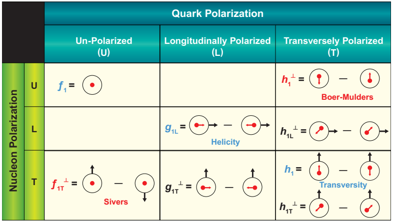
Various types of TMDs



nucleon pol. \ gluon pol.	U	L	linear
U	f_1^g		$h_1^{\perp g}$
L		g_{1L}^g	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	g_{1T}^g	$h_1^g,\ h_{1T}^{\perp g}$

- Probe unpolarized TMDs via *h* and *hh*.
- From spin-asymmetries, we can study spin-dependent TMDs such as the Sivers function $f_{1T}^{\perp}$.

A Tale of Two Gluon Distributions

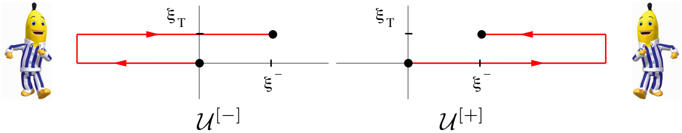
In terms of operators (TMD def. [Bomhof, Mulders and Pijlman, 06]), two gauge invariant gluon definitions: [Dominguez, Marquet, Xiao and Yuan, 11]

I. Weizsäcker Williams gluon distribution:

$$xG_{\mathrm{WW}}(x,k_\perp) = 2\int \frac{d\xi^- d\xi_\perp}{(2\pi)^3 P^+} e^{ixP^+\xi^- - ik_\perp\cdot\xi_\perp} \mathrm{Tr}\langle P|F^{+i}(\xi^-,\xi_\perp)\mathcal{U}^{[+]\dagger}F^{+i}(0)\mathcal{U}^{[+]}|P\rangle.$$

II. Color Dipole gluon distributions:

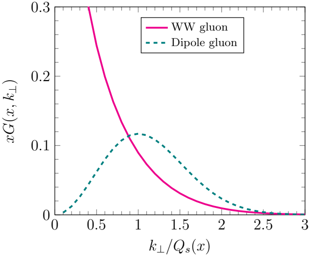
$$xG_{\mathrm{DP}}(x,k_\perp) = 2\int \frac{d\xi^- d\xi_\perp}{(2\pi)^3 P^+} e^{ixP^+\xi^- - ik_\perp\cdot\xi_\perp} \mathrm{Tr}\langle P|F^{+i}(\xi^-,\xi_\perp)\mathcal{U}^{[-]\dagger}F^{+i}(0)\mathcal{U}^{[+]}|P\rangle.$$



- The WW gluon distribution is the conventional gluon distributions.
- The dipole gluon distribution has no such interpretation.
- Two topologically different gauge invariant definitions.
- Same after integrating over $k_\perp$;

A Tale of Two Gluon Distributions

Measuring the gluon distributions in various processes I. Weizs*ä*cker Williams gluon distribution; II. Color Dipole gluon distributions.



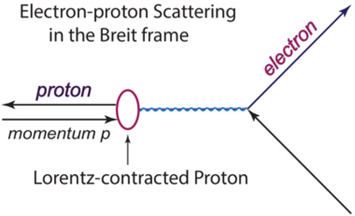
- Modified Universality for Gluon Distributions:

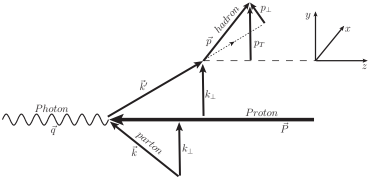
	Inclusive	Single Inc	DIS dijet	γ +jet	dijet in pA
$xG_{\rm WW}$	$\times$	$\times$	$\surd$	$\times$	$\surd$
$xG_{\rm DP}$	$\surd$	$\surd$	$\times$	$\surd$	$\surd$

$\times \Rightarrow$ Do Not Appear. $\surd \Rightarrow$ Apppear.

Semi-Inclusive DIS

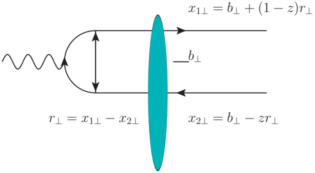
Study unpolarized quark TMDs in the Breit frame ('brick wall' frame) in SIDIS

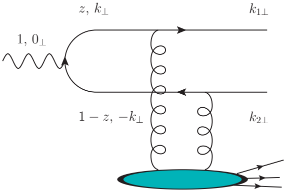


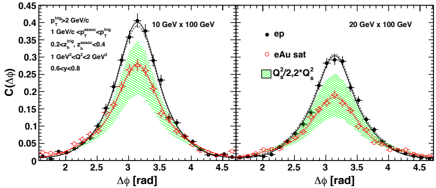


- In the Breit frame $q^\mu = (0,0,0,-Q)$, $k = (k_0, k_\perp, k_3 = Q/2)$, $z_h \equiv \frac{p\cdot P}{q\cdot P}$.
- We need to measure the recoiled electron to reconstruct the incoming virtual momentum.

Dijet production in DIS

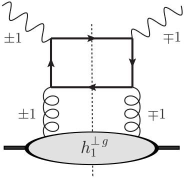


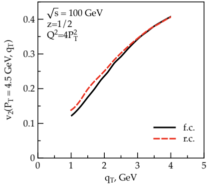




- Back-to-back correlation measurement $C(\Delta\phi)$: [Zheng, Aschenauer, Lee and BX, 14] Unique golden measurement for the Weizsäcker Williams gluon distributions.
- EIC will be a perfect machine to study gluon saturation inside protons/nuclei.

Linearly Polarized Gluon distribution





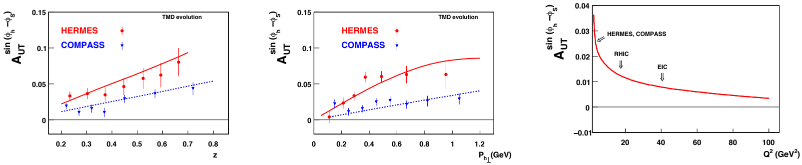
$$\frac{d\sigma}{dy_1\, dy_2\, dy\, dx_{\scriptscriptstyle B}\, d^2\boldsymbol{q}_{\scriptscriptstyle T} d^2\boldsymbol{K}_\perp} = \delta(1-z_1-z_2) \times \frac{\alpha^2\alpha_s}{\pi s M_\perp^2}\,\frac{(1+yx_{\scriptscriptstyle B})}{y^5 x_{\scriptscriptstyle B}}\left[A + \frac{\boldsymbol{q}_{\scriptscriptstyle T}^2}{M^2}\, B\, \cos 2(\phi_{\scriptscriptstyle T}-\phi_\perp)\right].$$

$$B^{eh\to eQ\bar{Q}X} = \sum_Q e_Q^2\, h_1^{\perp\, g}(x, \boldsymbol{q}_{\scriptscriptstyle T}^2)\mathcal{B}^{eg\to eQ\bar{Q}}\,,$$

- [Boer, Brodsky, Mulders, Pisano, 11; Metz, Zhou, 11]
  Probing the Linearly Polarized Gluon distribution $h_1^{\perp g}(x, q_\perp^2)$ at EIC.
- Due to linearly polarized gluon distribution, there could be the analog of elliptic flow v_2 in DIS as well. [Dumitru, Lappi, Skokov, 15]

Transverse single spin asymmetry (SSA) in SIDIS

Extracting the quark Sivers function via SSA in SIDIS



- [Aybat, Prokudin and Rogers, 12] indicates a couple of percent of SSA at EIC.
- SSA in SIDIS as a probe to the quark Sivers function $f_{1T}^{\perp}$

$$A_{UT}^{\sin(\phi_h-\phi_S)} = \frac{\int d\phi_h d\phi_s 2\sin(\phi_h-\phi_S)(\sigma(\phi_h,\phi_S)-\sigma(\phi_h,\phi_S+\pi))}{\int d\phi_h d\phi_S(\sigma(\phi_h,\phi_S)+\sigma(\phi_h,\phi_S+\pi))}.$$

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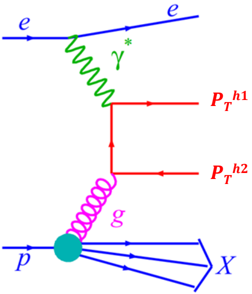

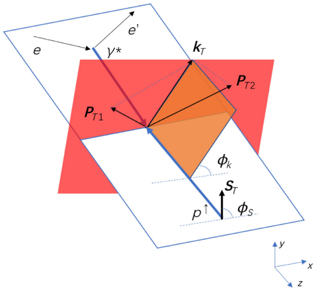

- [BX, Diehl, 12; Zheng, Aschenauer, Lee, Xiao, Yin, 18] indicates a couple of percent of SSA at EIC.
- SSA in this process as a probe to the gluon Sivers function $f_{1T}^{\perp}$

$$A_{UT}(\phi_{kS}, k_T) = \frac{d\sigma^\uparrow(\phi_{kS}, k_T) - d\sigma^\downarrow(\phi_{kS}, k_T)}{d\sigma^\uparrow(\phi_{kS}, k_T) + d\sigma^\downarrow(\phi_{kS}, k_T)} \propto \frac{\Delta^N f_{g/p^\uparrow}(x, k_\perp)}{2 f_{g/p}(x, k_\perp)},$$

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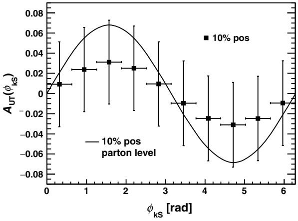

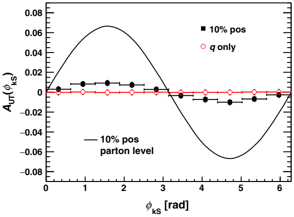

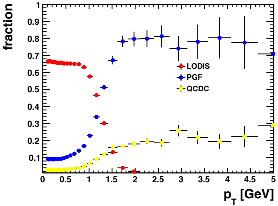

$$f_{1T}^{\perp g} = -\frac{2\sigma M_p}{k_\perp^2 + \sigma^2} f_g(x, k_\perp), \qquad \sigma = 0.8 \text{ GeV},$$