# Accessing the gluon Wigner distribution in nuclear targets

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Y. Hagiwara, Y. Hatta, R. Pasechnik, M. Tasevsky , O. Teryaev, Phys. Rev. D96 (2017) 034009 arXiv:1706.01765

#### Nucleon tomography: phase space distributions



#### Nucleon 5D tomography: the "mother distribution"

✓ 5D tomography: <u>Generalised TMD (GTMD)</u>

<u>Husimi distribution</u>

Wigner distribution

Wigner'1932

Meissner, Metz, Schlegel (2009)...

Y. Hagiwara, Y. Hatta (2015)...

Belitsky, Ji, Yuan (2004); Ji (2003); Lorce, Pasquini (2011); Y. Hatta (2011)...

**Example: leading-twist quark Wigner distribution** 

+ many more studies...

$$W(x,\vec{k}_{\perp},\vec{b}_{\perp}) = \int \frac{d^{2}\Delta_{\perp}}{(2\pi)^{2}} e^{i\vec{b}_{\perp}\cdot\vec{\Delta}_{\perp}} \int \frac{dz^{-}d^{2}z_{\perp}}{16\pi^{3}} e^{ixP^{+}z^{-}-i\vec{k}_{\perp}\cdot\vec{z}_{\perp}} \langle P - \frac{\Delta}{2} |\bar{q}(-z/2)\gamma^{+}q(z/2)|P + \frac{\Delta}{2} \rangle$$





Non-trivial correlation between the transverse momentum and the impact parameter due to <u>orbital angular momentum!</u>



Spin decomposition of the nucleon:

$$\frac{1}{2}\Delta\Sigma + \Delta G + L^q + L^g \equiv \frac{1}{2}$$

$$L = \int dx d^2 b_{\perp} d^2 k_{\perp} \, (\vec{b}_{\perp} \times \vec{k}_{\perp})_z \cdot W(x, \vec{k}_{\perp}, \vec{b}_{\perp})$$

canonical orbital angular momentum

Wigner/GTMD distributions provide the most complete information on partonic "image" of the nucleon!

#### The gluon Wigner distribution at small x: dipole picture

From quark to gluon:  $\bar{\Psi}(\vec{r}-\xi/2)\Gamma\Psi(\vec{r}+\xi/2) \rightarrow F^{+\nu}(\vec{r}-\xi/2)F_{\nu}^{+}(\vec{r}+\xi/2)$ 

$$U_{+}$$

$$U_{+}$$

$$U_{+}$$

$$U_{-}$$

$$U_{-}$$

$$U[z_{1}^{+}, z_{2}^{+}; \vec{z}_{\perp}] \equiv \mathcal{P} \exp\left(ig \int_{z_{1}^{+}}^{z_{2}^{+}} dz^{+} \hat{A}^{-}(z^{+}, \vec{z}_{\perp})\right)$$

 $x \ll 1$   $e^{-ixP^-z^+} \approx 1$ 

Y. Hatta, B. W. Xiao, F. Yuan, PRL 116, 202301 (2016)

$$\begin{aligned} xW_g(x,\mathbf{k},\mathbf{b}_{\perp}) &= \frac{2N_c}{\alpha_S} \int \frac{d^2\mathbf{r}}{(2\pi)^2} e^{i\mathbf{k}\cdot\mathbf{r}} \left(\frac{1}{4}\nabla^2_{\mathbf{b}_{\perp}} - \nabla^2_{\mathbf{r}}\right) S_Y(\mathbf{r},\mathbf{b}_{\perp}) \qquad Y = \ln\frac{1}{x} \end{aligned}$$

$$\begin{aligned} \mathbf{Dipole S-matrix:} \quad S_Y(\vec{q}_{\perp},\vec{\Delta}_{\perp}) &= \int \frac{d^2\vec{r}_{\perp}d^2\vec{b}_{\perp}}{(2\pi)^4} e^{i\vec{\Delta}_{\perp}\cdot\vec{b}_{\perp} + i\vec{q}_{\perp}\cdot\vec{r}_{\perp}} \left\langle\frac{1}{N_c} \operatorname{Tr} U\left(\vec{b}_{\perp} + \frac{\vec{r}_{\perp}}{2}\right) U^{\dagger}\left(\vec{b}_{\perp} - \frac{\vec{r}_{\perp}}{2}\right) \right\rangle_Y \end{aligned}$$

#### Nucleon tomography: relevant processes

Combination of TMD and GPD provide a deep 3D picture of the quark and gluon content of the nucleon



Review: e.g. N. Stefanis et al. arXiv: 1612.03077

γ\*(Q²)

**X+**ξ

**Deeply-Virtual Compton Scattering** 





What about accessing the 5D Wigner/GTMD distributions?

#### **Gluon Wigner from diffractive DIS processes**



#### **Elliptic Wigner distribution and dipole orientation**



angular correlation in DVCS etc

#### Accessing the gluon Wigner from exclusive dijets in UPC



#### **Photon-target cross section:**

$$\frac{d\sigma^{p\gamma}}{dy_1 dy_2 d^2 \vec{k}_{1\perp} d^2 \vec{k}_{2\perp}} = N_c \alpha_{em} (2\pi)^2 q^+ \delta(k_1^+ + k_2^+ - q^+) \sum_f e_f^2 2z (1-z)(z^2 + (1-z)^2) |\vec{M}|^2 \qquad z = \frac{k_{1\perp} e^{y_1}}{k_{1\perp} e^{y_1} + k_{2\perp} e^{y_2}} dz$$

Nucleus-target cross section:  

$$\frac{d\sigma^{pA}}{dy_1 dy_2 d^2 \vec{k}_{1\perp} d^2 \vec{k}_{2\perp}} \approx \omega \frac{dN}{d\omega} \frac{2(2\pi)^4 N_c \alpha_{em}}{P_{\perp}^2} \sum_f e_f^2 z (1-z)(z^2 + (1-z)^2) (A^2 + 2\cos 2(\phi_P - \phi_\Delta) AB)$$
Separate measurements

$$S_{0}(P_{\perp}, \Delta_{\perp}) = -\frac{1}{P_{\perp}} \frac{\partial}{\partial P_{\perp}} A(P_{\perp}, \Delta_{\perp})$$

$$\tilde{S}(P_{\perp}, \Delta_{\perp}) = -\frac{\partial B(P_{\perp}, \Delta_{\perp})}{\partial P_{\perp}^{2}} + \frac{2}{P_{\perp}^{2}} \int_{0}^{P_{\perp}^{2}} \frac{dP_{\perp}^{\prime 2}}{P_{\perp}^{\prime 2}} B(P_{\perp}^{\prime}, \Delta_{\perp})$$
Separate measurements  
of A and B  
full information  
about the gluon Wigner!

#### **CGC results: BK vs MV**



### Conclusions

- Quasi-probability (quark and gluon) Wigner distributions represent
   5D snapshot of the hadronic structure and contain full information about
   it equivalent to knowing the exact wave functions of partons in the nucleon.
- The elliptic gluon Wigner distribution contains an important info on azimuthal angle correlation due to dipole orientation effects and is responsible e.g. for the elliptic flow and angular correction in exclusive dijet production.
- One of the most promising ways to access the gluon Wigner distribution is by measuring the differential cross section of exclusive dijet production in ultraperipheral pA/AA collisions. A dedicated analysis for a given experiment is necessary.