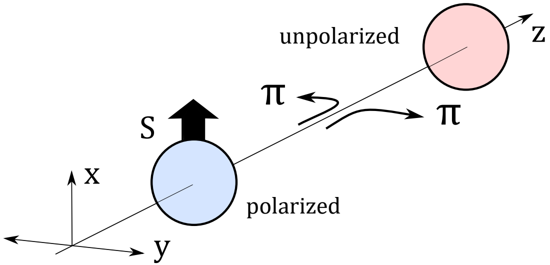
Single spin asymmetries in ultra peripheral pA collisions

Sanjin Benić (YITP)

SB, Hatta, in preparation

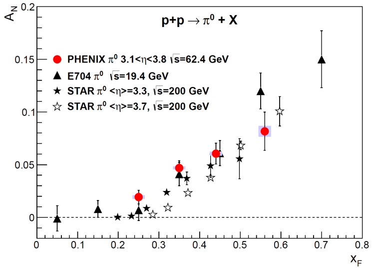
YKIS2018b, Kyoto, June 11, 2018

Single spin asymmetry 1/2



$$A_N = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

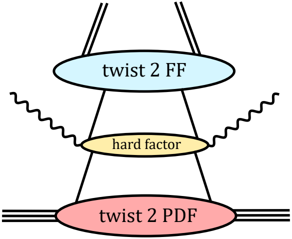
$$x_F = \frac{2P_h^3}{\sqrt{s}}$$



PHENIX, Phys. Rev. D **90**, no. 1, 012006 (2014)

SSA 2/2

- twist-3 observable



SSA 2/2

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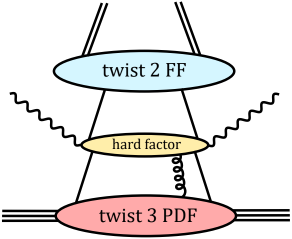
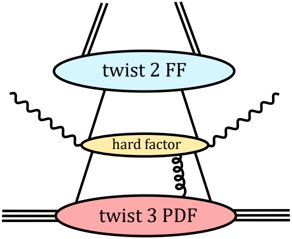
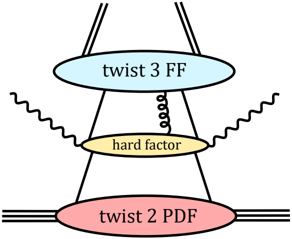


- initial (Qiu-Sterman)

SSA 2/2

- twist-3 observable

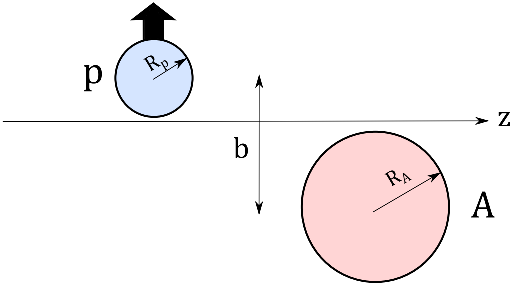




- initial (Qiu-Sterman) vs final (Collins)

- fragmentantion contribution dominates?
  Gamberg, Kang, Pitonyak, Prokudin, Phys. Lett. B **770**, 242 (2017)

Ultra-peripheral collisions



- RHIC already measures $p^{\uparrow}A$ collisions!
- a new channel for SSA
- Z^2 cross section enhancement
- cleaner than $pp^{\uparrow}$, simpler than $ep^{\uparrow}$

From SIDIS to UPC

- $q^2 = -Q^2 \to 0$
- $\frac{e^2}{q^4} L_{\mu\nu} \to -g_{\perp\mu\nu}$
- $d\sigma_{pA} = \int_0^\infty d\omega \frac{dN}{d\omega} d\sigma$
- photon flux

$$\frac{dN}{d\omega} = \frac{2Z^2\alpha_{em}}{\pi\omega}\left[\xi K_0(\xi)K_1(\xi) - \frac{\xi^2}{2}(K_1^2(\xi) - K_0^2(\xi))\right]$$

$\xi = \omega\frac{R_p + R_A}{\gamma}$

Cross sections

- unpolarized

  Meng, Olness, Soper, Nucl. Phys. B **371**, 79 (1992)

- polarized

1. twist-3 quark-gluon

   Eguchi, Koike, Tanaka, Nucl. Phys. B **763**, 198 (2007)

$$d\Delta\sigma \sim \left[x\frac{dG_F(x,x)}{dx} - G_F(x,x)\right]\Delta\hat{\sigma}_1 + G_F(0,x)\Delta\hat{\sigma}_2 + \tilde{G}_F(0,x)\Delta\hat{\sigma}_3$$

2. twist-3 gluon

   Beppu, Koike, Tanaka, Yoshida, Phys. Rev. D **82**, 054005 (2010)

$$d\Delta\sigma \sim \left[\delta_a\left(\frac{dO(x)}{dx} - O(x)\right) + \frac{dN(x)}{dx} - N(x)\right]\Delta\hat{\sigma}_g$$

3. twist-3 fragmentation

   Kanazawa, Koike, Phys. Rev. D **88**, 074022 (2013)

Twist-3 frag. contribution 1/3

$$\frac{d\Delta\sigma_{\text{frag}}}{d^2P_{h\perp}dy_h} = \frac{\alpha_{\text{em}}\alpha_s}{2\hat{s}}\frac{8}{z_f}M_N \sin\Phi_s \sum_{k=1,2}\tilde{\mathcal{A}}_k \int_{x_{\min}}^1 \frac{dx}{x}\int_{z_{\min}}^1 \frac{dz}{z}\delta\left(q_T^2 + x\left(1-\frac{1}{\hat{z}}\right)\hat{s}\right)$$
$$\times \sum_a e_a^2 h_1^a(x)\left[\frac{\hat{e}_1^a(z)}{z}\Delta\hat{\sigma}_k^1 + \frac{d}{d(1/z)}\left(\frac{\text{Im}\tilde{e}^a(z)}{z}\right)\Delta\hat{\sigma}_k^2 + \text{Im}\tilde{e}^a(z)\Delta\hat{\sigma}_k^3\right.$$
$$\left. - 2\int_z^\infty \frac{dz'}{z'^2}\frac{\text{Im}\hat{E}_F^a(z',z)}{1/z-1/z'}\Delta\hat{\sigma}_k^4\right]$$

- $h_1^a(x)$ transversity
- $\text{Im}\tilde{e}^a(z)$ (Collins)
- $\text{Im}\hat{E}_F^a(z',z) \sim \langle 0|\psi|P_h,X\rangle\langle P_h,X|\bar{\psi}F^{\alpha\beta}|0\rangle$

SB, Hatta, in preparation

Twist-3 frag. contribution 2/3

- equation of motion relation (EOMR)

$$\hat{e}_{\bar{1}}^{a}(z) = z\mathrm{Im}\tilde{e}^{a}(z) + z\int_{z}^{\infty}\frac{dz'}{z'^{2}}\frac{\mathrm{Im}\hat{E}_{F}^{a}(z',z)}{\frac{1}{z'}-\frac{1}{z}}$$

- Lorentz invariance relation (LIR)

$$\hat{e}_{\bar{1}}^{a}(z) = \frac{1}{2}\frac{d}{d(1/z)}\left(\frac{\mathrm{Im}\tilde{e}^{a}(z)}{z}\right) + \frac{1}{z}\int_{z}^{\infty}\frac{dz'}{z'^{2}}\frac{\mathrm{Im}\hat{E}_{F}^{a}(z',z)}{\left(\frac{1}{z}-\frac{1}{z'}\right)^{2}}$$

Kanazawa, Koike, Metz, Pitonyak, Schlegel, Phys. Rev. D **93**, no. 5, 054024 (2016)

Twist-3 frag. contribution 3/3

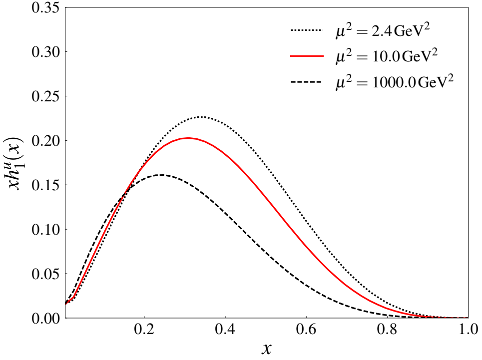
$$\frac{d\Delta\sigma_{\text{frag}}}{d^2P_{h\perp}dy_h} = \frac{\alpha_{em}\alpha_s}{2\hat{s}}\frac{16}{z_f}M_N \sin\Phi_s \int_{x_{\min}}^1 \frac{dx}{x}\int_{z_{\min}}^1 \frac{dz}{z}\delta\left(q_T^2 + x\left(1-\frac{1}{\hat{z}}\right)\hat{s}\right)$$
$$\times \sum_a e_a^2 h_1^a(x)\left[\frac{\hat{e}_{\bar{1}}^a(z)}{z}\Delta\hat{\sigma}_1 + \frac{d}{d(1/z)}\left(\frac{\text{Im}\tilde{e}^a(z)}{z}\right)\Delta\hat{\sigma}_2\right]$$

- integrals over z' completely eliminated (NOT possible in SIDIS!)
- $k = 2$ contribution vanishes

SB, Hatta, in preparation

Calculation scheme

- extraction of $h_1(x)$ and $\mathrm{Im}\tilde{e}(z)$
- Wilczek-Wandzura approximation: $\hat{e}_{\bar{1}}(z) = z\mathrm{Im}\tilde{e}(z)$



Kang, Prokudin, Sun, Yuan, Phys. Rev. D **93**, no. 1, 014009 (2016)

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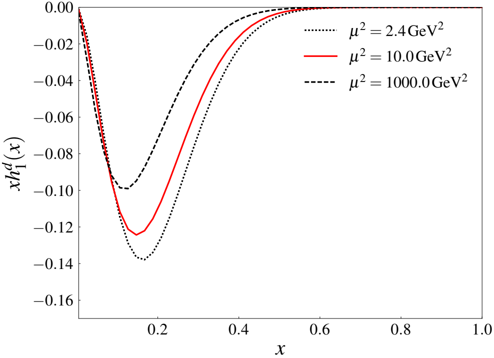

Kang, Prokudin, Sun, Yuan, Phys. Rev. D **93**, no. 1, 014009 (2016)

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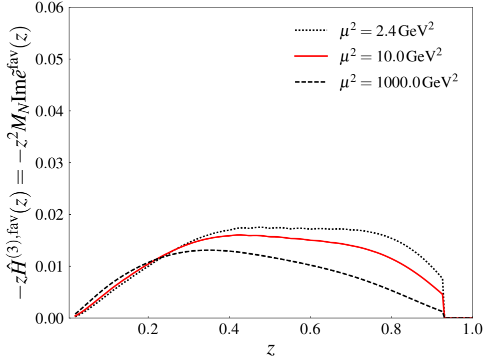

Kang, Prokudin, Sun, Yuan, Phys. Rev. D **93**, no. 1, 014009 (2016)

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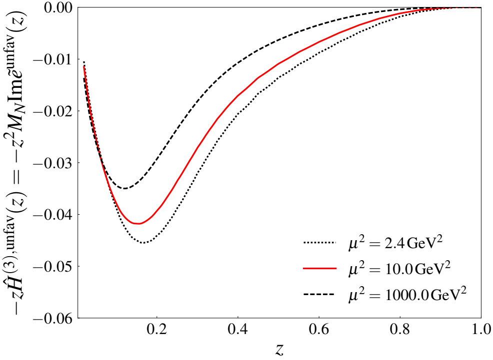
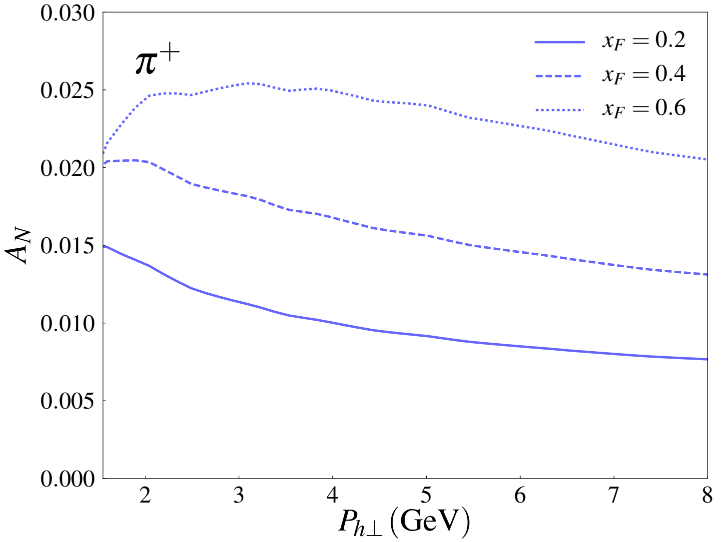


Kang, Prokudin, Sun, Yuan, Phys. Rev. D **93**, no. 1, 014009 (2016)

Results: A_N vs. $P_{h\perp}$



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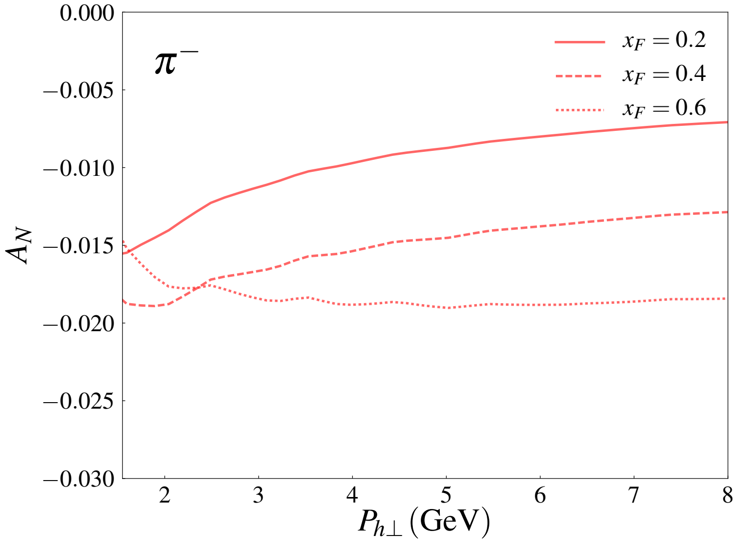

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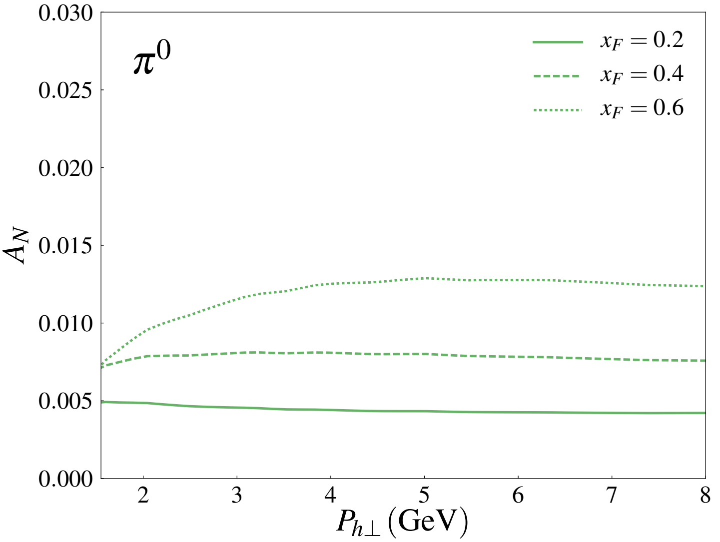
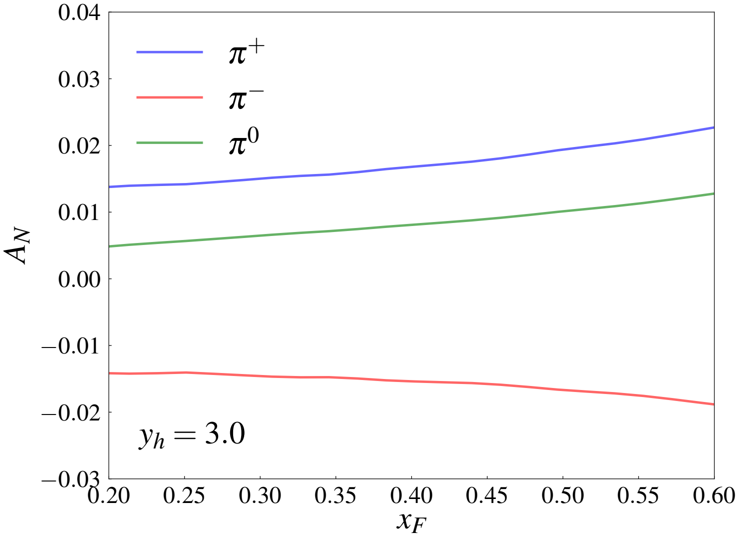
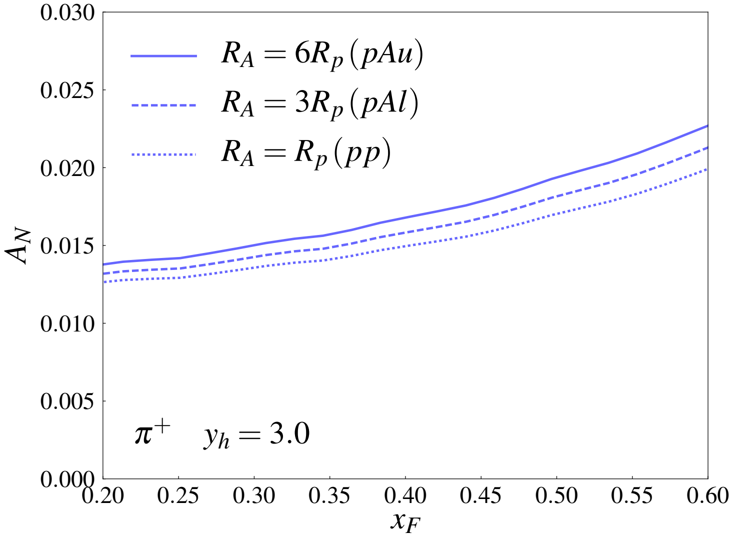


Results: A_N vs. x_F



Results: nuclear dependence



Conclusions

- SSA in UPC as a new probe of the polarized proton
- numerical calculation of the FF contribution

  does the FF contribution dominate?
- A_N of the order of a few percent
- very small nuclear dependence