Transverse Single Spin Asymmetry of Open Heavy Flavor Electrons in 200 GeV p↑+p Collisions at Midrapidity at PHENIX

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Spin-Momentum Correlations in Hadrons

We know that valence quarks do not carry all of the proton spin...

How is spin of quarks and gluons correlated with proton spin?

How is orbital motion of quarks and gluons correlated with proton spin?

Table of TMD PDFs

nucleon (N)
unpolarized quark (Q)
nucleon spin
quark spin
quark k_T

N \ Q	U	L	T
U	f_1 number density		$h_1^\perp$ Boer-Mulders
L		g_1 helicity	$h_{1L}^\perp$ worm-gear
T	$f_{1T}^\perp$ Sivers	$g_{1T}^\perp$ worm-gear	h_1 transversity, $h_{1T}^\perp$ pretzelosity

Transverse Single Spin Asymmetries (TSSAs)

Measured to be large despite pQCD predictions of <1%[1]

- Implies nonpertubative spin-momentum and spin-spin correlations in hadrons!
- Two theoretical frameworks for describing observed TSSAs...

Higher Twist Effects

- Collinear, so only need one hard scale (Q)
- Need higher twist

Transverse Momentum Dependent Functions (TMDs)

- Explicit dependence on transverse momentum of partons within the proton
- Need access to both a hard and soft scale with sufficient scale separation

$$A_N = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$

Considering open heavy flavor production -- dominated by gg fusion at 200 GeV midrapidity

$$A_N \propto \sum_{abc} \phi_{a/A}^{(3)}(x_1, x_2, \vec{s}_\perp) \otimes \phi_{b/B}(x') \otimes \hat{\sigma} \otimes D_{c\to C}(z) + \quad (2)$$

gluon transversity distribution = 0

$$\sum_{abc} \delta q_{a/A}(x, \vec{s}_\perp) \otimes \phi_{b/B}^{(3)}(x_1', x_2') \otimes \hat{\sigma}' \otimes D_{c\to C}(z) + \quad (4)$$

$$\sum_{abc} \delta q_{a/A}(x, \vec{s}_\perp) \otimes \phi_{b/B}(x') \otimes \hat{\sigma}'' \otimes D_{c\to C}^{(3)}(z_1, z_2). \quad (3)$$

ggg correlator not well constrained from previous measurements

Electron Detection at PHENIX

Acceptance: $\Delta\phi = 0.5\pi$ per arm, $|\eta| < 0.35$

Tracking: drift chamber (DC), pad chambers (PCs), and VTX

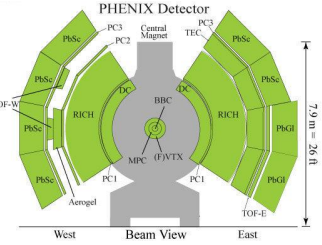
Energy: EMCal measures energy deposits

PID: RICH Cherenkov threshold of $\gamma = 35$
- e/π separation (20 MeV/c , 5 GeV/c)

Conversion Veto: Hit pattern measured by VTX

Luminosity: Measured by the beam beam counter (BBC)

Polarization: Measured by RHIC polarimeters



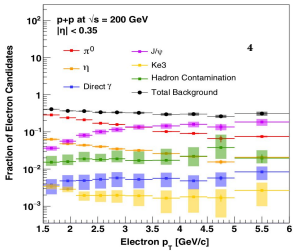
TSSA Observable: Relative luminosity formula, integrate over the φ ranges of individual arms

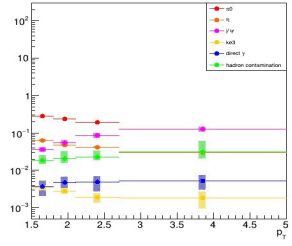
$$A_N = \frac{1}{\langle|\cos\phi|\rangle} \frac{1}{P} \frac{N_L^\uparrow - R \cdot N_L^\downarrow}{N_L^\uparrow + R \cdot N_L^\downarrow} \quad \text{where } R = \frac{\mathcal{L}^\uparrow}{\mathcal{L}^\downarrow}$$

Background Correction

- charged hadrons -- E/p and RICH information
- electrons from other sources -- electron cocktail method
  - **photonic electrons:** π^0, η, γ
  - **nonphotonic electrons:** J/ψ, Ke3 (Ke3 contribution is negligible and ignored)
  - Note: Open heavy flavor electrons (signal) are nonphotonic

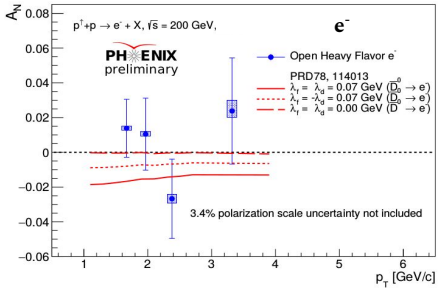
$$A_N^{OHF\to e} = \frac{A_N^e - f_{h^\pm} A_N^{h^\pm} - f_{J/\psi\to e} A_N^{J/\psi\to e}}{1 - f_{h^\pm} - f_{J/\psi\to e} - f_{\pi^0\to e} - f_{\eta\to e} - f_{\gamma\to e}}$$

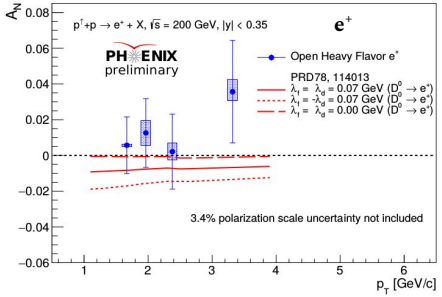




Results

- Most precise measurement of open heavy flavor and nonphotonic electron TSSA at midrapidity
  - Consistent with zero in all cases





- Open heavy flavor results plotted alongside $D^0 \to e^{+/-}$ -- $A_N(p^\uparrow + p \to D^0 + X)$ calculations taken from PRD78, 114013
  - Ordering of curves is different for e^+ and e^- → sensitivity to constrain λ parameters
- λ parameters correspond to normalizations of trigluon correlators with respect to the unpolarized gluon PDF[3]

References

1. G. L. Kane, J. Pumplin, and W. Repko - PRL 41, 1689 (1978)
2. PHENIX Collaboration - PRD98, 012006 (2018)
3. Kang, Qiu, Vogelsang, Yuan - PRD78, 114013 (2008)
4. PHENIX Collaboration - PRD99 092003 (2019)
5. PHENIX Collaboration - PRD86 099904 (2012)