Investigating the transverse single spin asymmetry in the inelastic J/Ψ photoproduction in $p^\uparrow p$ and $p^\uparrow A$ collisions

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In this paper we propose to investigate the transverse single spin asymmetry in the inelastic J/Ψ photoproduction in $p^\uparrow p$ and $p^\uparrow A$ collisions at RHIC energies. At leading order this process probes the gluon Sivvers function. We predict large values for the cross sections, which indicates that its experimental analysis is, in principle, feasible. The rapidity dependence of the single spin asymmetry is presented. We obtain that the asymmetry is strongly dependent on the model used for the gluon Sivvers function and that it can be probed by the analysis of the J/Ψ production at forward rapidities. Our results indicate that a future experimental analysis of this process can be useful to constrain the gluon Sivvers function.

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I. INTRODUCTION

The study of high energy processes involving polarized hadrons allows to improve our understanding of the polarized quark and gluon structure of the hadrons and the QCD dynamics at a high-energy scale (See e.g. Refs. [1,2]). In particular, the analysis of the transverse spin phenomena in hard processes is expected to provide a three-dimensional picture of the partons inside the nucleon. One of the current challenges in hadronic physics is the understanding of the large transverse single-spin asymmetries (SSAs), which have been observed in several experiments [3–10]. A possible explanation for the presence of this asymmetry was proposed many years ago [11] and is known as Sivvers effect, which considers the correlation between the transverse momentum of partons and the polarization vector of the nucleon. In recent years there has been significant progress in both experimental and theory toward understanding the origin of the SSAs (See e.g. [12]). In particular, the experimental data released by the HERMES, COMPASS, Jefferson Lab, PHENIX and STAR Collaborations has allowed the extraction of the Sivvers functions for u and d quarks [13–16]. However, the size of the gluon Sivvers function still remains an open question, with no hard constraint existing apart from the positivity bound [17].

One process that can be used to probe gluons inside hadrons is the quarkonium production [18]. Several authors have proposed to constrain the gluon Sivvers function using

the experimental data for the quarkonium production in proton-proton [19] and electron-proton [20,21] collisions, considering different initial and final states as e.g. $p^\uparrow p \rightarrow J/\Psi \gamma X$, $p^\uparrow p \rightarrow J/\Psi J/\Psi X$ and $ep^\uparrow \rightarrow e' J/\Psi \gamma X$ (For a recent review see e.g. Ref. [22]). These studies indicate that this process is ideal to get a deeper knowledge of the nucleon structure. Our goal in this paper is to complement these previous analysis and propose the study of the gluon Sivvers function in the photoproduction of vector mesons in $p^\uparrow p$ and $p^\uparrow A$ collisions at high energies. During the last years, the study of photon-induced interactions [23] at Tevatron, RHIC and LHC became a reality [24–32] and new data are expected to be released soon (For a recent review see e.g. [33]). One the main motivations to the study of these processes is the possibility to constrain the main aspects of the treatment of the QCD dynamics at high energies and large nuclei (See e.g. Refs. [34–39]). These previous analysis have been performed considering the collision of unpolarized hadrons. Here we extend these studies for the case where one transversely polarized proton beam is present and estimate the impact of different models for the gluon Sivvers function on the transverse single spin asymmetry.

The basic idea in photon-induced interactions is that an ultrarelativistic charged hadron (proton or nucleus) gives rise to strong electromagnetic fields, such that the photon stemming from the electromagnetic field of one of the two colliding hadrons can interact with one photon of the other hadron (photon-photon process) or can interact directly with the other hadron (photon-hadron process) [23]. In these processes the total cross section can be factorized in terms of the equivalent flux of photons into the hadron projectile and the photon-photon or photon-target cross section. In the particular case of the inelastic J/Ψ photoproduction in $p^\uparrow p$ and $p^\uparrow A$ collisions, we will assume that

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the unpolarized hadron (p or A) is the source of photons, which interact with the transversely polarized protons at high energies, producing a J/Ψ and dissociating the proton target. In the nuclear case, such approximation is justified due to enhancement by a factor Z^2 in the nuclear photon flux in comparison to that for a proton (see below), which implies that the photon-induced interactions are dominated by photons from the nucleus. In the case of $p^\uparrow p$ collisions, the process of interest can be separated by tagging the unpolarized proton in the final state, which is present when it emits the photon. As a consequence, the hadronic cross section will be factorized as follows

$$\sigma_{hp^\uparrow \rightarrow hJ/\Psi X}(\sqrt{s}) = \int dx_\gamma d^2\mathbf{k}_{\perp\gamma} f_{\gamma/h}(x_\gamma, \mathbf{k}_{\perp\gamma}) \cdot \sigma_{\gamma p^\uparrow \rightarrow J/\Psi X}(W_{\gamma p}^2), \quad (1)$$

where x_γ is the energy fraction of hadron carried by the photon with transverse momentum $\mathbf{k}_{\perp\gamma}$ and $f_{\gamma/h}$ is the photon flux associated to hadron h . Moreover, $W_{\gamma h}$ is the c.m.s. photon-proton energy given by $W_{\gamma p} = [2\omega\sqrt{s}]^{1/2}$, where ω is the photon energy and $\sqrt{s}$ is the c.m.s energy of the hadron-proton system. The final state will be characterized by the presence of one rapidity gap and an intact hadron, which we assume to be the unpolarized one. Both aspects can be used in principle to experimentally separate the vector mesons produced by photon-induced interactions. In our exploratory study we will assume that the transverse momentum dependence of the photon distribution can be described by a simple Gaussian form: $f_{\gamma/h}(x_\gamma, \mathbf{k}_{\perp\gamma}) = f_{\gamma/h}(x_\gamma) \times \exp(-k_{\perp\gamma}^2/\langle k_{\perp\gamma}^2 \rangle)/(\pi\langle k_{\perp\gamma}^2 \rangle)$. Moreover, we will assume that the photon spectrum $f_{\gamma/h}(x_\gamma)$ associated to a proton is given by [40],

$$f_{\gamma/p}(x_\gamma) = \frac{\alpha_{\text{em}}}{2\pi} \frac{1 + (1 - x_\gamma)^2}{x_\gamma} \times \left(\ln \Omega - \frac{11}{6} + \frac{3}{\Omega} - \frac{3}{2\Omega^2} + \frac{1}{3\Omega^3} \right), \quad (2)$$

with the notation $\Omega = 1 + [(0.71 \text{ GeV}^2)/Q_{\text{min}}^2]$ and $Q_{\text{min}}^2 = m_p^2 x_\gamma^2/(1 - x_\gamma)$. This expression is derived considering the Weizsäcker-Williams method of virtual photons and using an elastic proton form factor (For more details see Refs. [40,41]). In the case of pA collisions, an analytic approximation for the equivalent photon flux of a nuclei can be calculated considering the requirement that photo-production is not accompanied by hadronic interaction (ultra-peripheral collision), which is given by [23]

$$f_{\gamma/A}(x_\gamma) = \frac{\alpha_{\text{em}} Z^2}{\pi} \frac{1}{x_\gamma} [2\eta K_0(\eta) K_1(\eta) - \eta^2 \mathcal{U}(\eta)] \quad (3)$$

where $K_0(\eta)$ and $K_1(\eta)$ are the modified Bessel functions, $\eta = x_\gamma m_p b_{\text{min}}$ and $\mathcal{U}(\eta) = K_1^2(\eta) - K_0^2(\eta)$. In our analysis

we will assume that $b_{\text{min}} = R_p + R_A$, which suppress the strong interactions.

In order to estimate the inelastic J/Ψ photoproduction in hadronic collisions, we should to specify the underlying mechanism governing heavy quarkonium production, which is still a subject of intense debate. As reviewed in Ref. [18], a number of theoretical approaches have been proposed in the last years for the calculation of the heavy quarkonium production, as for instance, the nonrelativistic QCD (NRQCD) approach, the fragmentation approach, the color singlet model (CSM), the color evaporation model and the k_T -factorization approach. In our analysis we will assume the color evaporation model [42–46], generalized to take into account the transverse momentum dependence of the gluon distribution function [20]. Our motivation to use this model is associated to its simplicity and to the fact that we have checked that this model is able to describe the HERA data for the inelastic J/Ψ photoproduction (See also Ref. [43]). The basic idea in the color evaporation model is that the formation of the color singlet state is not enforced at the perturbative level. The cross section for the process is given essentially by the boson-gluon cross section and the assumption that the color neutralization of the $Q\bar{Q}$ occurs by interaction with the surrounding color field. In CEM, quarkonium production is treated identically to open heavy quark production with exception that in the case of quarkonium, the invariant mass of the heavy quark pair is restricted to be below the open meson threshold, which is twice the mass of the lowest meson mass that can be formed with the heavy quark. Moreover, the CEM assumes that the quarkonium dynamics is identical to all quarkonium states, although the $Q\bar{Q}$ pairs are typically produced at short distances in different color, angular momentum and spin states. In the case of charmonium states, the hadronization from the $c\bar{c}$ pairs is nonperturbative, usually involving the emission of one or more soft gluons. Depending on the quantum numbers of the initial $c\bar{c}$ pair and the final state, a different matrix element is needed for the production of the charmonium state. The average of these nonperturbative matrix elements are combined into the universal factor $F[nJ^{PC}]$, which is process- and kinematics-independent and describes the probability that the $c\bar{c}$ pair binds to form a quarkonium of a given spin J , parity P , and charge conjugation C . Considering the J/Ψ production in $\gamma p^\uparrow$ interactions, the CEM predicts that the cross section will be given by

$$\sigma_{\gamma p^\uparrow \rightarrow J/\Psi X} = F_{J/\Psi} \bar{\sigma}_{\gamma p^\uparrow \rightarrow c\bar{c} X}, \quad (4)$$

where the short distance contribution is

$$\bar{\sigma}_{\gamma p^\uparrow \rightarrow c\bar{c} X} = \int_{4m_c^2}^{4m_D^2} dM_{c\bar{c}}^2 dx_g d^2\mathbf{k}_{\perp g} f_{g/p^\uparrow}(x_g, \mathbf{k}_{\perp g}) \times \frac{d\sigma[\gamma g \rightarrow c\bar{c}]}{dM_{c\bar{c}}^2}, \quad (5)$$

where $M_{c\bar{c}}$ is the invariant mass of the $c\bar{c}$ pair, m_c is the charm quark mass and $2m_D$ is the $D\bar{D}$ threshold. One have that the cross section for the inelastic J/Ψ photoproduction is proportional to the number density of gluons inside a proton with transverse polarization $\mathbf{S}$ and momentum $\mathbf{P}$, which is usually parametrized as [47]

$$f_{g/p^\uparrow}(x_g, \mathbf{k}_{\perp g}, \mathbf{S}) \equiv f_{g/p}(x_g, k_{\perp g}) + \frac{1}{2} \Delta^N f_{g/p^\uparrow}(x_g, k_{\perp g}) \hat{\mathbf{S}} \cdot (\hat{\mathbf{P}} \times \hat{\mathbf{k}}_{\perp g}), \quad (6)$$

where x_g is the longitudinal momentum fraction of the gluon and $\mathbf{k}_{\perp g}$ its transverse momentum. Moreover, $f_{g/p}(x_g, k_{\perp g})$ is the unpolarized transverse momentum dependent (TMD) gluon distribution and $\Delta^N f_{g/p^\uparrow}(x_g, k_{\perp g})$ is the gluon Sivvers function.

In order to probe the gluon Sivvers function in the inelastic J/Ψ photoproduction in $p^\uparrow p$ and $p^\uparrow A$ collisions, in what follows we will investigate the impact of different models for $\Delta^N f_{g/p^\uparrow}(x_g, k_{\perp g})$ in the rapidity (Y) dependence of the single spin asymmetry, defined as

$$A_N(Y) = \frac{\frac{d\sigma^\uparrow}{dY} - \frac{d\sigma^\downarrow}{dY}}{\frac{d\sigma^\uparrow}{dY} + \frac{d\sigma^\downarrow}{dY}}, \quad (7)$$

where $\frac{d\sigma^\uparrow}{dY}$ and $\frac{d\sigma^\downarrow}{dY}$ are respectively the differential cross sections measured when the proton is transversely polarized up ($\uparrow$) and down ($\downarrow$) with respect to the scattering plane, calculated using Eqs. (1), (4) and (6). As in Ref. [20] we will estimate the numerator with a weight factor $\sin(\phi_{q_T} - \phi_S)$, where ϕ_{q_T} and ϕ_S are the azimuthal angles of the J/Ψ and proton spin, respectively. One has that [20]

$$\begin{aligned} \frac{d\sigma^\uparrow}{dY} - \frac{d\sigma^\downarrow}{dY} &= F_{J/\Psi} \int d\phi_{q_T} \int q_T dq_T \\ &\times \int_{4m_c^2}^{4m_D^2} dM_{c\bar{c}}^2 \int d^2\mathbf{k}_{\perp g} f_{\gamma/h}(x_g, \mathbf{q}_T - \mathbf{k}_{\perp g}) \\ &\times [f_{g/p^\uparrow}(x_g, \mathbf{k}_{\perp g}) - f_{g/p^\downarrow}(x_g, \mathbf{k}_{\perp g})] \\ &\times \hat{\sigma}_0(M_{c\bar{c}}^2) \sin(\phi_{q_T} - \phi_S) \end{aligned} \quad (8)$$

and

$$\begin{aligned} \frac{d\sigma^\uparrow}{dY} + \frac{d\sigma^\downarrow}{dY} &= 2F_{J/\Psi} \int d\phi_{q_T} \int q_T dq_T \int_{4m_c^2}^{4m_D^2} dM_{c\bar{c}}^2 \\ &\times \int d^2\mathbf{k}_{\perp g} f_{\gamma/h}(x_g, \mathbf{q}_T - \mathbf{k}_{\perp g}) \\ &\times f_{g/p}(x_g, \mathbf{k}_{\perp g}) \hat{\sigma}_0(M_{c\bar{c}}^2), \end{aligned} \quad (9)$$

where q_T is the transverse momentum of the vector meson and $\hat{\sigma}_0$ is the partonic cross section for the $\gamma g \rightarrow c\bar{c}$ process [48]. It is important to emphasize that the spin asymmetry is

not dependent on $F_{J/\Psi}$. Our motivation to investigate the rapidity dependence of A_N is associated to the fact that the rapidity Y of the vector meson determines the typical values of x_γ and x_g probed in the interaction, which are given by $x_{g,\gamma} = M_{c\bar{c}}/\sqrt{s} \exp(\pm Y)$. Therefore, its analysis allow us to know the value of x_g that is being probed in the gluon Sivvers function. In what follows we will assume that the unpolarized TMD gluon distribution $f_{g/p}(x_g, \mathbf{k}_{\perp g})$ can be described by a Gaussian form:

$$f_{g/p}(x_g, \mathbf{k}_{\perp g}) = f_{g/p}(x_g, \mu^2) \frac{1}{\pi \langle k_{\perp g}^2 \rangle} e^{-k_{\perp g}^2 / \langle k_{\perp g}^2 \rangle} \quad (10)$$

with the factorization scale μ^2 being given by $M_{c\bar{c}}^2$. As in Refs. [20,49], we choose a frame where the proton is moving along the z -axis with momentum $\mathbf{P}$, is transversely polarized along y -axis and $\mathbf{k}_\perp = k_\perp (\cos \phi_{k_{\perp g}}, \sin \phi_{k_{\perp g}}, 0)$, which implies that $\hat{\mathbf{S}} \cdot (\hat{\mathbf{P}} \times \hat{\mathbf{k}}_{\perp g}) = \cos \phi_{k_{\perp g}}$. Moreover, we will consider that the gluon Sivvers function can be described as follows

$$\Delta^N f_{g/p^\uparrow}(x_g, k_{\perp g}) = 2N_g(x_g) f_{g/p}(x_g, \mu^2) h(k_{\perp g}) \frac{e^{-k_{\perp g}^2 / \langle k_{\perp g}^2 \rangle}}{\pi \langle k_{\perp g}^2 \rangle}, \quad (11)$$

where

$$N_g(x_g) = N_g x_g^\alpha (1 - x_g)^\beta \frac{(\alpha + \beta)^{(\alpha + \beta)}}{\alpha^\alpha \beta^\beta} \quad (12)$$

with $|N_g| \leq 1$ and

$$h(k_{\perp g}) = \sqrt{2e} \frac{k_{\perp g}}{M'} e^{-k_{\perp g}^2 / M'^2}. \quad (13)$$

The $k_\perp$ dependent part of the Sivvers function can expressed as follows

$$h(k_{\perp g}) \frac{e^{-k_{\perp g}^2 / \langle k_{\perp g}^2 \rangle}}{\pi \langle k_{\perp g}^2 \rangle} = \frac{\sqrt{2e}}{\pi} \sqrt{\frac{1 - \rho}{\rho}} k_{\perp g} \frac{e^{-k_{\perp g}^2 / \rho \langle k_{\perp g}^2 \rangle}}{\langle k_{\perp g}^2 \rangle^{3/2}}, \quad (14)$$

where $\rho \equiv M'^2 / (\langle k_{\perp g}^2 \rangle + M'^2)$. The parametrization given by Eq. (11) was proposed in Ref. [13] and recently used in Ref. [49], where the authors have considered the mid-rapidity data on the transverse single spin asymmetry measured in $pp \rightarrow \pi^0 X$ by the PHENIX Collaboration at RHIC and the present information on the quark Sivvers functions to get a first estimate on the gluon Sivvers distribution. Assuming $\langle k_{\perp g}^2 \rangle = 0.25 \text{ GeV}^2$, they have obtained two different sets for the best-fit parameters N_g , α , β and ρ , denoted by SIDIS1 and SIDIS2 (For details see [49]).

FIG. 1. Rapidity distribution for the inelastic J/Ψ photoproduction in pp (left panel) and pAu (right panel) collisions at $\sqrt{s} = 200$ and 500 GeV.

In what follows we will present our predictions for $A_N(Y)$ considering the inelastic J/Ψ photoproduction in $p^\uparrow p$ and $p^\uparrow Au$ collisions at different values of the center-of-mass energy. We will consider the SIDIS1 and SIDIS2 models for the gluon Sivers function. In order to estimate the impact of different gluon Sivers distributions on $A_N(Y)$, we also will consider two alternative models obtained assuming that [50] (a) $N_g(x) = [N_u(x) + N_d(x)]/2$ and (b) $N_g(x) = N_u(x)$, which we will denote by BV-a and BV-b hereafter. In our study we will consider the best fit parameters for the u and d quark Sivers functions obtained recently in Ref. [15] from the latest SIDIS data. Moreover, we will integrate the transverse momentum of the vector meson in the range $0 \leq q_T \leq 1.0$ GeV, assume that $m_c = 1.5$ GeV and $m_D = 1.864$ GeV and use the CTEQ6LO parametrization [51] for the unpolarized gluon distribution ($f_{g/p}$). Although the predictions for the rapidity distributions and total cross sections are sensitive to the modeling of $f_{g/p}$ and m_c (See e.g. [52]), we have verified that the predictions for the rapidity distributions our results for $A_N(Y)$ are almost independent of these choices.

Initially let us present in Fig. 1, by the first time, our predictions for the rapidity distribution considering pp and pAu collisions at $\sqrt{s} = 200$ and 500 GeV. We will assume that $F_{J/\Psi} = (1/9) \cdot \rho_{J/\Psi}$, where the factor $1/9$ represent the statistical probability that the $c\bar{c}$ will be in a color singlet state asymptotically and $\rho_{J/\Psi}$ is a nonperturbative parameter, determined by fitting the data. As in Refs. [44,45] we will assume that $\rho_{J/\Psi} = 0.5$. In the case of pp collisions, the rapidity distribution shown have been obtained assuming that one of the incident protons acts as the photon source and the other as target. Such assumption implies an asymmetric distribution for a symmetric collision. On the other hand, for pAu collisions, the distribution is asymmetric due to Z^2 enhancement present in the nuclear photon flux. The predictions for the total cross sections are presented in Table I. As expected, the total cross sections

for pAu collisions are larger than for pp one. In comparison to the predictions for the exclusive vector meson production presented e.g. in Ref. [35], the inelastic production is smaller by a factor ≥ 4 , in agreement with the results obtained in Ref. [52]. However, the final state for inelastic production is distinct of the exclusive case and, as indicated in Ref. [53], the analysis of the transverse momentum distribution of the vector meson are different, the separation of the inclusive and exclusive contributions is, in principle, feasible. Finally, we have verified that the predictions for the rapidity distributions and total cross sections are modified by $\approx 15\%$ if the NRQCD formalism is used to describe the quarkonium production, in agreement with the results presented in Ref. [53].

Our predictions for the single spin asymmetry are presented in Fig. 2 considering $p^\uparrow p$ collisions at $\sqrt{s} = 200$ GeV (left panel) and 500 GeV (right panel). We have that the magnitude and signal of $A_N(Y)$ is strongly dependent on the model used for the gluon Sivers function, with the position of the peak occurring at larger values of Y with the increasing of the energy. Moreover, we have that the maximum and minimum values of A_N are almost independent of energy. These results are consistent with those obtained in Refs. [20] for the J/Ψ production in $ep^\uparrow$ collisions. Our results indicate that the signal and magnitude of the asymmetry can be probed by the analysis of the J/Ψ production at forward rapidities. Additionally, we also have estimated A_N for $p^\uparrow Au$ collisions and obtained that its rapidity dependence, position of the peak and value of the maximum and minimum are very similar to those obtained

TABLE I. Total cross sections for the inelastic J/Ψ photoproduction in pp/pAu collisions at RHIC energies. Values in nb.

	$\sqrt{s} = 200$ GeV	$\sqrt{s} = 500$ GeV
$p^\uparrow p$	0.932	1.245
$p^\uparrow Au$	380.0	1664.5

FIG. 2. Predictions for the single spin asymmetry in the inelastic J/Ψ photoproduction in $p^\uparrow p$ collisions at $\sqrt{s} = 200$ (left panel) and 500 GeV (right panel) considering different models for the gluon Siverts function.

in $p^\uparrow p$ collisions. Such behavior is expected, since the photon flux is present in the numerator and denominator of Eq. (7), which implies that the Z^2 enhancement of the nuclear flux does not affect A_N . Therefore, we predict similar asymmetry in $p^\uparrow p$ and $p^\uparrow Au$ collisions. However, it is important to emphasize that the magnitude of the rapidity distribution in nuclear collisions is almost three orders of magnitude larger than in proton-proton collisions (See Fig. 1), which implies that the study of the single spin asymmetry in $p^\uparrow Au$ collisions is expected to be more easily performed.

Some comments are in order. In our exploratory study we have considered the color evaporation model to describe the quarkonium production. As pointed before, this subject is still a theme of intense debate. We have verified that if the quarkonium production is treated using the NRQCD formalism, the difference in our predictions for A_N is smaller than 5%. Such small difference in A_N is expected since we are estimating a ratio between cross sections. Similar results have been obtained in Refs. [20,21] for J/Ψ production in $ep^\uparrow$ collisions. One aspect that deserves more detailed studies is the analysis is the inclusion of the QCD evolution in the TMD gluon distribution (See e.g. [20,21]). We postpone the analysis of this topic for a future study. Additionally, we would like to emphasize that the analysis of the inelastic J/Ψ photoproduction in $p^\uparrow p/p^\uparrow A$ collisions should also be possible in the AFTER@LHC experiment [54]. Considering the planned characteristics of the experiment (high luminosity, fixed-target collisions,...), and that our results indicate that the maximum value of A_N is almost energy independent, with the peak occurring at large rapidities, we believe that the study of this process is feasible in this experiment. We plan to present more detailed results in a future publication. Finally, it is important to emphasize that in our analysis we only have

considered the central values of the parameters obtained in Refs. [15,49]. As already pointed out in [49] and carefully estimated in Ref. [15], the current uncertainty in these parameters still is large, which has direct impact on the modelling of the gluon Siverts function. As a consequence, the values for A_N obtained in our analysis and presented in Fig. 2 should be considered illustrative of the potential of the inelastic J/Ψ photoproduction in $p^\uparrow p/p^\uparrow A$ collisions as a probe of gluon Siverts function. Our hope is that the results presented here motivate a future experimental analysis.

Finally, let us summarize our main results and conclusions. During the last years, the experimental results from Tevatron, RHIC and LHC have demonstrated that the study of hadronic physics using photon induced interactions in $pp/pA/AA$ colliders is feasible. In this paper we have estimated, by the first time, the inelastic J/Ψ photoproduction in $p^\uparrow p/p^\uparrow A$ collisions at RHIC energies. Moreover, the impact of different models for the gluon Siverts function on the transverse single spin asymmetry have been investigated. Our results indicate that the asymmetry is strongly dependent on the modeling of the gluon Siverts function. Moreover, the signal and magnitude of the asymmetry can be investigated by the analysis of the J/Ψ production at forward rapidities. Such aspects motivate a future experimental analysis of this process as a probe of the gluon Siverts function.

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