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Exclusive vector meson production with a leading neutron in photon - hadron interactions at hadronic colliders

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In this paper we study leading neutron production in photon - hadron interactions which take place in pp and pA collisions at large impact parameters. Using a model that describes the recent leading neutron data at HERA, we consider exclusive vector meson production in association with a leading neutron in pp/pA collisions at RHIC and LHC energies. The total cross sections and rapidity distributions of ρ, ϕ and J/Ψ produced together with a leading neutron are computed. Our results indicate that the study of these processes is feasible and that it can be used to improve the understanding of leading neutron processes and of exclusive vector meson production.

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I. INTRODUCTION

Understanding leading particle production is crucial to understand forward physics at hadron colliders and also cosmic ray physics [1]. Indeed, the interpretation of cosmic ray data is strongly dependent on the accurate knowledge of the leading baryon momentum spectrum and its energy dependence (See e.g. Ref. [2]). Moreover, particle production at forward rapidities and high energies probes the QCD dynamics at very small - x, where non-linear effects associated to high gluonic density in the target are expected to contribute significantly [3]. This new regime of the QCD dynamics is a field of intense activity and the exclusive production of vector mesons in $ep(A)$ collisions and in ultraperipheral hadronic collisions is one of the most promising observables to constrain the main properties of the theory (See, e.g. Refs. [4–10]).

Leading neutron production has been investigated in ep collisions at HERA, from where we have high precision experimental data on semi - inclusive $e + p \rightarrow e + n + X$ processes [11] as well as on exclusive ρ photoproduction associated with a leading neutron ($\gamma p \rightarrow \rho^0 \pi^+ n$) [12]. In these processes the incident proton is converted into a neutron via pion emission. In Refs. [13, 14] we proposed an unified description of inclusive and exclusive processes with a leading neutron, based on the color dipole formalism, and we have demonstrated that the available experimental HERA data on the x_L (Feynman momentum) distribution of leading neutrons can be very well described in this approach. An important property of our approach is that its main elements are constrained by the HERA data on processes without a leading neutron. As a consequence, our analysis of leading neutron data has put limits on the magnitude of the nonperturbative absorptive corrections and on the models of the pion flux (which describes the pion emission by the incident proton). Moreover, we were able to present parameter - free predictions for the inclusive and exclusive processes with a leading neutron at the energies of the future ep colliders [15–17]. Unfortunately, in view of the construction schedule of the these new colliders, these predictions will only be tested in a distant future. Given the impact of leading neutron production in forward physics, it is fundamental to consider alternative ways to learn more about this process (See. e.g. Refs. [18, 19]).

In this paper we propose the study of the leading neutron production in the photon - hadron (γh) interactions, which are present in hadronic collisions [20]. In particular, we will consider exclusive vector meson production associated with a leading neutron in γp interactions at pp and pA collisions. Recent theoretical and experimental studies have

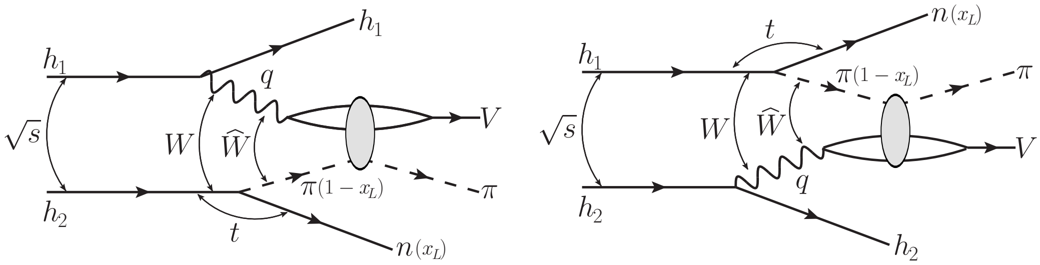

FIG. 1: Exclusive vector meson production associated with a leading neutron in γh interactions at hadronic colliders.

demonstrated that hadronic colliders can also be used to study photon - hadron and photon - photon interactions in a new kinematical range and that several open questions in the theory of strong interactions can be investigated by analysing different final states produced in these reactions (For a recent review see Ref. [1]). As we will demonstrate below, such conclusion is also valid for leading neutron processes. In what follows we will investigate the exclusive ρ, ϕ and J/Ψ production associated with a leading neutron in pp and pA collisions at RHIC and LHC energies and present our estimates for the total cross section and rapidity distributions of these distinct final states. Our goal is to demonstrate that the experimental analysis of these processes is feasible and that they may be used to study leading neutron physics as well as to study exclusive vector meson production.

This paper is organized as follows. In the next Section we present the main concepts in photon - induced interactions and discuss exclusive vector meson production associated with a leading neutron. In Section III we present our predictions for the rapidity distributions and total cross sections for exclusive ρ, ϕ and J/Ψ production associated with a leading neutron in pp and pA collisions at RHIC and LHC energies. Finally, in Section IV we summarize our main conclusions.

II. PHOTON - INDUCED INTERACTIONS AND EXCLUSIVE VECTOR MESON PRODUCTION ASSOCIATED WITH A LEADING NEUTRON

In this section we will present a brief review of the formalism needed to describe the vector meson production associated with a leading neutron in photon - induced interactions at hadronic collisions. We refer the reader to our previous papers [8, 9, 13, 14] for a more detailed discussion. At high energies, the incident charged hadrons (proton or nuclei) generate strong electromagnetic fields, which can be represented in terms of an equivalent photon flux. As a consequence, in a hadronic collision, a photon stemming from the electromagnetic field of one of the two colliding hadrons can interact with one photon coming from the other hadron (photon - photon process) or it can interact directly with the other hadron (photon - hadron process) [20, 21]. In this paper we will focus on the latter. A basic property of these photon - induced interactions is that the cross section can be factorized in terms of the equivalent flux of photons (from the hadron projectile) and the photon - target cross section, with the photon flux being well known. Consequently, the cross section of a photon - induced process in hadronic collisions is a direct probe of the photon - hadron cross section. Therefore, the study of these processes in hadronic colliders can be considered complementary to the analysis performed at HERA, as demonstrated by recent results on exclusive vector meson photoproduction in pp/pA collisions. The main difference in comparison to HERA and future ep colliders, is that photon - induced interactions are characterized by real photons, while in ep colliders it is possible to investigate vector meson production at different photon virtualities. We will extend the formalism used to treat photon - induced interactions to the description of the leading neutron processes. Exclusive vector meson production associated with a leading neutron will be represented by the diagrams in Fig. 1, which can be seen as a sequence of four factorizable subprocesses: i) a photon is emitted by one of the incident hadrons; ii) this photon fluctuates into a quark-antiquark pair (the color dipole), iii) the color dipole interacts diffractively with the pion, while the proton remains intact, and iv) the vector meson and the leading neutron are formed. The final state will be characterized by two rapidity gaps, one associated to the photon exchange and another to the colorless system exchanged between the dipole and the pion, as well as by a pion produced at large rapidities and by a leading neutron. The corresponding rapidity distribution will be given by

$$\frac{d\sigma\,\left[h_1 + h_2 \rightarrow h_3 \otimes V \otimes \pi + n\right]}{dY} = \left[\omega \frac{dN}{d\omega}|_{h_1}\, \sigma_{\gamma h_2 \rightarrow V\otimes\pi+n}\left(\omega\right)\right]_{\omega_L} + \left[\omega \frac{dN}{d\omega}|_{h_2}\, \sigma_{\gamma h_1 \rightarrow V\otimes\pi+n}\left(\omega\right)\right]_{\omega_R} \quad (1)$$

where h_3 corresponds to the initial hadron (h_1 or h_2) which has emitted the photon, Y is the rapidity of the vector meson V $(= \rho, \phi, J/\Psi)$ in the final state, which can be determined by the photon energy ω in the collider frame and by mass M_V of the vector meson $[Y \propto \ln(\omega/M_V)]$. The symbol $\otimes$ represents a rapidity gap in the final state and $\omega_L\,(\propto e^{-Y})$ and $\omega_R\,(\propto e^{Y})$ denote photons from the h_1 and h_2 hadrons, respectively. In our study we will assume that the equivalent photon spectrum $\frac{dN}{d\omega}$ of a relativistic proton is given by [22],

$$\frac{dN_{\gamma/p}(\omega)}{d\omega} = \frac{\alpha_{\rm em}}{2\pi\,\omega}\left[1+\left(1-\frac{2\,\omega}{\sqrt{s}}\right)^2\right]\left(\ln\Omega - \frac{11}{6} + \frac{3}{\Omega} - \frac{3}{2\,\Omega^2} + \frac{1}{3\,\Omega^3}\right)\,, \tag{2}$$

with the notation $\Omega = 1 + [\,(0.71\,\mathrm{GeV}^2)/Q^2_{\rm min}\,]$, $Q^2_{\rm min} = \omega^2/[\,\gamma_L^2\,(1-2\,\omega/\sqrt{s})\,] \approx (\omega/\gamma_L)^2$, γ_L is the Lorentz boost of a single beam and $\sqrt{s}$ is the c.m.s energy of the hadron-hadron system. The equivalent photon flux of a nucleus is given by [20]

$$\frac{dN_{\gamma/A}\,(\omega)}{d\omega} = \frac{2\,Z^2\alpha_{em}}{\pi\,\omega}\,\left[\bar{\eta}\,K_0\,(\bar{\eta})\,K_1\,(\bar{\eta}) + \frac{\bar{\eta}^2}{2}\,\mathcal{U}(\bar{\eta})\right] \tag{3}$$

where $\bar{\eta} = \omega\,(R_{h_1} + R_{h_2})/\gamma_L$, $K_{0,1}$ are the modified Bessel functions of second kind and $\mathcal{U}(\bar{\eta}) = K_1^2\,(\bar{\eta}) - K_0^2\,(\bar{\eta})$. One of the main differences between the photon fluxes for the proton and for the nucleus is that the latter is enhanced by a factor Z^2. This implies that the rapidity distribution of the vector mesons produced in pA collisions will be asymmetric and determined by γp interactions, with the photon coming from the nucleus. In contrast, the rapidity distribution for pp collisions will be symmetric with respect to $Y = 0$.

Following Refs. [13, 14] we will assume that the absorptive corrections associated to soft rescatterings [23, 24] can be approximated by a constant factor $\mathcal{K}$, which implies that the total cross section for the process $\gamma p \rightarrow V \otimes \pi + n$ can be expressed by

$$\sigma_{\gamma p \rightarrow V\otimes\pi+n}(W^2) = \mathcal{K}\cdot\int dx_L dt\, f_{\pi/p}(x_L,t)\cdot\sigma_{\gamma\pi\rightarrow V\otimes\pi}(\hat{W}^2) \tag{4}$$

where W is the center-of-mass energy of the photon-proton system, x_L is the proton momentum fraction carried by the neutron and t is the square of the four-momentum of the exchanged pion. Moreover, $f_{\pi/p}$ is the flux of virtual pions emitted by the proton and $\sigma_{\gamma\pi\rightarrow V\otimes\pi}(\hat{W}^2)$ is the cross section of the interaction between the photon and the pion at center-of-mass energy $\hat{W}$, which is given by $\hat{W}^2 = (1-x_L)\,W^2$. As discussed in detail in Refs. [13, 14], the precise form of the pion flux is still a subject under investigation. In what follows we will assume that the pion flux is given by

$$f_{\pi/p}(x_L,t) = \frac{1}{4\pi}\frac{2g^2_{p\pi p}}{4\pi}\frac{-t}{(t-m_\pi^2)^2}(1-x_L)^{1-2\alpha(t)}[F(x_L,t)]^2 \tag{5}$$

where $g^2_{p\pi p}/(4\pi) = 14.4$ is the $\pi^0 pp$ coupling constant, m_π is the pion mass and $\alpha(t)$ is the Regge trajectory of the pion. In particular, we will consider that the form factor $F(x_L,t)$, which accounts for the finite size of the nucleon and of the pion, can be expressed as follows [25]

$$F(x_L,t) = \exp\left[b(t-m_\pi^2)\right] \quad , \quad \alpha(t) = \alpha(t)_\pi \tag{6}$$

where $\alpha_\pi(t) \simeq t$ (with t in GeV^2) and $b = 0.3$ GeV^{-2}. As demonstrated in Ref. [14], this model (denoted f_3 in [14]) reproduces well the HERA data on the exclusive ρ photoproduction associated with a leading neutron.

In order to describe the $\gamma\pi \rightarrow V\otimes\pi$ cross section, in Ref. [14] we extended the color dipole formalism (widely used in exclusive γp processes) to $\gamma\pi$ interactions. Consequently, we assumed that $\sigma_{\gamma\pi\rightarrow V\otimes\pi}$ can be expressed by

$$\sigma(\gamma\pi \rightarrow V\otimes\pi) = \int_{-\infty}^{0}\frac{d\sigma}{d\hat{t}}\,d\hat{t} = \frac{1}{16\pi}\int_{-\infty}^{0}|\mathcal{A}^{\gamma\pi\rightarrow V\pi}(x,\Delta)|^2\,d\hat{t}\,, \tag{7}$$

with the scattering amplitude being given by

$$\mathcal{A}^{\gamma\pi\rightarrow V\pi}(\hat{x},\Delta) = i\int dz\,d^2\boldsymbol{r}\,d^2\boldsymbol{b}e^{-i[\boldsymbol{b}-(1-z)\boldsymbol{r}].\boldsymbol{\Delta}}\;(\Psi^{V*}\Psi)\;2\mathcal{N}_\pi(\hat{x},\boldsymbol{r},\boldsymbol{b}) \tag{8}$$

where $(\Psi^{V*}\Psi)$ denotes the overlap between the real photon and exclusive final state wave functions, which we assume to be given by the Gauss-LC model described in Ref. [13]. The variable z $(1-z)$ is the longitudinal momentum fraction of the quark (antiquark) and Δ denotes the transverse momentum lost by the outgoing pion ($\hat{t} = -\Delta^2$). The variable $\boldsymbol{b}$ is the transverse distance from the center of the target to the center of mass of the $q\bar{q}$ dipole and the factor in the exponential arises when one takes into account non-forward corrections to the wave functions [26]. Moreover, $\mathcal{N}^\pi(\hat{x}, \boldsymbol{r}, \boldsymbol{b})$ is the imaginary part of the forward amplitude of the scattering between a small dipole (a colorless quark-antiquark pair) and a pion, at a given rapidity interval $y = \ln(1/\hat{x})$. This quantity is directly related to the QCD dynamics at high energies [3]. As in Refs. [13, 14] we will assume that $\mathcal{N}^\pi$ can be expressed in terms of the dipole-proton scattering amplitude $\mathcal{N}^p$, usually probed in the inclusive and exclusive processes at HERA, as follows

$$\mathcal{N}^\pi(\hat{x}, \boldsymbol{r}, \boldsymbol{b}) = R_q \cdot \mathcal{N}^p(\hat{x}, \boldsymbol{r}, \boldsymbol{b}) \tag{9}$$

with R_q being a constant. Moreover, we will assume that $\mathcal{N}_p(\hat{x}, \boldsymbol{r}, \boldsymbol{b})$ is given by the bCGC model proposed in Ref. [5]:

$$\mathcal{N}_p(\hat{x}, \boldsymbol{r}, \boldsymbol{b}) = \begin{cases} \mathcal{N}_0 \left(\frac{r\,Q_{s,p}}{2}\right)^{2\left(\gamma_s + \frac{\ln(2/rQ_{s,p})}{\kappa\,\lambda\,y}\right)} & rQ_{s,p} \le 2 \\ 1 - \exp\left[-A\,\ln^2\left(B\,r\,Q_{s,p}\right)\right] & rQ_{s,p} > 2 \end{cases} \tag{10}$$

with $y = \ln(1/\hat{x})$ and $\kappa = \chi''(\gamma_s)/\chi'(\gamma_s)$, where χ is the LO BFKL characteristic function [27]. The coefficients A and B are determined uniquely from the condition that $\mathcal{N}_p(\hat{x}, \boldsymbol{r}, \boldsymbol{b})$, and its derivative with respect to rQ_s, are continuous at $rQ_s = 2$. In this model, the proton saturation scale $Q_{s,p}$ depends on the impact parameter:

$$Q_{s,p} \equiv Q_{s,p}(\hat{x}, \boldsymbol{b}) = \left(\frac{x_0}{\hat{x}}\right)^{\frac{\lambda}{2}} \left[\exp\left(-\frac{b^2}{2B_{\rm CGC}}\right)\right]^{\frac{1}{2\gamma_s}} . \tag{11}$$

Following [28] we will assume in what follows that $\gamma_s = 0.6599$, $B_{CGC} = 5.5$ GeV^{-2}, $\mathcal{N}_0 = 0.3358$, $x_0 = 0.00105 \times 10^{-5}$ and $\lambda = 0.2063$. As demonstrated in Ref. [7], this phenomenological dipole reproduces quite well the HERA data on exclusive ρ and J/Ψ production. Moreover, the results from Refs. [8, 9] demonstrated that this model gives a good description of the recent LHC data on exclusive vector meson photoproduction in pp and pPb collisions.

The main assumptions in our approach for inclusive and exclusive leading neutron processes are that i) the absorptive corrections can be represented by a $\mathcal{K}$ factor, which is assumed to be energy and x_L independent and ii) the dipole - pion amplitude can be related to the dipole - proton one by a constant factor R_q. Both assumptions surely deserve more detailed studies (For more discussions see Refs. [13, 14]). However, the results presented in Refs. [13, 14] demonstrated that these assumptions are supported by the available HERA data. In particular, in Ref. [14] we have assumed $R_q = 2/3$, as expected from the additive quark model, and we have used the experimental HERA data on $\sigma(\gamma p \to \rho \otimes \pi + n)$ [12] to constrain the range of possible values of the $\mathcal{K}$ - factor. In the calculations of the exclusive vector meson production associated with a leading neutron in photon - induced interactions we will also assume that $R_q = 2/3$ and we will use the values of the $\mathcal{K}$ - factor in the range determined in Ref. [14]. As a consequence, the predictions to be presented in the next section are parameter – free. Therefore, the analysis of this process in hadronic colliders, which have cross sections larger than those studied at HERA, will be very useful to test our approach and its underlying assumptions.

III. RESULTS

In this section we present our predictions for the exclusive vector meson production associated with a leading neutron in photon - induced interactions considering pp/pA collisions at RHIC and LHC energies. In particular, we will consider pp collisions at $\sqrt{s} = 0.2$, 0.5, 8 and 13 TeV, pAu collisions at $\sqrt{s} = 0.2$ and 0.5 TeV and pPb collisions at $\sqrt{s} = 5$ and 8.8 TeV. In order to estimate the total cross section $\gamma p \to V \otimes \pi + n$, given by Eq. (4), we will assume that $p_T = \sqrt{|t|} < 0.2$ GeV, as implemented in the analysis of the H1 Collaboration [12]. Moreover, in [14] we have estimated three possible values for the $\mathcal{K}$ - factor considering the central value of the total cross section for exclusive ρ photoproduction with a leading neutron and its upper and lower bounds determined in Ref. [12]. In what follows we will assume these same values, which are given by $(\mathcal{K}_{min}, \mathcal{K}_{med}, \mathcal{K}_{max}) = (0.152, 0.179, 0.205)$. As a consequence, instead of a single curve for the rapidity distribution we will obtain a band. Similarly, we will derive a range of possible values for the total cross sections.

In Fig. 2 we present our predictions for the rapidity distributions of the vector mesons produced in pp collisions at $\sqrt{s} = 0.2$, 0.5, 8 and 13 TeV. As expected from the symmetry of the initial state, the distributions are symmetric with respect to $Y = 0$. Moreover, the predictions for midrapidities $Y \approx 0$ increase with the energy and decrease for heavier vector mesons. Additionally, the growth with the energy is faster for J/Ψ production. This can be directly

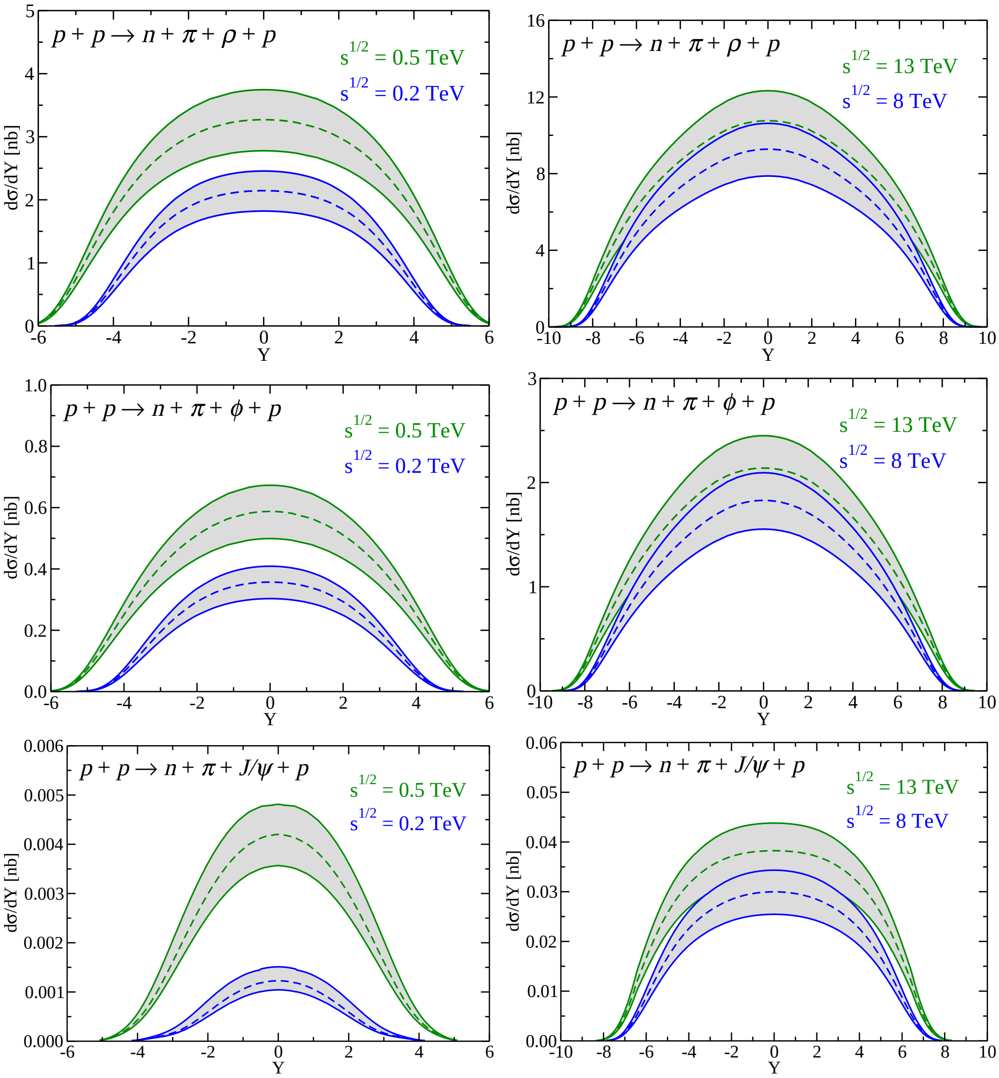

FIG. 2: Rapidity distribution for the exclusive ρ, ϕ and J/Ψ production associated with a leading neutron in γp interactions at pp collisions.

associated to the fact that charmonium production is dominated by color dipoles of small size. On the other hand, the overlap functions $(\Psi^{V*}\Psi)$ of the lighter mesons (ρ and ϕ) peak at larger pair separations at a fixed photon virtuality [5]. As a consequence, the impact of the non-linear effects is larger for these states and they reduce the growth of the cross sections with the energy.

In Fig. 3 we present our predictions for the rapidity distributions of the vector mesons produced in pAu collisions at $\sqrt{s} = 0.2$ and 0.5 TeV as well as in pPb collisions at $\sqrt{s} = 5.0$ and 8.8 TeV. In this case we have asymmetric distributions, since the photon - induced interactions are dominated by photons emitted by the nucleus. This behaviour is directly associated to the fact that the photon flux of a nucleus is proportional to Z^2. This enhancement has direct impact on the magnitude of the distributions, which are amplified in comparison with the pp one.

In Tables I and II we present our predictions for the total cross sections considering γp interactions in pp and pA collisions, respectively. As expected from the analysis of the rapidity distributions, the cross sections increase with the energy and decrease with the mass of the vector meson. Moreover, their magnitude is enhanced in pA collisions in comparison with the predictions for vector meson production in pp ones. In the case of ρ production, we predict values of the order of 10^1 (10^4) nb in pp (pAu) collisions at RHIC energies. At LHC energies, we predict that the total cross section will be $\approx 10^2$ (10^5) nb in pp (pPb) collisions. In comparison with the photoproduction of vector mesons in γp interactions at hadronic collisions in processes without the presence of a leading neutron (See, e.g. Refs. [4, 6, 8, 9, 29–31]), our predictions are smaller by approximately two orders of magnitude, as expected from the experimental results obtained in γp collisions at HERA. However, it is important to emphasize that these events

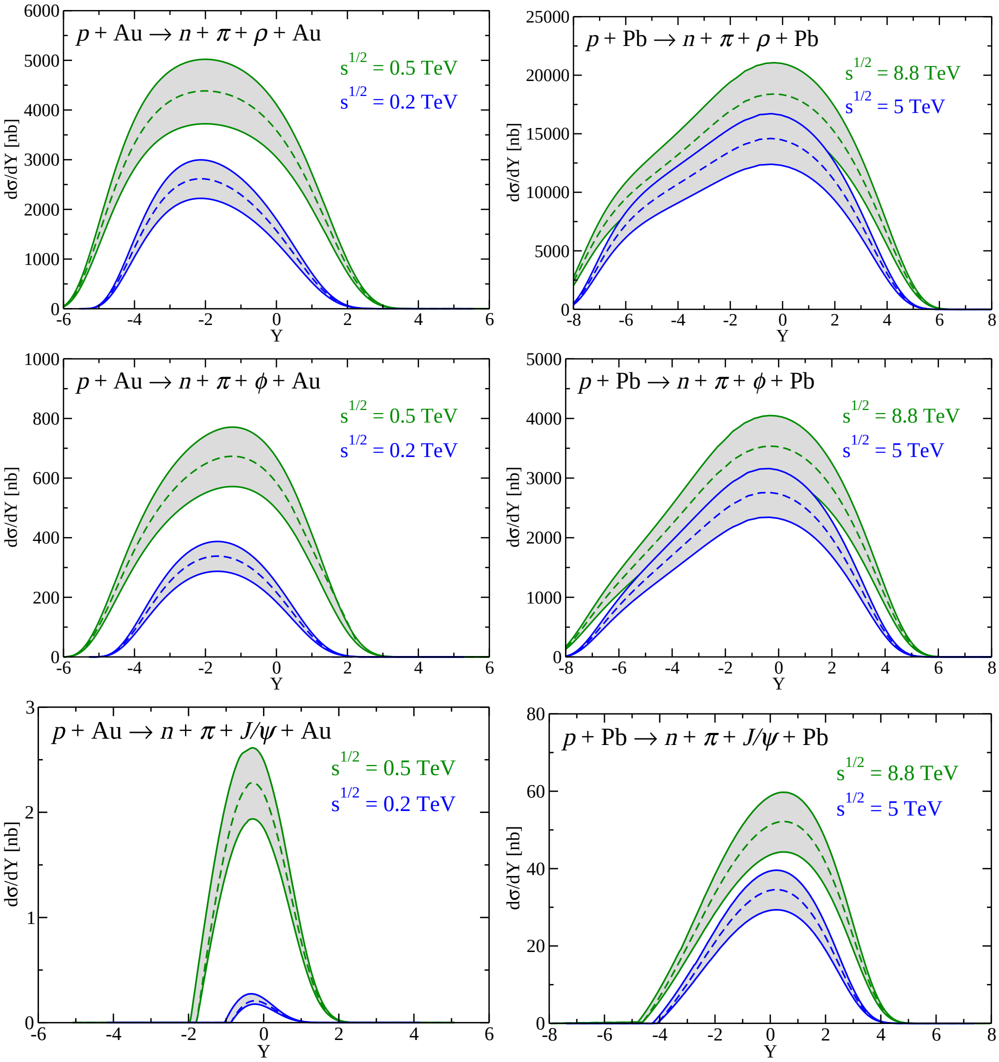

FIG. 3: Rapidity distribution for the exclusive ρ, ϕ and J/Ψ production associated with a leading neutron in γp interactions at pA collisions.

will be characterized by a very forward neutron, which can be used to tag the events and allow for the study the process. This possibility has been discussed e.g. in Refs. [32, 33]. In particular, in Ref. [33] the author has analysed the capabilities of the neutron Zero Degree Calorimeters detectors to select events with one leading forward neutron, which could be tagged and then studied using the central ALICE detector. Finally, considering the design luminosities for pp and pA collisions at LHC given by $\mathcal{L}^{\rm pp} = 10^7$ mb^{-1}s^{-1} and $\mathcal{L}^{\rm pPb} = 150$ mb^{-1}s^{-1}, respectively, and assuming a run time of 10^7 (10^6) s for collisions with protons (ions), we predict that the ρ production rates will be of the order of 10^{10} (10^7) events per year. In the case of J/Ψ production, we predict 10^7 (10^4) events per year. These results demonstrate that the experimental analysis of vector meson production with a leading neutron in γp interactions at pp and pA collisions is, in principle, feasible at the LHC.

IV. SUMMARY

Our understanding of the hadron structure, the QCD dynamics and the description of inclusive and exclusive processes has advanced with the successful operation of the DESY ep collider HERA. However, several questions remains without answer. As HERA has stopped to operate and the next generation of ep collider is still to be constructed, the study of alternatives which could help to study the processes mentioned above are timely and necessary. One possibility is the use of the hadronic colliders to study photon - induced interactions in a new kinematical range of γh center - of - mass energies. Recent results have demonstrated that the analysis of these

$\sigma(V)$ [nb]		$\sqrt{s} = 0.2$ TeV	$\sqrt{s} = 0.5$ TeV	$\sqrt{s} = 8.0$ TeV	$\sqrt{s} = 13.0$ TeV
ρ	K_{min}	12.17	22.06	90.12	110.51
	K_{med}	14.34	25.98	106.12	130.14
	K_{max}	16.42	29.75	121.54	149.04
ϕ	K_{min}	1.83	3.58	16.67	20.73
	K_{med}	2.15	4.21	19.63	24.42
	K_{max}	2.46	4.83	22.48	27.96
J/ψ	K_{min}	0.0042	0.019	0.25	0.35
	K_{med}	0.0049	0.022	0.30	0.42
	K_{max}	0.0064	0.026	0.34	0.48

TABLE I: Total cross sections for the exclusive ρ, ϕ and J/Ψ production associated with a leading neutron in pp collisions considering different center - of - mass energies and distinct values for the magnitude of the absorptive corrections, described by the $\mathcal{K}$ - factor.

$\sigma(V)$ [nb]		$\sqrt{s} = 0.2$ TeV	$\sqrt{s} = 0.5$ TeV	$\sqrt{s} = 5.0$ TeV	$\sqrt{s} = 8.8$ TeV
ρ	K_{min}	9176.88	20819.90	102785.00	139110.00
	K_{med}	10807.00	24518.30	121043.00	163821.00
	K_{max}	12376.70	28079.50	138625.00	187616.00
ϕ	K_{min}	1090.55	2863.67	17326.20	24154.90
	K_{med}	1278.41	3386.65	20403.80	28445.60
	K_{max}	1470.81	3862.20	23367.50	32577.30
J/ψ	K_{min}	0.19	3.94	135.53	234.50
	K_{med}	0.23	4.65	159.61	276.16
	K_{max}	0.32	5.65	184.04	317.05

TABLE II: Total cross sections for the exclusive ρ, ϕ and J/Ψ production associated with a leading neutron in pAu collisions at $\sqrt{s} = 0.2$ and 0.5 TeV and pPb collisions at at $\sqrt{s} = 5.0$ and 8.8 TeV considering different values for the magnitude of the absorptive corrections, described by the $\mathcal{K}$ - factor.

processes is feasible at RHIC and LHC, and that it is possible to use the resulting experimental data to investigate e.g. the nuclear effects in the gluon distribution, the QCD dynamics at high energies and several other issues that still lack a satisfactory description. This possibility has stimulated the improvement of the theoretical description of these processes as well as the proposal of new forward detectors to be installed in the LHC [34, 35]. One important issue is the understanding of the leading neutron processes, which have strong implications in the forward physics at colliders and ultrahigh energy cosmic rays. Recently, we proposed a model to describe inclusive and exclusive leading neutron processes in *ep* collisions, which reproduce quite well the HERA data. However, several questions deserve more detailed studies and the comparison of these predictions, as well those from other models of leading neutron processes, with a larger and more precise set of experimental data is fundamental to improve our understanding of these processes. In this paper we proposed the analysis of vector meson production associated with a leading neutron in γp interactions at pp and pA collisions as an alternative to study leading neutron processes. Considering that all the elements of our model have been constrained by the HERA data, we have presented parameter – free predictions for ρ, ϕ and J/Ψ production with a leading neutron at RHIC and LHC energies. We predicted large values for the total cross sections and event rates, which implies that the experimental analysis of this process is, in principle, feasible. We expect that our results motivate future experimental analysis at RHIC and LHC colliders, which undoubtedly will allow to constrain the description of the leading neutron processes.

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