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Double Parton Interactions in p-A collisions and Partonic Correlations

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Abstract. The Double Parton Scattering dynamics is different in p-p and in p-A collisions. Their joint study of DPS in p-p and in p-A collisions can therefore provide valuable information on the non-perturbative input to the process, namely multi-parton correlations, which cannot be obtained by studying DPS in p-p only. By studying WJJ production in p-Pb collisions, we estimate that the fraction of events due to DPS may be larger by a factor 3 or 4, as compared to p-p collisions, while the amount of the increased fraction can give information on the importance of different correlation terms.

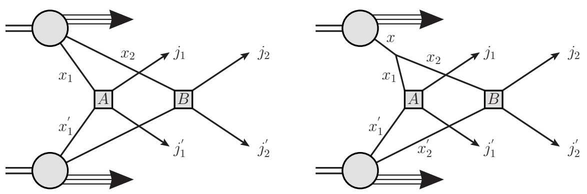

Figure 1. Disconnected and connected Double Parton Scattering.

1 Introduction

Multiple Parton Interactions have been introduced to solve the unitarity problem generated by the fast raise of the inclusive hard cross sections at small longitudinal fractional momenta x [1–3]. For some fixed final state, at small x the hard cross section can in fact become larger than the total inelastic cross section. The inclusive cross section counts the multiplicity of interactions and, when the average multiplicity of interactions becomes large, an inclusive cross section larger than the total inelastic cross section is no more inconsistent with unitarity.

The simplest case of Multiple Parton Interaction is Double Parton Scattering (DPS). The final state of DPS is characterized by a typical back to back configuration of four large p_t partons, produced by the leading contribution at small x and utilized as a distinctive signature for the experimental search of DPS events. It has been pointed out that this configuration can be generated through two different mechanisms (Fig. 1) such that the hard part of the interaction may be either disconnected or connected[4, 5]. In the first case the hard process takes place in two different points in transverse space and it is initiated by four partons. The connected contribution is on the contrary initiated by three partons, all localized in the same point in the transverse space. The incoming parton flux is thus larger in the disconnected contribution, which is therefore dominant at small x, while the connected contribution becomes dominant at large x. The two contributions are also expected to be characterized by different correlations in rapidity and it should thus be possible to disentangle them experimentally.

On the other hand there is no experimental indication on the size of the connected contribution in the kinematical regimes where DPS are observed, while present experimental evidence is not inconsistent with the expectations of the disconnected contribution. We will therefore take the simplified attitude of neglecting the connected contribution. In this way we will be able to make definite predictions and, when the experimental evidence will deviate from the expectations based on this simplest dynamics, it will be easier to identify the properties of different additional interaction mechanisms.

The disconnected contribution is characterized by the geometrical features pointed out in Figure 2. The non-perturbative components are thus factorized into functions which depend on two fractional momenta and on the relative transverse distance b between the two interaction points and thus between the interacting partons inside the nucleon.

When neglecting spin and color and assuming factorization, the inclusive double parton-scattering cross-section for two parton processes A and B in a p-p collision is given by

$$\sigma_D^{pp\ (A,B)} = \frac{m}{2}\sum_{i,j,k,l}\int \Gamma_{i,j}(x_1,x_2;b)\,\hat\sigma^A_{i,k}(x_1,x_1') \qquad (1)$$
$$\times\,\hat\sigma^B_{j,l}(x_2,x_2'))\,\Gamma_{k,l}(x_1',x_2';b)\;dx_1dx_1'dx_2dx_2'd^2b$$

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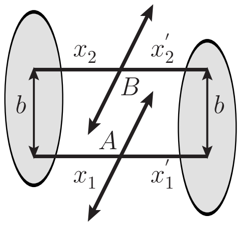

Figure 2. The incoming flux is maximal when the hard component of the interaction is disconnected.

where $\Gamma_{i,j}(x_1, x_2; b)$ are the double parton distribution functions and the dependence on the fractional momenta of the interacting partons, $x_{1,2}$, and on their relative transverse distance b is explicitly indicated, while the dependence on the scales of the two hard processes A and B is understood. The indices i and j label partons flavors. For identical interactions the combinatorial coefficient is $m = 1$ and $m = 2$ otherwise. $\hat{\sigma}^A$, $\hat{\sigma}^B$ are the two elementary cross sections.

On general grounds, the inclusive cross section should depend also on spin and color. However, color-correlations are Sudakov suppressed, and therefore should give only small corrections. Spin correlations are instead expected to affect the results in particular reaction channels. On the other hand, at present, there are no experimental indications on the importance of spin in DPS and this is true also for flavor. We will therefore make the further simplification of neglecting the spin and flavor degrees of freedom.

In the experimental analysis the DPSs are investigated through the so-called "pocket formula" :

$$\sigma_D^{pp\ (A,B)} = \frac{m}{2} \frac{\sigma^A \sigma^B}{\sigma_{eff}}, \tag{2}$$

which provides an operational definition of the scale factor characterizing the process, namely the effective cross section σ_{eff}. Actually, when hard interactions are rare, the probability to have the process B in a inelastic interaction is given by the ratio σ_B/σ_{inel}. Once the process A takes place, the probability to have the process B in the same inelastic interaction is different. It can anyway be always written as σ_B/σ_{eff}, where σ_{eff} plays *effectively* the role, which was of the inelastic cross section in the unbiased case.

The "pocket formula" of the inclusive cross-section has been shown to be able to describe the experimental results of the direct search of double parton collisions in rather different kinematical regimes with a value of σ_{eff} compatible with a universal constant [6–10], while the study of CDF about the dependence of σ_{eff} on the fractional momenta of the incoming partons, is again compatible with a value of σ_{eff} only weakly dependent on x.

Furthermore, when the DPS cross section is generalized by introducing parton distributions depending on transverse momenta and off shell T-matrix elements, the same value of σ_{eff} allows describing DPS also in the regime of very small x, where the back to back kinematical configuration, typical of the large p_t partons originated by DPS, is lost.

The measurement of Double Parton Scattering only in p-p collisions does not provide however enough information to decide how much the observed value of σ_{eff} is originated by the typical separation in transverse space between the two pairs of interacting partons and how much it is rather due to the actual distribution in multiplicity of parton pairs in the hadronic structure. Additional information, which allows to discriminate between the two cases, can be nevertheless obtained by studying DPS in p-A collisions. Multiple Parton Interactions in p-A collisions introduce in fact novel features in the process, since MPI can occur also through a mechanism where two or more target nucleons are active participants in the hard process.

2 Partonic correlations and effective cross section

Eq. (2) can be derived from Eq. (1), which allows to express the effective cross section as a function of the correlations between partons inside a proton.

A simple parametrization of the Double Parton Distributions is given by

$$\Gamma(x_1, x_2; b) = K_{x_1 x_2}\, G(x_1)\, G(x_2)\, f_{x_1 x_2}(b) \tag{3}$$

where f is normalized to one, $\int f_{x_1 x_2}(b) d^2 b = 1$. The function $G(x_1, x_2)$ is thus obtained by integrating out all the dependence on the transverse degree of freedom. Correlations in fractional momenta are then characterized by the parameter $K_{x_1 x_2}$:

$$G(x_1, x_2) \equiv \int \Gamma(x_1, x_2; b)\, d^2 b \tag{4}$$

$$\equiv K_{x_1 x_2}\, G(x_1)\, G(x_2), \tag{5}$$

where $G(x)$ are the usual one-body parton distribution functions.

$G(x)$ and $G(x_1, x_2)$ are therefore respectively the parton multiplicity and the multiplicity of parton-pairs at given fractional momenta:

$$G(x) = \langle n \rangle_x \tag{6}$$

$$G(x_1 x_2) = \langle n(n-1) \rangle_{x_1, x_2}, \tag{7}$$

$K_{x_1 x_2}$ accounts for the second moment of the multiparton exclusive multiplicity distribution. Actually

$$K_{x_1 x_2} = \frac{\langle n(n-1) \rangle_{x_1, x_2}}{\langle n \rangle_{x_1} \langle n \rangle_{x_2}}. \tag{8}$$

In the simplest case where $K_{x_1 x_2} = 1$, after the integration over b we thus obtain a Poisson multi-parton distribution in multeplicity.

By inserting Eq. (3) in Eq. (1), the expression of the inclusive cross section for DPS in p-p collisions results is

$$\begin{aligned}
&\sigma_D^{pp\,(A,B)}(x_1,x_1',x_2,x_2') = \frac{m}{2} K_{x_1x_2} K_{x_1'x_2'} \qquad (9)\\
&\times G(x_1)\,\hat{\sigma}_A(x_1,x_1')\,G(x_1')\,G(x_2)\,\hat{\sigma}_B(x_2,x_2')\,G(x_2')\\
&\times \int f_{x_1x_2}(b) f_{x_1'x_2'}(b)\, d^2b\\
&= \frac{m}{2} \frac{K_{x_1x_2}K_{x_1'x_2'}}{\pi\Lambda^2(x_1,x_1',x_2,x_2')}\,\sigma_A(x_1,x_1')\sigma_B(x_2,x_2')
\end{aligned}$$

where Λ is defined by

$$\int f_{x_1x_2}(b) f_{x_1'x_2'}(b)\, d^2b = \frac{1}{\pi\Lambda^2(x_1,x_1',x_2,x_2')}. \qquad (10)$$

and parametrizes the typical transverse distance between the pairs of interacting partons, for given values of the fractional momenta.

The comparison between Eq. (9) and Eq. (2) provides the expression of σ_{eff} in terms of K and Λ

$$\sigma_{eff}(x_1,x_1',x_2,x_2') = \frac{\pi\Lambda^2(x_1,x_1',x_2,x_2')}{K_{x_1x_2}K_{x_1'x_2'}}. \qquad (11)$$

Therefore σ_{eff} is completely understood in terms of Λ and K. As mentionned in Sect. 1, the experiments show that the effective cross section depends only weakly on fractional momenta, therefore both Λ and K should be mildly dependent on x. In the limiting case, where there are no correlations, partons are not correlated neither in multiplicity, nor in transverse coordinates. This situation corresponds to take $K_{x_1x_2} = 1$ while $\Gamma(x_1,x_2;b)$ is given by the product of the two transverse single-parton distributions $\Gamma(x;b)$

$$\Gamma(x;b) = G(x) f_x(b), \qquad \text{with} \int f_x(b)\, d^2b = 1. \qquad (12)$$

The function $f_x(b)$ in Eq. 12 is the known two-gluon form factor [18] which is normalized to one. The transverse distribution is therefore given by

$$f_{x_1x_2}(b) = \int f_{x_1}(b') f_{x_2}(b-b')\, d^2b'.$$

If all these assumptions were right, one would obtain $\sigma_{eff} = \pi\Lambda^2 = 32$ mb which is about twice the experimental measurement.We gather thus that either K is not equal to one or $\pi\Lambda^2$ is not equal to 32 mb or both.

One may thus conclude that there is convincing evidence of correlations between partons in the hadron structure. However, since all new information on the hadron structure is summarized by a single quantity, σ_{eff}, the study of Double Parton Scattering in p-p collisions does not allow to disentangle Λ and K.

3 Double Parton Scattering in p-A collisions

In the case of p-A collisions, when non additive corrections to the nuclear parton distributions can be considered negligible, the Double Parton Scatterings originate either from interactions with a single active target nucleon or from interactions with two different active target nucleons as depicted in figure 3.

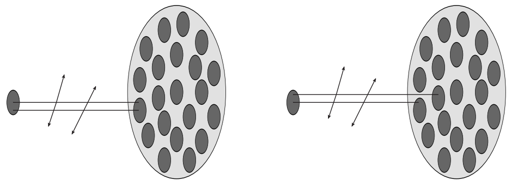

Figure 3. One or two nuclear nucleons participate to the double interactions. In the second case, the distance b does not provide information about the transverse distribution of partons inside a nucleon and so the dependence on the transverse degree of freedom decouples.

Whereas the first contribution is just an amplification of the DPS on a isolated nucleon, the second contribution enhances the effects of correlations in the partons multiplicity. The relative transverse distance between the interacting pairs does not play in fact any relevant role, when compared to the much larger nuclear radius [11–16].

The selection of the contribution to DPS with two active target nucleons could thus supply a direct access to the correlations in the partons multiplicity of the hadron structure.

The inclusive cross section splits into two terms:

$$\sigma_D^{pA} = \sigma_D^{pA}\big|_1 + \sigma_D^{pA}\big|_2 \qquad (13)$$

The probabilistic approach of Glauber's model provides a first indication about the dependence on the mass number A of the nucleus of the two terms:

$$\sigma_D^{pA}\big|_1 = \frac{1}{2}\frac{\sigma_S^2}{\sigma_{eff}} \int d^2B\, T(B) \propto A, \qquad (14)$$

$$\sigma_D^{pA}\big|_2 = \frac{1}{2}\sigma_S^2 \int d^2B\, T^2(B) \propto A^{4/3} \qquad (15)$$

where the case of two identical partonic interactions has been considered. Here σ_S is the inclusive single scattering cross section and $T(B)$ is the nuclear thickness, as a function of the impact parameter of the collisions B. The latter contribution is so enhanced with respect to the first one providing an "anti-shadowing" effect: the nuclear nucleons do not shadow each others generating a decrease on the trivial nuclear cross section expectation (namely $\sigma_D^{pA}|_1$) but make larger the cross section.

However this is only a rough estimate; the study of the kinematics of the process in figure 4 shows that when the two target partons are identical, the forward scattering amplitude has not only a diagonal contribution but also an interference one. Since each of the two active nucleons can generate each of the two interacting partons independenty, the two nuclear configurations add coherently in the cross section. However this second contribution might complicate the interpretation of the experimental results [13, 14]. A suitable reaction channel, where the interference terms are absent, is W^+ JJ production. Moreover the study of

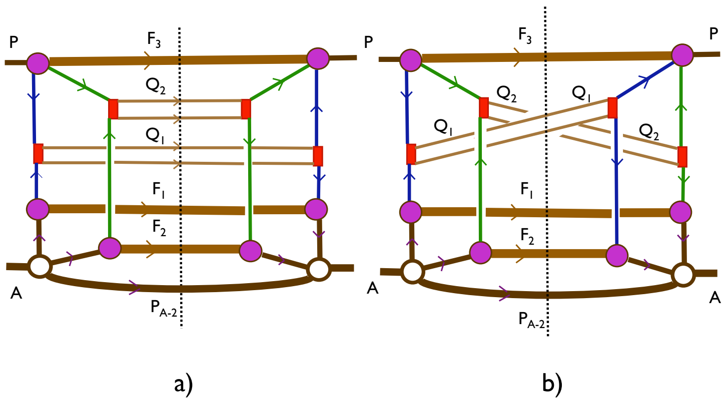

Figure 4. Diagrams of the forward scattering amplitude relative to diagonal and off-diagonal contributions to the p-A DPS with two active nucleons.

this process in DPS is instructive because already studied in p-p collisions both by ATLAS and CMS [9, 10].

3.1 WJJ process

The final state W JJ can be produced both through a single interaction and double interactions (one producing the boson, the other one the dijet). The related inclusive cross section is so equal to

$$\sigma^{pA}(WJJ) = \sigma_S^{pA}(WJJ) + \sigma_D^{pA}(WJJ) \tag{16}$$

where S (D) stands for single (double) scattering, with the double contribution given by the Eq. (13).

The single interaction term is given by

$$\sigma_S^{pA}(WJJ) = Z\sigma_S^{p[p]}(WJJ) + (A-Z)\sigma_S^{p[n]}(WJJ), \tag{17}$$

with Z the atomic number and $[p]$ ($[n]$) labelling a nuclear proton (neutron).

The contribution due to a double parton scattering in a collision with a single target nucleon, $\sigma_D^{pA}(WJJ)|_1$ in Eq. (13), has an analogous structure

$$\sigma_D^{pA}(WJJ)\Big|_1 = \frac{1}{\sigma_{eff}}[Z\sigma_S^{p[p]}(W)\sigma_S^{p[p]}(JJ) + (A-Z)\sigma_S^{p[n]}(W)\sigma_S^{p[n]}(JJ)], \tag{18}$$

where $\sigma_S^{p[p],p[n]}(W)$ are the single scattering cross sections for inclusive production of a W in a collision of a proton with a bound proton or with a bound neutron, while $\sigma_S^{p[p],p[n]}(JJ)$ is, analogously, the single scattering cross section to produce a pair of jets. The effective cross section, σ_{eff}, has been assumed to be a universal constant (and so Λ and K).

The last term, $\sigma_D^{pA}(WJJ)\Big|_2$, where two different nucleons participate to the double parton interaction provides new information about the hadronic structure. The corresponding contribution to the cross section is

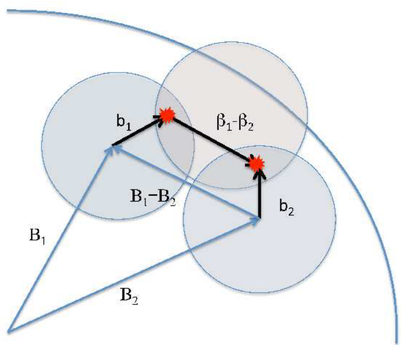

Figure 5. The configuration in transverse space corresponding to the DPS cross section in Eq. (19).

$$\begin{aligned}\sigma_D^{pA}(WJJ)\Big|_2 &= K_{x_1x_2}\sigma_S(W)\sigma_S(JJ)\\ &\times \int f_{x_1x_2}(\beta_1-\beta_2)f_{x_1'}(b_1)f_{x_2'}(b_2)\rho(B_1,z_1;\,B_2,z_2)\\ &\times dz_1dz_2\,\delta(B_1-B_2+b_1-b_2+\beta_1-\beta_2)\\ &\times db_1\,db_2\,d(\beta_1-\beta_2)\,dB_1\,dB_2\end{aligned} \tag{19}$$

where we made the assumptions that the distribution functions related to the nuclear partons are described by a one-parton transverse function $\Gamma(x;b) = G(x)f_x(b)$ with $f_x(b)$ the two-gluon form factor [19]. The nuclear dependence is expressed by the nuclear density $\rho(B_1,z_1;\,B_2,z_2)$, with z_i the longitudinal coordinates of the two interactiong nucleons. The cross section in Eq. (19) is proportional to the overlap integral in the transverse coordinates which involves three diffent scales as shown in figure 5.

A sensible approximation is to neglect the hadronic scale when compared to the nuclear scale. However the DPSs force the two target nucleons to be very close in transverse space, in such a way that the contribution of short range correlations in the two body nuclear density may give non negligible effects, considering that the value of the scale of the short range nuclear correlation is $r_c \simeq 0.5$fm [18]. This correlation is treated as a perturbation; for small relative distances it is approximated as

$$\rho^{(C,2)}(r_1, r_2)\Big|_{r_1 \simeq r_2} \approx [\rho^{(1)}(r_1)]^2[1 - C(r_1 - r_2)]^2.$$

Since the functions $f_{x_i'}(b_i)$, $f_{x_1x_2}(\beta_1-\beta_2)$ are normalized to one and $\rho^{(2)}(r_1, r_2)$ is smooth as a function of $r_1 - r_2$, in absence of short range nuclear correlations the contribution to the overlap integral is equal to $\int T(B)^2 d^2B$.

In order to solve the overlap integral with short range nuclear correlations, we have to use explicit expressions for $f_{x_i'}(b_i)$ and $f_{x_1x_2}(\beta_1 - \beta_2)$. The calculations are easier in the Fourier space where the transform of $f_x(b)$ is a known quantity parametrized e.g. as in [18]:

$$\tilde{f}_{x'}(q) = \Big(1 + \frac{q^2}{m_g^2}\Big)^{-2} \tag{20}$$

with $m_g^2 \simeq 1.1$ Gev^2, for $x' \approx .03$ and small q^2.
In the hypothesis $\tilde{f}_{x_1x_2}(q) = \tilde{f}_{x_1}(q)\tilde{f}_{x_2}(q)$ we obtain

$$\frac{1}{\sigma_{eff}} = \frac{K^2}{\pi^2\Lambda} = \frac{m_g^2}{28\pi} \tag{21}$$

As mentionned in Sect. 3, in this scenario we are not able to obtain the actual value of the effective cross section. Therefore we assume the simplest option, where the functional form of $\tilde{f}_{x_1x_2}(q)$ is the same as in the uncorrelated case and the only modification is in the value of the scale m_g, which we replace with the relevant scale for the transverse separation between the parton pairs, which we denote with h_c. To obtain the observed value of σ_{eff}, when $K^2 = 2$, $h_c = m_g$ while for $K^2 = 1$ $h_c \approx 1.52$ GeV.

By evaluating the overlap integral we have

$$\frac{1}{(2\pi)^2}\int \tilde{f}_{x_1x_2}(q)\tilde{f}_{x_1'}(q)\tilde{f}_{x_2'}(q)\tilde{C}(q)d^2q = C_K\, r_c \tag{22}$$

Finally, we obtain that the contribution with two active nuclear nucleons has a more complex structure:

$$\sigma_D^{pA}(WJJ)\Big|_2 = K\Big[\frac{Z}{A}\sigma_S^{pp}(W) + \frac{A-Z}{A}\sigma_S^{pn}(W)\Big]\sigma_S^{pp}(JJ) \times \Big[\int T(B)^2d^2B - 2\int \rho(B,z)^2d^2Bdz \times r_c\, C_K\Big] \tag{23}$$

where $T(B)$ is the thickness function producing the Glauber growth as $A^{4/3}$ and $r_c\, C_K$ accounts for the short range nuclear correlation giving a local contribution proportional to A through the nuclear density ρ. Because of its definition, C_K contains a mild residual dependence on Λ, which however has only a minor effect on K.

More details can be found in [17]

3.2 Some results

We worked in the simplest hypothesis where σ_{eff}, Λ and K are independent of x and we exploited for σ_{eff} the two values measured by ATLAS and CMS respectively,

$$\sigma_{eff}^{ATLAS} = 15 \text{ mb} \qquad \sigma_{eff}^{CMS} = 20.7 \text{ mb}. \tag{24}$$

The cross section has been evaluated in two extreme cases

a) $K^2 = 1$ and $\pi\Lambda^2 = \sigma_{eff}$; when there is no correlation in multiplicity the σ_{eff} gives the typical value of the transverse area where the Double Parton Scattering takes place

b) $K^2 = 2$ and $\pi\Lambda^2 = K^2\sigma_{eff}$; the observed value of σ_{eff} is completely due to the correlation in multiplicity.

In order to evaluate the effect of anti-shadowing, we introduce the ratio

$$\mathcal{R} = \frac{\sigma_D^{pA}(WJJ)}{\sigma_D^{pA}(WJJ)\big|_1} \tag{25}$$

which is independent on the final state phase space:

$$\mathcal{R} = 1 + K\frac{\sigma_{eff}}{A} \times \Big[\int T(B)^2d^2B - 2\int \rho(B,z)^2d^2Bdz \times r_c\, C_K\Big]$$

We evaluated this ratio when the proton collides with a ^{208}Pb nucleus. In the two limit cases one obtains:

a) $K^2 = 1$ and $\pi\Lambda^2 = \sigma_{eff}$ (no correlation in multiplicity)

$$\mathcal{R} \approx 1 + 2.03$$

namely a 200% enhancement;

b) $K^2 = 2$ and $\pi\Lambda^2 = K^2\sigma_{eff}$ (no transverse correlation)

$$\mathcal{R} \approx 1 + 2.94$$

namely a 300% enhancement.

The amount of anti-shadowing changes only by about 6% when changing ATLAS value of σ_{eff} with CMS value. This is due to the strong dependence of $\sigma_D^{pA}(WJJ)|_2$ (Eq.23) on K and on its weak dependence on Λ (only through C_K).

Furthermore, a larger anti-shadowing corresponds to a larger fraction of events with DPI with respect to the total events. The growth is from about 8% (ATLAS) to about 22.5%, if the distribution in multiplicity is Poissonian (case a) and to about 27.3%, if there are no transverse correlations (case b).

Nuclear effects and the different roles of parton correlations are more evident in the differential distributions.

The elementary cross sections are evaluated at the leading order in perturbation theory. For the numerical integration we used the LO MSTW (MSTW2008lo68cl) set. The Leading Order matrix elements are generated by means of MadGraph 5 in the framework of the Standard Model with the CKM matrix. For the multi-dimensional integration we used VEGAS; more specifically we used Suave (SUbregion-Adaptive VEgas), an algorithm implemented in the CUBA library [20], which combines the advantages of Vegas and subregion sampling.

For a more direct comparison with available results in p-p, we simulated both p-p and p-Pb collisions, in the same kinematical conditions of the ATLAS DPS measurements [9].

In figure 6 we plot the distributions in p_t of the leading jet in p-p and p-Pb collisions (right and left panel respectively). In the DPS contribution (in green) we used the ATLAS value for $\sigma_{eff} = 15$ mb. The same distribution is shown in p-Pb collisions in the right panel. The pink histograms refer to the single scattering contribution, the green ones to the DPS contribution, the black histograms are the sum of the two contributions.

Whereas in p-p collisions the DPSs represent a little contribution to the p_t spectrum of the leading jet produced in the process, the DPSs acquire a stronger importance in the p_t spectrum of the leading jet in p-Pb collisions where the shape of the distribution is very different for p_t smaller than 40 GeV.

The distributions in figure 7 show the dependence of the transverse spectrum of the leading jet on the value of the σ_{eff} and of K. As expected, the change of σ_{eff} from ATLAS to CMS value does not involve an appreciable difference in the distributions. Moreover, the shape in p_t shows an appreciably dependence on the value of K, after subtracting the single scattering contribution, which can be be considered as a known quantity, once the DPSs have been measured in p-p collisions in the same kinematical conditions.

An observable more sensible to the multiplicity of the multi-parton distribution is the p_t spectrum of the charged lepton, produced by the decay of the W^+. In a single scattering collision W bosons recoil against the produced jets and are typically characterized by a transverse momentum of the order of the lower cutoff in p_t of the observed accompanying jets. Instead in the case of a DPS, the jets and the W are produced in different partonic interactions. The transverse momentum of the W is therefore typically rather small and the lepton produced by its decay has a transverse spectrum limited to values close to $1/2$ of the W mass. The spectrum of the decay lepton is thus rather different in single and in double parton scattering.

In figure 8 we plot the distribution in p_t of the charged lepton from the W^+ decay. in p-p collisions (left panel) and in p-Pb collisions (right panel). The enhancement of the spectrum at $p_t < 40$ GeV, due to the contribution of DPS, is not significant in p-p collisions but it is important in p-Pb collisions, where the difference with respect to the contribution to the spectrum due to single parton scattering (pink histograms in figure 8) is quite noticeable.

The figures 9 remark the dependence of the p_T spectra of the charged lepton in p-Pb collisions on the choice of the value of σ_{eff} and of K. In the left panel we show the spectrum in the case $K^2 = 1$ for $\sigma_{eff} = 15$ mb and $\sigma_{eff} =$ 20.7 mb; in the right panel we show the case $K^2 = 2$. The enhancement of the spectrum due to the DPS contribution at $p_t < 40$ GeV is rather substantial and the amount of the increase is significantly different as a function of K.

Finally, one may notice that the spectra in p-Pb do not depend much on the value of σ_{eff} measured in p-p collisions, as apparent in the figures 7 and 9, where the dotted and the continuous histograms are obtained by using the two different values for σ_{eff} measured by CMS and ATLAS respectively.

4 Concluding summary

In the simplest model for Double Parton Scattering, which is not inconsistent with the present experimental evidence, only disconnected hard interactions are considered and σ_{eff} does not depend on fractional momenta.

In our model, σ_{eff} is given by the ratio of the typical transverse interaction area $\pi\Lambda^2$ and the multiplicity of parton pairs, K^2. DPS in p-p collisions can thus provide information only about the ratio between Λ and K.

In p-A collisions the DPS interaction is simpler for processes which do not involve identical partons. We have thus studied in some detail the produciton of $W + JJ$ in pPb collisions

In p-A collisions the DPS inclusive cross section is characterized by a very strong anti-shadowing (a $\sim 2 -$ 300% positive correction term). The anti-shadowing correction term is proportional to the multiplicity of parton pairs in the projectile proton K and has a weak dependence on the partonic correlations in the transverse coordinates.

In particular, when compared with p-p, the p_T spectra of the leading jet and of the large p_T lepton are characterized by the following peculiar features:

- the spectrum of the leading jet is expected to show an evident change of shape at $p_T < 40$ GeV;

- the spectrum of the lepton shows a substantial increase at p_T 40 GeV (namely at transverse momenta of about one half the mass of the W boson).

If the expectations of the model were verified, both qualitatively and, at least to some extent, also quantitatively, one would have a reasonable argument to claim that the amount of anti-shadowing, in DPS in pPb collisions, gives reliable indications on the average number of pairs of partons in the proton. Once an estimate of K is available, Λ is obtained from the measured value of σ_{eff} in the same kinematical regime and, in this way, one would be able to obtain unprecedented information on the three-dimensional structure of the proton.

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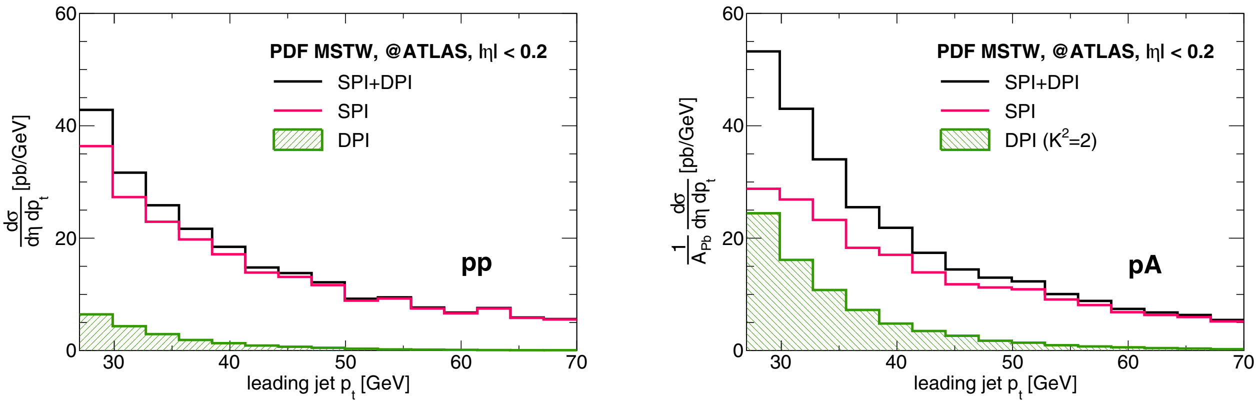

Figure 6. The spectrum in p_T of the leading jet in p-p and ppb collisions with $K^2 = 2$. The shape is very different in p-p and pPb case for $p_T < 40$ GeV. The increase of double parton scattering importance in p-A collisions with respect p-p case is shown by comparing the extention of the green areas in the two cases.

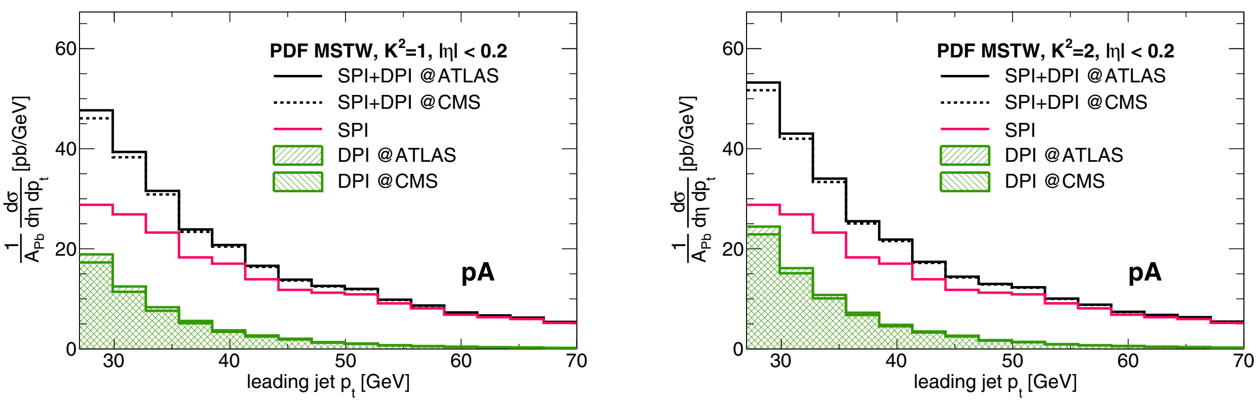

Figure 7. The spectra in p_T of the leading jet in pPb case in the two extreme cases, $K^2 = 1, 2$.

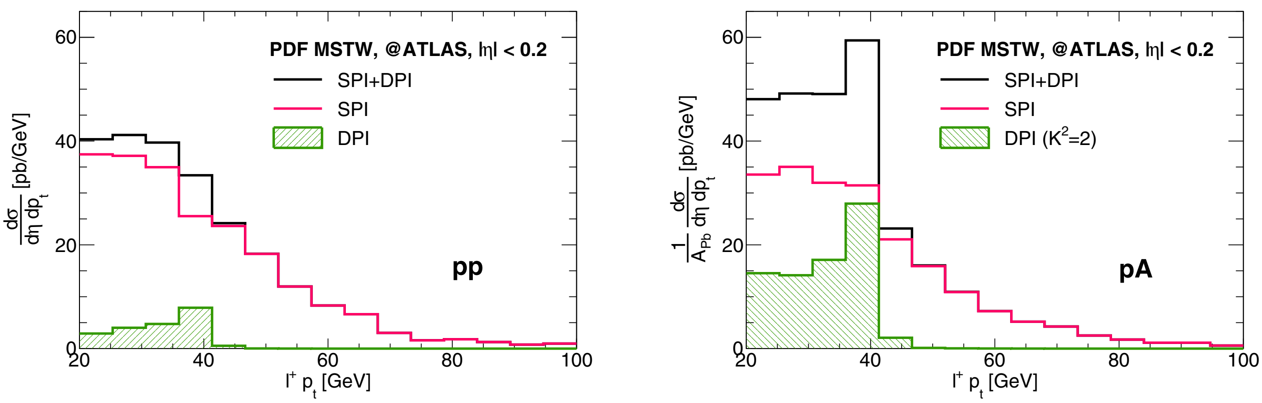

Figure 8. The p_T spectrum of the charged lepton coming from the decay of W^+ in p-p and p-A collisions with $K^2 = 2$. While the spectrum does not change much in p-p collisions, the effect in pPb collisions is dramatic with a high peak at about $p_T = 40$ GeV.

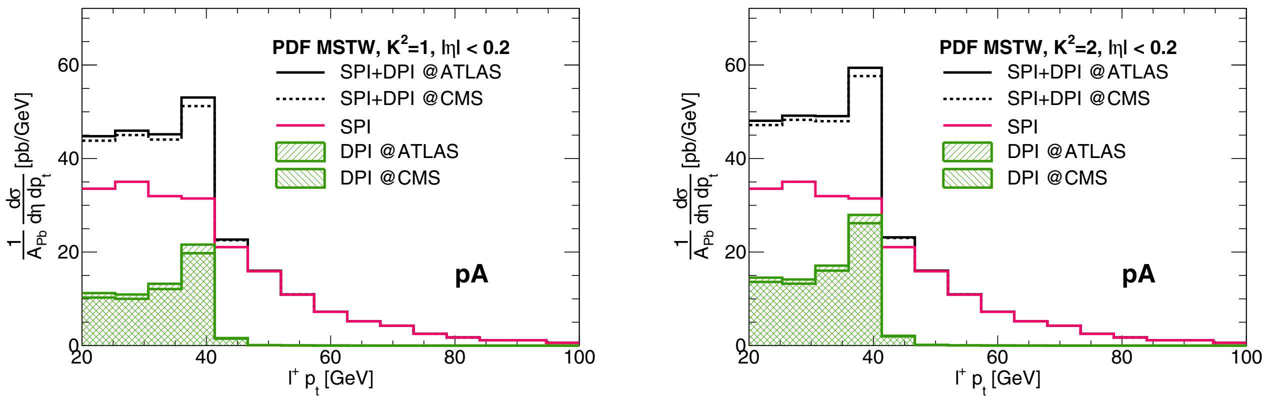

Figure 9. The p_T spectrum of the charged lepton coming from the decay of W^+ in p-A collisions in the two extreme cases.

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