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Parton correlations in same-sign W pair production via double parton scattering at the LHC

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Same-sign W boson pair production is a promising channel to look for signatures of double parton interactions at the LHC. The corresponding cross section has been calculated by using double parton distribution functions, encoding two parton correlations, evaluated in a light-front quark model. The obtained result is in line with previous estimates which make use of an external parameter, the so-called effective cross section, not necessary in our approach. The possibility to observe for the first time two-parton correlations, in the next LHC runs, has been established.

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It has been known for a long time that a proper description of final states in hadronic collisions requires the inclusion of processes where more than one pair of partons participate in a single hadronic collision, the so-called multiple partonic interactions (MPI) [1,2]. Because of LHC operation, the wide subject of MPI is now having a renewed interest [3]. At low transverse momenta, MPI enhance particle production and affect particle multiplicities and energy flows. The effect of MPI is present also in hard scattering processes. In this article, we are interested in double parton scattering (DPS), in which parton pairs from two hadrons interact with each other, and both collisions are hard enough to apply perturbative techniques. While these processes need to be well controlled since they could represent a background for new physics searches, the main focus of this work is the sensitivity of DPS to relevant features of the nonperturbative nucleon structure, not accessible otherwise. In particular, the DPS cross section depends on nonperturbative quantities, the so-called double parton distribution functions (dPDFs). The latter represent the number density of parton pairs with longitudinal fractional momenta x_1, x_2, at a relative transverse distance $\vec{b}_\perp$. If extracted from data, dPDFs would offer for the first time the opportunity to investigate two-parton correlations, as noticed a long time ago [4]. Since dPDFs are two-body distributions, this information is different and complementary to the one encoded in one-body distributions, such as ordinary and generalized parton distributions [5]. The present article aims at establishing to what extent this novel information can be accessed in the next runs of LHC, looking at a specific final state, namely, the production of a pair of W bosons with the same sign ($ssWW$). In fact, this channel has been found to be promising for DPS observation [6–8], since single parton scattering (SPS) at tree level starts contributing to higher order in the strong coupling [9]. For such reasons, diboson production via DPS has been theoretically investigated in detail [10–14].

Let us define now the quantities we are going to calculate. If final states A and B are produced in a DPS process, the corresponding cross section can be sketched as [1]

$$d\sigma^{AB}_{\rm DPS} = \frac{m}{2}\sum_{i,j,k,l}\int d\vec{b}_\perp D_{ij}(x_1,x_2;\vec{b}_\perp) \times D_{kl}(x_3,x_4;\vec{b}_\perp) d\hat{\sigma}^A_{ik} d\hat{\sigma}^B_{jl}, \qquad (1)$$

where $m = 1$ if A and B are identical and $m = 2$ otherwise, and $i,j,k,l = \{q,\bar{q},g\}$ are the parton species contributing to the final states $A(B)$. In Eq. (1) and in the following, $d\sigma$ is used for the cross section, differential in the relevant variables. The functions D_{ij} in Eq. (1) are the dPDFs which depend additionally on factorization scales $\mu_{A(B)}$, $D_{ij}(x_1,x_2;\vec{b}_\perp,\mu_A,\mu_B)$. To date, dPDFs are very poorly known, so that it has been useful to describe the DPS cross section independently of the dPDFs concept, using the approximation

$$d\sigma^{AB}_{\rm DPS} \simeq \frac{m}{2} d\sigma^A_{\rm SPS}\frac{d\sigma^B_{\rm SPS}}{\sigma_{\rm eff}}, \qquad (2)$$

where $d\sigma^A_{\rm SPS}$ is the SPS cross section with final state A,

$$d\sigma^A_{\rm SPS} = \sum_{i,k} f_i(x_1,\mu_A) f_k(x_3,\mu_A) d\hat{\sigma}^A_{ik}(x_1,x_3,\mu_A). \qquad (3)$$

In Eq. (3) $f_{i(j)}$ are parton distribution functions (PDFs) and an analogous expression holds for the final state B. The physical meaning of Eq. (2) is that, once the process A has occurred with cross section $\sigma_{\rm SPS}^A$, the ratio $\sigma_{\rm SPS}^B/\sigma_{\rm eff}$ represents the probability of process B to occur. A constant value of $\sigma_{\rm eff}$ has been assumed in all the experimental analyses performed so far, so that the technical implementation of Eq. (2) is rather easy. A comprehensive compilation of experimental results on $\sigma_{\rm eff}$ is reported in Ref. [15], where the latest DPS measurement in the four jet final state is presented. In that paper, it is shown that, in general, the different collaborations have extracted values of $\sigma_{\rm eff}$ which are roughly consistent within errors, irrespective of center-of-mass energy of the hadronic collisions and of the final state considered. On the other hand, it should be noted that very recent values of $\sigma_{\rm eff}$, extracted with double heavy quarkonia in the final state, are significantly smaller than the others.

To understand the approximation leading to Eq. (2) from Eq. (1), let us write dPDFs in the latter in a fully factorized form,

$$D_{ij}(x_1, x_2, \mu_A, \mu_B, \vec{b}_\perp) = f_i(x_1, \mu_A) f_j(x_2, \mu_B) T(\vec{b}_\perp), \quad (4)$$

where the function $T(\vec{b}_\perp)$ describes the probability to have two partons at a transverse distance $\vec{b}_\perp$. Then, inserting Eq. (4) into Eq. (1), one obtains $\sigma_{\rm eff}$ from Eq. (2), as follows:

$$\sigma_{\rm eff}^{-1} = \int d\vec{b}_\perp [T(\vec{b}_\perp)]^2, \quad (5)$$

with $T(\vec{b}_\perp)$ controlling the double parton interaction rate. It is clear that, as a consequence of the approximation (4), $\sigma_{\rm eff}$ does not show any dependence on parton fractional momenta, hard scales, or parton species.

Actually, if factorized expressions are not used, $\sigma_{\rm eff}$ depends on longitudinal momenta. Since dPDFs are basically unknown, and only sum rules relating them to PDFs are available [16,17], model calculations, developed at low energy, but able to reproduce relevant features of nucleon parton structure, can be useful and have been proposed. In such model calculations, factorized structures, Eq. (4), do not arise, and $\sigma_{\rm eff}$ depends nontrivially on longitudinal momenta. In particular, this was found in a light-front (LF) Poincaré covariant constituent quark model (CQM), reproducing the sum rules of dPDFs [18,19], as well as in a holographic approach [20]. In this article we will evaluate DPS cross sections, using different models of dPDFs, to establish whether forthcoming LHC data will exhibit (for the considered final state) such features, not yet seen in the present uncertain experimental scenario.

The feasibility of the measurement in this particular channel was originally established in Ref. [8], where various strategies to control backgrounds was proposed allowing the extraction of the DPS signal with an acceptable signal-to-background ratio. At present, background estimates are embedded in the experimental analysis [21,22], since the extraction of the DPS signal from data proceeds via a multivariate statistical analysis which requires one to take fully into account all backgrounds sources. Therefore, in this paper, we take advantage of these results and concentrate on the modelization of the signal. Before giving details on our calculation, let us summarize the available experimental information in the considered channel. At $\sqrt{s} = 8$ TeV [21] with an integrated luminosity $\mathcal{L} = 19.7\ {\rm fb}^{-1}$ a lower limit on $\sigma_{\rm eff}$ was obtained, $\sigma_{\rm eff} > 5.91$ mb at 95% confidence level. More recently a new analysis has been performed at $\sqrt{s} = 13$ TeV [22] with an integrated luminosity $\mathcal{L} = 35.9\ {\rm fb}^{-1}$, where the DPS signal cross section was found to be, after correcting for the $W \to l\nu$ branching ratio, of the order of one picobarn and affected by large errors.

We first consider the SPS $W^\pm$ production and subsequent decay into muon at center-of-mass energy $\sqrt{s}$,

$$pp \to W^\pm (\to \mu^\pm \overset{(-)}{\nu}_\mu) X, \quad (6)$$

indicating the corresponding integrated and differential cross sections with $\sigma^\pm$ and $d\sigma^\pm$, respectively. Defining quarks according to their charge, i.e. $D = d$, s, b and $U = u$, c, t, we consider the following partonic subprocesses:

$$U(p_a)\bar{D}(p_b) \to \mu^+(p_\mu)\nu_\mu(p_\nu), \quad (7)$$

$$D(p_a)\bar{U}(p_b) \to \mu^-(p_\mu)\bar{\nu}_\mu(p_\nu), \quad (8)$$

where particle four-momenta are indicated in parentheses. Differential cross sections are calculated in terms of the muon transverse momentum $p_T = |\vec{p}_T|$ and pseudorapidity η_μ, defined in the hadronic center-of-mass frame. The partonic Lorentz invariants $\hat{u}$ and $\hat{t}$, in terms of these variables, read

$$\begin{aligned} \hat{t} &= (p_a - p_\mu)^2 = -x_a \sqrt{s}\, p_T e^{-\eta_\mu}, \\ \hat{u} &= (p_b - p_\mu)^2 = -x_b \sqrt{s}\, p_T e^{\eta_\mu}, \end{aligned} \quad (9)$$

from which parton fractional momenta can be calculated as

$$x_a = e^{\eta_\mu} \frac{M_W}{\sqrt{s}} (A \pm B), \qquad x_b = e^{-\eta_\mu} \frac{M_W}{\sqrt{s}} (A \mp B), \quad (10)$$

with $A = M_W/(2p_T)$, $B = \sqrt{A^2 - 1}$, and M_W the W-boson mass. The unobserved neutrino causes an underdetermination of the W rapidity and, in turn, the twofold ambiguity in Eq. (10). The $d\sigma^+$ cross section is evaluated in the narrow width approximation, i.e. at fixed $\hat{s} = (p_a + p_b)^2 = M_W^2$, and reads

$$\frac{d^2\sigma^{pp\to W^+(\to\mu^+\nu)X}}{d\eta dp_T} = \frac{G_F^2}{6s\Gamma_W}\frac{V_{U\bar{D}}^2}{\sqrt{A^2-1}} \times [f_U(x_a,\mu_F)f_{\bar{D}}(x_b,\mu_F)\hat{t}^2 + f_{\bar{D}}(x_a,\mu_F)f_U(x_b,\mu_F)\hat{u}^2], \quad (11)$$

where G_F is the Fermi constant, Γ_W the W boson decay width, and V_{ij} the Cabibbo-Kobayashi-Maskawa matrix elements. The numerical values of these parameters are taken from Ref. [23]. The $d\sigma^-$ cross section is obtained exchanging $U \leftrightarrow D$ and $\hat{t} \leftrightarrow \hat{u}$ in Eq. (11). The PDFs appearing in Eq. (11) are evaluated at a factorization scale $\mu_F = M_W$, and therefore PDFs from CQM calculations, related to low momentum scales, need to be properly evolved. The evolution is performed at Leading Order (LO) by using Dokshitzer-Gribov-Lipatov-Altarelli-Parisi equations. We adopt a variable flavor number scheme and parameters as in the LO version of MSTW08 distribution [24]. In particular heavy quark masses are set to $m_c = 1.4$ GeV and $m_b = 4.75$ GeV, and the one-loop running coupling is fixed at the Z-boson mass scale to be $\alpha_s^{(n_f=5)}(M_Z^2) = 0.13939$ [24]. For PDFs provided by the LF CQM one has

$$f_d(x,Q_0^2) = 1/2 f_u(x,Q_0^2), \quad (12)$$

at the hadronic scale Q_0^2, where three valence quarks carry all proton momentum. Since this scale is generally located in the infrared regime, PDFs evolution and corresponding cross sections are very sensitive to its choice. In the present paper we choose to fix Q_0^2 requiring that σ^+ and σ^-, calculated by using evolved LF PDFs, match the corresponding predictions obtained with the DYNNLO code [25] at LO by using MSTW08 PDFs [24]. For both simulations we set $\sqrt{s} = 13$ TeV and define the muon fiducial phase space in SPS to be $p_T^\mu > 20$ GeV and $|\eta^\mu| < 2.4$. As shown in Fig. 1, considering the cross section summed over the W boson charge, this procedure locates the central value of the initial scale at $Q_0^2 = 0.26$ GeV^2 [where $\alpha_s(Q_0^2) = 1.99$]. We note that, for a given value of Q_0^2, a simultaneous description of σ^+ and σ^- cannot be achieved, a fact which is related to the model assumption for PDFs in Eq. (12), and it is an example of a typical drawback of PDFs CQM predictions. In order to take into account this deficiency and to explore the sensitivity of the cross sections to the particular choice of Q_0^2, we allow it to vary in the range $0.24 < Q_0^2 < 0.28$ GeV^2, where the limits are fixed requiring that cross sections obtained via the LF model reproduce σ^+ and σ^- predicted by DYNNLO (straight lines in Fig. 1). Having fixed Q_0^2 in SPS processes and being dPDFs obtained within the same LF model adopted for PDFs, we can use the same Q_0^2 range for dPDFs. In this way the estimate of DPS cross sections does not require additional parameters. Double PDFs in the LF model are defined at Q_0^2 as [18]

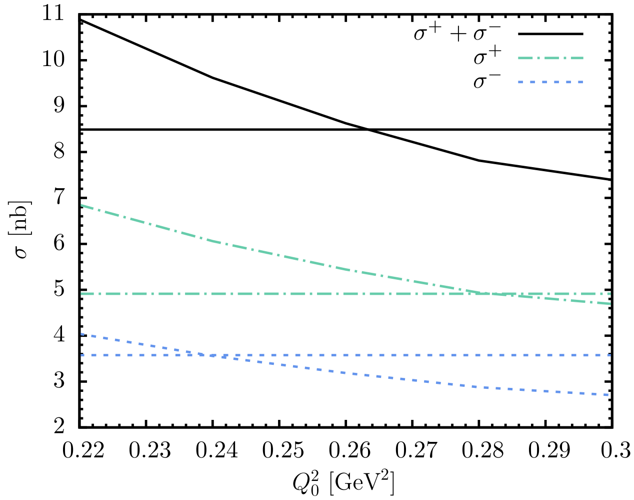

FIG. 1. W production cross sections as predicted by LF PDFs as a function of Q_0^2, compared to DYNNLO predictions (straight lines) at LO by using LO MSTW08 parton distributions in the fiducial region indicated in the text.

$$f_{du} = f_{ud} = f_{uu}(x_1,x_2,Q_0^2,\vec{b}_\perp). \quad (13)$$

At this scale, when integrated over $\vec{b}_\perp$, dPDFs satisfy number and momentum sum rules [16]. Their perturbative QCD evolution is presently known only at leading logarithmic accuracy [26,27]; however, the presence of the so-called inhomogeneous term in the evolution equations is still under investigation [3,17,28]. In the present paper dPDFs are evolved with the same scheme and parameters adopted for PDFs but use homogeneous evolution equations valid at fixed values of $\vec{b}_\perp$ [3,29]. The DPS cross section, Eq. (1), in the $ssWW$ channel reads

$$\begin{aligned}
&\frac{d^4\sigma^{pp\to\mu^\pm\mu^\pm X}}{d\eta_1 dp_{T,1} d\eta_2 dp_{T,2}} \\
&= \sum_{i,k,j,l}\frac{1}{2}\int d^2\vec{b}_\perp \\
&\times D_{ij}(x_1,x_2,\vec{b}_\perp,M_W)D_{kl}(x_3,x_4,\vec{b}_\perp,M_W) \\
&\times \frac{d^2\sigma_{ik}^{pp\to\mu^\pm X}}{d\eta_1 dp_{T,1}}\frac{d^2\sigma_{jl}^{pp\to\mu^\pm X}}{d\eta_2 dp_{T,2}}\mathcal{I}(\eta_i,p_{T,i}). \quad (14)
\end{aligned}$$

The function $\mathcal{I}(\eta_i,p_{T,i})$ in Eq. (14) implements the kinematical cuts reported in Table I, which we borrow from the 8 TeV analysis of Ref. [21]. In particular, the last one, involving the invariant mass of the same sign lepton pair, $M_{\rm inv} = (p_{\mu 1} + p_{\mu 2})^2$, is introduced in the experimental analysis in order to reduce the WZ background. In Eq. (14) we are neglecting the supposed small contributions coming from longitudinally polarized dPDFs [13], effects of color correlations, suppressed at high scales [30], as well as flavor and fermion number interference effects [3,13].

TABLE I. Fiducial DPS phase space used in the analysis.

pp, $\sqrt{s} = 13$ TeV
$p_{T,\mu}^{\mathrm{leading}} > 20$ GeV, $p_{T,\mu}^{\mathrm{subleading}} > 10$ GeV
$\lvert p_{T,\mu}^{\mathrm{leading}}\rvert + \lvert p_{T,\mu}^{\mathrm{subleading}}\rvert > 45$ GeV
$\lvert\eta_\mu\rvert < 2.4$
20 GeV $< M_{\mathrm{inv}} <$ 75 GeV or $M_{\mathrm{inv}} >$ 105 GeV

TABLE II. Model predictions for W-charge summed cross sections in the fiducial region in Table I.

dPDFs	$\sigma^{++} + \sigma^{--}$ [fb]
MSTW	$0.77^{+0.23}_{-0.21}$ $(\delta\mu_F)$ $^{+0.18}_{-0.18}$ $(\delta\bar{\sigma}_{\mathrm{eff}})$
GS09	$0.82^{+0.24}_{-0.26}$ $(\delta\mu_F)$ $^{+0.19}_{-0.19}$ $(\delta\bar{\sigma}_{\mathrm{eff}})$
QM	$0.69^{+0.18}_{-0.18}$ $(\delta\mu_F)$ $^{+0.12}_{-0.16}$ (δQ_0)

Equation (14) will be evaluated with three different models of dPDFs described in the following in order of increasing complexity. In the simplest one, called MSTW, dPDFs are parametrized as products of MSTW08 PDFs according to Eq. (4). In the second one, the so-called GS09 model [16], the factorized form Eq. (4), properly corrected to fulfill dPDFs sum rules, is assumed only at a momentum scale Q_0^2. Such initial conditions are evolved with dPDFs evolution equations with the inhomogenous term included [26,27]. Therefore, with respect to model MSTW, GS09 takes into account additional perturbative correlations [4,16,29,31]. The DPS cross section based on MSTW and GS09 models can be evaluated only assuming a value of σ_{eff} in Eq. (2). In the present work, we will use, as a reference value, $\bar{\sigma}_{\mathrm{eff}} = 17.8 \pm 4.2$ mb, which is the average of two recent extractions [32,33] in the W-boson plus dijet final state, the latter being the closest to the one considered here.

In the last model [18], called QM, dPDFs have been evaluated within the LF framework, generalizing the approach of Ref. [34] for the calculation of PDFs. As a result, fully correlated dPDFs are obtained [18]. In such a model, longitudinal and transverse correlations are generated among valence quarks and propagated by perturbative evolution to sea quark and gluon dPDFs. The use of this model in the present analysis is particularly relevant. First of all, within this model, the DPS cross section can be calculated using Eq. (1), without any assumption on σ_{eff}, at variance with MSTW and GS09. Moreover, the simultaneous use of single and double PDFs obtained from the same LF dynamics, allows one to investigate the role of parton correlations on potentially sensitive observables. Theoretical systematic errors are associated with our predictions as follows. Uncertainties related to missing higher order corrections, denoted by $\delta\mu_F$, are estimated for all models, varying μ_F in the range $0.5M_W < \mu_F < 2.0M_W$; the ones due to Q_0 fixing, denoted by δQ_0, are given by varying this parameter in the range $0.24 < Q_0^2 < 0.28$ GeV^2. A further error, $\delta\bar{\sigma}_{\mathrm{eff}}$, is assigned to MSTW and GS09 predictions, due to $\bar{\sigma}_{\mathrm{eff}}$ uncertainty. In Table II we report DPS cross sections, integrated in the fiducial volume, evaluated using the above models. Predictions based on MSTW and GS09 are close, while the QM one is smaller by around 15%, although they are all consistent within errors.

Our results for the GS09 model are in line with those listed in Table III of Ref. [8], provided the kinematics, kinematical cuts, and values of $\bar{\sigma}_{\mathrm{eff}}$ of Ref. [8], different from ours, are used. In particular, the invariant mass cut used in the present analysis, and not included in Ref. [8], reduces the predicted cross sections by about 30%. Moreover, the different values of $\bar{\sigma}_{\mathrm{eff}}$ (17.8 mb here versus 14.5 mb in Ref. [8]) amounts to a further reduction of 20%. For all the considered models, cross sections rise as μ_F increases, an effect induced by the sea quark growth at $\langle x\rangle \sim 10^{-2}$ (typical of this process). The central values of the QM and GS09 predictions can be discriminated if the error on the measurement, assumed to be one sigma, is smaller than their difference. Assuming that statistical experimental errors follow a Poisson distribution (i.e. they scale as $\sqrt{N_{ev}}$ where N_{ev} is the number of observed events) and the measurement is dominated by statistical uncertainties, by using the predicted values for the integrated cross sections in Table II, a lower limit on the required integrated luminosity needed to discriminate QM and GS09 models is derived to be 300 fb^{-1}. It is worth noting that, if the measurement were performed also in the $e\mu$ $(e\mu + ee)$ channel, the number of signal events would increase by a factor of 3 (4), and the obtained lower limit on the integrated luminosity would decrease.

In Table III, predictions of models GS09 and QM for default values of parameters of charged $ssWW$ cross sections (indicated by σ^{--} and σ^{++}) integrated in the fiducial volume are compared. While agreement between model predictions is found for σ^{++}, a rather smaller σ^{--} is obtained in model QM, due to the assumption in Eq. (10). The ratio σ^{--} and σ^{++} is therefore a suitable observable to investigate the flavor structure of dPDFs.

In Ref. [8], the DPS cross section has been analyzed as a function of the variable $\eta_1 \cdot \eta_2$ which, neglecting the boost generated by W decay into leptons, can be approximated via Eqs. (10) as

$$\eta_1 \cdot \eta_2 \simeq \frac{1}{4} \ln\frac{x_1}{x_3} \ln\frac{x_2}{x_4}, \tag{15}$$

TABLE III. Ratio of cross sections for same sign muons production in the fiducial region.

dPDFs	σ^{++} [fb]	σ^{--} [fb]	σ^{++}/σ^{--}
GS09	0.54	0.28	1.9
QM	0.53	0.16	3.4
GS09/QM	1.01	1.78	

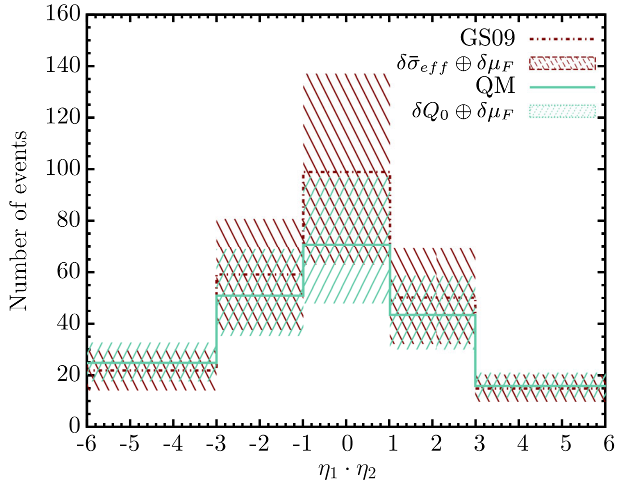

FIG. 2. Number of expected events with $\mathcal{L}^{-1} = 300$ fb^{-1} as a function of the product of muon rapidities.

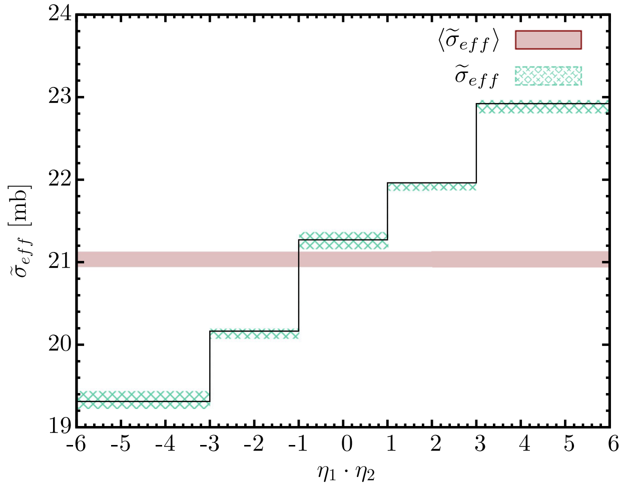

FIG. 3. $\tilde{\sigma}_{\rm eff}$ and $\langle\tilde{\sigma}_{\rm eff}\rangle$ as a function of the product of muon rapidities. The error band represents scale variations added in quadrature.

where fractional momenta are subject to the invariant mass constraint $x_1 x_3 = x_2 x_4 = M_W^2/s$. Our result for the DPS cross section, differential in $\eta_1 \cdot \eta_2$ and converted into per bin number of events assuming an integrated luminosity $\mathcal{L} = 300$ fb^{-1}, is presented in Fig. 2. The maximun is located at $\eta_1 \cdot \eta_2 \sim 0$, where annihilating partons equally share the momentum fractions, $x \sim M_W/\sqrt{s}$, in at least one scattering. At large and positive (negative) values of $\eta_1 \cdot \eta_2$, muons are produced in the same (opposite) hemisphere, and the fast drop of the cross section is associated with the fall off of dPDFs as one ($\eta_1 \cdot \eta_2 \ll 0$) or both ($\eta_1 \cdot \eta_2 \gg 0$) partons in the same proton approach the large x limit. We note that predictions based on GS09 and QM models show a rather similar shape and are compatible within their sizable errors. To deal with such large uncertainties, differential cross sections, normalized to the total ones (Table II), may be considered. In this way, the predictions of MSTW and GS09 models do not depend any more on the particular value of $\sigma_{\rm eff}$ and the corresponding error cancels. Moreover, for model QM, we verified that the scale variations $\delta\mu_F$ and δQ_0, acting basically on normalizations, almost cancel in the ratio as well. A shape comparison can then be used to discriminate among models and their factorized structure. In the present analysis, however, we prefer to discuss the effects of correlations on a more familiar quantity, $\sigma_{\rm eff}$, showing its dependence on $\eta_1 \cdot \eta_2$.

To this aim we use the LF approach for both PDFs and dPDFs to evaluate SPS and DPS differential cross sections, Eqs. (11) and (14), respectively, integrated in bins of $\eta_1 \cdot \eta_2$. With these ingredients we obtain, through Eq. (2), a prediction for $\sigma_{\rm eff}$ intrinsic to the LF model, called hereafter $\tilde{\sigma}_{\rm eff}$. If a corresponding procedure is performed on cross sections integrated in the fiducial volume, one obtains the constant value

$$\langle\tilde{\sigma}_{\rm eff}\rangle = 21.04^{+0.07}_{-0.07}(\delta Q_0)\,^{+0.06}_{-0.07}(\delta\mu_F)\ \text{mb}. \tag{16}$$

This value is compatible, within errors, with $\bar{\sigma}_{\rm eff}$ experimentally determined. Both $\tilde{\sigma}_{\rm eff}$ and $\langle\tilde{\sigma}_{\rm eff}\rangle$ are shown in Fig. 3 and, being ratios, are both stable against μ_F and Q_0 variations. The departure of $\tilde{\sigma}_{\rm eff}$ from a constant value is a measure of two parton correlations in the proton. These are primarily correlations in longitudinal momenta but, as shown using the fully correlated model QM, they are related to the ones in transverse space in an irreducible way [35]. Given the trend of $\tilde{\sigma}_{\rm eff}$ displayed in Fig. 3, a nonconstant behavior of the latter can be appreciated if its values in the first and last bins differ by more than one sigma. Imposing this condition and again assuming that the future measurements will be dominated by statistical uncertainties, a lower limit on the required integrated luminosity is derived to be 1000 fb^{-1}, reachable in the planned LHC runs. It is worth noting that this limit would decrease if measurements were performed also in the $e\mu$ and $(e\mu + ee)$ channels.

Our conclusion is that this observable analyzed as a function of $\eta_1 \cdot \eta_2$ is a convenient one to look for parton correlations.

Summarizing, we have calculated $ssWW$ cross sections in a LF model for dPDFs, carefully estimating the corresponding uncertainties. Our predictions, completely intrinsic to the approach, are in line with those obtained by other approaches which make use of the external parameter $\sigma_{\rm eff}$. This indicates that, since the DPS cross section is given by an integral over the transverse relative positions of the partons in the nucleon [cf. Eq. (1)], the model is able to catch such a global transverse structure. Furthermore, we have established that, in this specific final state, transverse and longitudinal correlations, embodied in dPDFs, could be observed in the next LHC runs.

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