DIS 2016

FORWARD PRODUCTION OF DRELL-YAN DILEPTONS AT HIGH ENERGIES AND LOW DILEPTON INVARIANT MASSES IN A k_t-FACTORIZATION APPROACH: DO WE SEE ONSET OF SATURATION?

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Contents

The work is based on our recent analysis:
W. Schäfer and A.S., arXiv:1602.06740,
Phys. Rev. **D92** (2016) in print.

Where the dipole formulae apply ?
Do we observe a sign of saturation ?

Introduction

1. The Drell-Yan process is one of important sources of the partonic structure
2. Drell-Yan production of low invariant masses in forward direction could be a good place in searching for onset of (gluon) saturation because small-x region
   (Brodsky et al., Gelis and Jalilian-Marian, ...)
3. Color dipole model with parametrized dipole-nucleon cross section in the so-called mixed representation inspired by saturation is often used.
   Only some observables available,
   not full kinematics, no experimental cuts on individual kinematical variables of leptons available
4. k_t-factorization with unintegrated quark/antiquark distribution functions (Szczurek-Slipek, Nefedov-Nikolaev-Saleev, Baranov-Lipatov-Zotov) was also used at mid rapidities.
5. At forward/backward directions (low-x) gluon distributions have to be taken into account (formally higher order).
6. A hybrid (collinear-k_t-factorization) approach is proposed using UGDFs

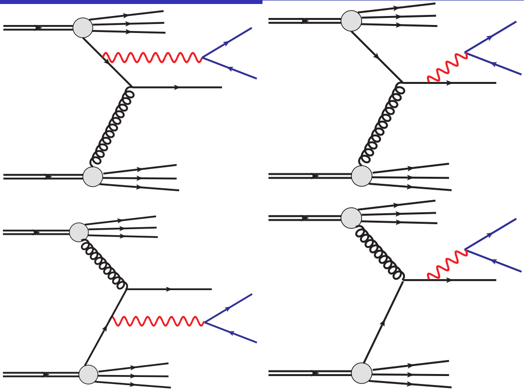
DIPOLE APPROACH TO THE DRELL-YAN PROCESS

- Brodsky, Hebecker, Quack, Phys. Rev. D55, 2584 (1997)
- Kopeliovich, Tarasov, Schäfer, Phys. Rev. C59, 1609 (1999)
- Betemps, Ducati, Machado, Phys. Rev. D66 014018 (2002)
- Betemps, Ducati, Machado, Raufeisen, Phys. Rev. D67 114008 (2003)
- Golec-Biernat, Lewandowska, Stasto, Phys. Rev. D82, 094010 (2010)
- Ducati, Griep, Machado, Phys. Rev. D66, 094014 (2014)
- Motyka, Sadzikowski, Stebel, JHEP 05, 087 (2015)
  (twist expansion and agular distributions)
- Basso, Goncalves, Nemchik, Pasechnik, Sumbera, Phys. Rev. D93, 034023 (2016) (also for Z boson production)

Short personal summary and critical remarks

- All in the so-called mixed (transverse position space) representation, use saturation inspired parametrizations of dipole-nucleon cross section.
- Approximate kinematics - only variables of the diphoton explicit (α and $p_{t,pair}$), associated jet not included in calculating x.
- Only one-side contribution included
- Not sufficient when cuts on individual leptons required.
- So far applied to rather low energies and midrapidities where the formalism does not apply.

Forward and backward production of dilepton pairs



Rysunek: The diagrams relevant for forward and backward production of dilepton pairs.

Similar diagrams as in the dipole approach.

INCLUSIVE LEPTON PAIR PRODUCTION

We have obtained in our recent paper the following formula for the inclusive dilepton cross section as

$$\frac{d\sigma(pp \to l^+ l^- X)}{dx_+ dx_- d^2\boldsymbol{k}_+ d^2\boldsymbol{k}_-} = \frac{\alpha_{\rm em}}{(2\pi)^2 M^2} \frac{x_F}{x_+ x_-} \Big\{ \Sigma_T(x_F, \boldsymbol{q}, M^2) D_T\left(\frac{x_+}{x_F}\right)$$
$$+ \Sigma_L(x_F, \boldsymbol{q}, M^2) D_L\left(\frac{x_+}{x_F}\right)$$
$$+ \Sigma_\Delta(x_F, \boldsymbol{q}, M^2) D_\Delta\left(\frac{x_+}{x_F}\right)\left(\frac{\boldsymbol{l}}{|\boldsymbol{l}|} \cdot \frac{\boldsymbol{q}}{|\boldsymbol{q}|}\right)$$
$$+ \Sigma_{\Delta\Delta}(x_F, \boldsymbol{q}, M^2) D_{\Delta\Delta}\left(\frac{x_+}{x_F}\right)\left(2\left(\frac{\boldsymbol{l}}{|\boldsymbol{l}|} \cdot \frac{\boldsymbol{q}}{|\boldsymbol{q}|}\right)^2 - 1\right)\Big\} \,. \quad (1)$$

We use the light-cone parametrization of particle momenta:

$$k^\pm_\mu = x_\pm \sqrt{\frac{S}{2}}\, n^+_\mu + \frac{\boldsymbol{k}^2_\pm}{x_\pm \sqrt{2S}}\, n^-_\mu + k^\pm_{\perp\mu} \,,$$
$$q_\mu = x_F \sqrt{\frac{S}{2}}\, n^+_\mu + \frac{M^2 + \boldsymbol{q}^2}{x_F \sqrt{2S}}\, n^-_\mu + q_{\perp\mu} \,. \quad (2)$$

so that

Inclusive lepton pair production

Finally, the functions $\Sigma_i(x_F, \boldsymbol{q}, M^2), i \in \{T, L, \Delta, \Delta\Delta\}$ parametrize the density matrix of production of the massive photon. Expressed in terms of helicity eigenstates, we have for the density matrix

$$\rho_{\lambda\lambda'} \frac{d\sigma(pp \to \gamma^*(M^2)X)}{dx_F d^2\boldsymbol{q}} = \frac{1}{x_F} \frac{\alpha_{\rm em}}{8\pi^2 S} W_{\mu\nu} \epsilon_\mu^{(\lambda)} \epsilon_\nu^{(\lambda')*} \,. \tag{6}$$

Or

$$\rho_{\lambda\lambda'} = \frac{W_{\mu\nu} \epsilon_\mu^{(\lambda)} \epsilon_\nu^{(\lambda')*}}{2W_T + W_L} \,, \; \rho_{++} + \rho_{--} + \rho_{00} = 1 \,. \tag{7}$$

Above we used the components

$$\Sigma_i(x_F, \boldsymbol{q}, M^2) = \rho_i \frac{d\sigma(pp \to \gamma^*(M^2)X)}{dx_F d^2\boldsymbol{q}} \equiv \frac{1}{x_F} \frac{\alpha_{\rm em}}{8\pi^2 S} W_i \,, \; i \in T, L, \Delta, \Delta\Delta \,. \tag{8}$$

THE PARTON LEVEL PROCESS: $qp \to \gamma^* X$

As we are interested in the “forward region” of phase space, it is reasonable to assume that the most important degrees of freedom will be quarks and antiquarks from one of the protons and small-x gluons from the second one.

$$\hat{\rho}_{\lambda\lambda'} \frac{d\hat{\sigma}(qp \to \gamma^*(z,\boldsymbol{q})X)}{dz d^2\boldsymbol{q}} = \frac{1}{2(2\pi)^2} \overline{\sum_{\sigma,\sigma'}} \int d^2\boldsymbol{r} d^2\boldsymbol{r}' \exp[-i\boldsymbol{q}(\boldsymbol{r}-\boldsymbol{r}')] \psi^{(\lambda)}_{\sigma\sigma'}(z,\boldsymbol{r}) \psi^{(\lambda')*}_{\sigma\sigma'}(z,\boldsymbol{r}') \times \Big(\sigma(x_2, z\boldsymbol{r}) + \sigma(x_2, z\boldsymbol{r}') - \sigma(x_2, z(\boldsymbol{r}-\boldsymbol{r}')) \Big) . \quad (9)$$

The light-front wave functions for the $q_\sigma \to \gamma^*_\lambda q'_\sigma$ transition (here σ, σ', λ denote the helicities of particles) read:

$$\psi^{(\lambda)}_{\sigma\sigma'}(z,\boldsymbol{r}) = \int \frac{d^2\boldsymbol{q}}{(2\pi)^2} \exp[-i\boldsymbol{r}\boldsymbol{q}] \psi^{(\lambda)}_{\sigma\sigma'}(z,\boldsymbol{q})$$

$$= e_q \sqrt{z(1-z)} \int \frac{d^2\boldsymbol{q}}{(2\pi)^2} \exp[-i\boldsymbol{r}\boldsymbol{q}] \frac{\bar{u}_{\sigma'}(1-z,-\boldsymbol{q}) \epsilon^{(\lambda)*}_\mu \gamma_\mu u_\sigma(1,\boldsymbol{0})}{\boldsymbol{q}^2 + \varepsilon^2} \quad (10)$$

with $\varepsilon^2 = (1-z)M^2 + z^2 m_q^2$.

THE PARTON LEVEL PROCESS: $qp \to \gamma^* X$

To derive the momentum-space k_T-factorization representation, we use the relation of the dipole cross section with the unintegrated gluon distribution

$$\sigma(x, \boldsymbol{r}) = \frac{1}{2} \int d^2\boldsymbol{\kappa} \, f(x, \boldsymbol{\kappa})(1 - \exp[i\boldsymbol{\kappa r}])(1 - \exp[-i\boldsymbol{\kappa r}]) \, . \tag{11}$$

Where $f(x, \boldsymbol{\kappa})$ is

$$f(x, \boldsymbol{\kappa}) = \frac{4\pi\alpha_S}{N_c} \frac{1}{\boldsymbol{\kappa}^4} \frac{\partial G(x, \boldsymbol{\kappa}^2)}{\partial \log \boldsymbol{\kappa}^2} \, . \tag{12}$$

Inserting (10) and (11) into Eq. (11), we obtain:

$$\hat{\rho}_{\lambda\lambda'} \frac{d\hat{\sigma}(qp \to \gamma^*(z, \boldsymbol{q})X)}{dz d^2\boldsymbol{q}} = \frac{1}{2(2\pi)^2} \overline{\sum_{\sigma,\sigma'}} \int d^2\boldsymbol{\kappa} f(x_2, \boldsymbol{\kappa})$$
$$\Big(\psi^{(\lambda)}_{\sigma\sigma'}(z, \boldsymbol{q}) - \psi^{(\lambda)}_{\sigma\sigma'}(z, \boldsymbol{q} - z\boldsymbol{\kappa})\Big)\Big(\psi^{(\lambda')}_{\sigma\sigma'}(z, \boldsymbol{q}) - \psi^{(\lambda')}_{\sigma\sigma'}(z, \boldsymbol{q} - z\boldsymbol{\kappa})\Big)^* \tag{13}$$

THE PARTON LEVEL PROCESS: $qp \to \gamma^* X$

From here, we obtain the impact-factor representation for the elements of the density matrix of production Σ_i, where $i = T, L, \Delta, \Delta\Delta$,

$$\hat{\Sigma}_i(z, \boldsymbol{q}, M^2) = \hat{\rho}_i \frac{d\hat{\sigma}(qp \to \gamma^*(z, \boldsymbol{q})X)}{dz d^2\boldsymbol{q}} = \frac{e_q^2 \alpha_{\rm em}}{2N_c} \int \frac{d^2\boldsymbol{\kappa}}{\pi \boldsymbol{\kappa}^4} \tag{14}$$

$$\alpha_S(\bar{q}^2) \mathcal{F}(x_2, \boldsymbol{\kappa}^2)\, I_i(z, \boldsymbol{q}, \boldsymbol{\kappa}), \tag{15}$$

with

$$I_T(z, \boldsymbol{q}, \boldsymbol{\kappa}) = \frac{1 + (1-z)^2}{z} |\boldsymbol{\Phi}|^2 + z^3 m_q^2 \Phi_0^2,$$
$$I_L(z, \boldsymbol{q}, \boldsymbol{\kappa}) = \frac{4(1-z)^2 M^2}{z} \Phi_0^2,$$
$$I_\Delta(z, \boldsymbol{q}, \boldsymbol{\kappa}) = \frac{2(2-z)(1-z)M}{z} \Big(\frac{\boldsymbol{q}}{|\boldsymbol{q}|} \cdot \boldsymbol{\Phi} \Big) \Phi_0,$$
$$I_{\Delta\Delta}(z, \boldsymbol{q}, \boldsymbol{\kappa}) = \frac{2(1-z)}{z} \Big(|\boldsymbol{\Phi}|^2 - 2\Big(\frac{\boldsymbol{q}}{|\boldsymbol{q}|} \cdot \boldsymbol{\Phi} \Big)^2 \Big), \tag{16}$$

where

k_T-FACTORIZATION FORM

To go to the hadron level, we will assume the collinear factorization on the quark side and write, choosing a factorization scale $\mu^2 \sim \boldsymbol{q}^2 + \varepsilon^2$ and include transverse momenta on the gluon side:

$$\Sigma_i(x_F, \boldsymbol{q}, M) = \sum_f \int dx_1 dz \, \delta(x_F - zx_1) \left[q_f(x_1, \mu^2) + \bar{q}_f(x_1, \mu^2) \right] \hat{\Sigma}_i(z, \boldsymbol{q}, M^2) \, .$$

$$= \sum_f \frac{e_f^2 \alpha_{\rm em}}{2N_c} \int_{x_F}^1 dx_1 \left[q_f(x_1, \mu^2) + \bar{q}_f(x_1, \mu^2) \right]$$

$$\int \frac{d^2 \boldsymbol{\kappa}_2}{\pi \boldsymbol{\kappa}_2^4} \mathcal{F}(x_2, \boldsymbol{\kappa}_2^2) \alpha_S(\bar{q}^2) I_i \left(\frac{x_F}{x_1}, \boldsymbol{q}, \boldsymbol{\kappa}_2 \right) .$$

k_T-FACTORIZATION FORM

The full dilepton cross section is then

$$\frac{d\sigma(pp\to l^+l^-X)}{dy_+dy_-d^2\boldsymbol{k}_+d^2\boldsymbol{k}_-} = x_+x_-\frac{d\sigma(pp\to l^+l^-X)}{dx_+dx_-d^2\boldsymbol{k}_+d^2\boldsymbol{k}_-}$$

$$= \frac{\alpha_{\rm em}^2}{8\pi^2 N_c M^2}\sum_f e_f^2\int_{x_F}^1 dx_1\left[x_1q_f(x_1,\mu^2)+x_1\bar{q}_f(x_1,\mu^2)\right]$$

$$\int\frac{d^2\boldsymbol{\kappa}_2}{\pi\boldsymbol{\kappa}_2^4}\mathcal{F}(x_2,\boldsymbol{\kappa}_2^2)\alpha_S(\bar{q}^2)$$

$$\left\{\frac{x_F}{x_1}I_T\left(\frac{x_F}{x_1},\boldsymbol{q},\boldsymbol{\kappa}_2\right)D_T\left(\frac{x_+}{x_F}\right)\right.$$

$$+\frac{x_F}{x_1}I_L\left(\frac{x_F}{x_1},\boldsymbol{q},\boldsymbol{\kappa}_2\right)D_L\left(\frac{x_+}{x_F}\right)$$

$$+\frac{x_F}{x_1}I_\Delta\left(\frac{x_F}{x_1},\boldsymbol{q},\boldsymbol{\kappa}_2\right)D_\Delta\left(\frac{x_+}{x_F}\right)\left(\frac{\boldsymbol{l}}{|\boldsymbol{l}|}\cdot\frac{\boldsymbol{q}}{|\boldsymbol{q}|}\right)$$

$$\left.+\frac{x_F}{x_1}I_{\Delta\Delta}\left(\frac{x_F}{x_1},\boldsymbol{q},\boldsymbol{\kappa}_2\right)D_{\Delta\Delta}\left(\frac{x_+}{x_F}\right)\left(2\left(\frac{\boldsymbol{l}}{|\boldsymbol{l}|}\cdot\frac{\boldsymbol{q}}{|\boldsymbol{q}|}\right)^2-1\right)\right\}.$$

k_T-FACTORIZATION FORM

If we also want to include the recoiling jet - insert

$$dx_J \delta(x_J + x_F - x_1)\, d^2\boldsymbol{k}_J\, \delta^{(2)}(\boldsymbol{\kappa}_2 - \boldsymbol{q} - \boldsymbol{k}_J)\,. \qquad (18)$$

This gives us the fully differential distribution

$$\begin{aligned} \frac{d\sigma(pp \to l^+l^-X)}{dy_+ dy_- dy_J d^2\boldsymbol{k}_+ d^2\boldsymbol{k}_- d^2\boldsymbol{k}_J} &= \frac{\alpha_{\rm em}^2}{8\pi^3 N_c M^2} \frac{x_F x_J}{x_F + x_J} \\ &\times \sum_f e_f^2 \Big[q_f(x_F + x_J, \mu^2) + \bar{q}_f(x_F + x_J, \mu^2) \Big] \\ &\frac{\alpha_S(\bar{q}^2)\mathcal{F}(x_2, \boldsymbol{q} + \boldsymbol{k}_J)}{(\boldsymbol{q} + \boldsymbol{k}_J)^4} \\ &\times \Big\{ I_T^f\Big(\frac{x_F}{x_F + x_J}, \boldsymbol{q}, \boldsymbol{q} + \boldsymbol{k}_J\Big) D_T\Big(\frac{x_+}{x_F}\Big) \\ &+ I_L^f\Big(\frac{x_F}{x_F + x_J}, \boldsymbol{q}, \boldsymbol{q} + \boldsymbol{k}_J\Big) D_L\Big(\frac{x_+}{x_F}\Big) \\ &+ I_\Delta^f\Big(\frac{x_F}{x_F + x_J}, \boldsymbol{q}, \boldsymbol{q} + \boldsymbol{k}_J\Big) D_\Delta\Big(\frac{x_+}{x_F}\Big)\Big(\frac{\boldsymbol{l}}{|\boldsymbol{l}|} \cdot \frac{\boldsymbol{q}}{|\boldsymbol{q}|}\Big) \\ &+ I_{\Delta\Delta}^f\Big(\frac{x_F}{x_F + x_J}, \boldsymbol{q}, \boldsymbol{q} + \boldsymbol{k}_J\Big) D_{\Delta\Delta}\Big(\frac{x_+}{x_F}\Big)\Big[2\Big(\frac{\boldsymbol{l}}{|\boldsymbol{l}|} \cdot \frac{\boldsymbol{q}}{|\boldsymbol{q}|}\Big)^2 - 1\Big]\Big\}\,. \end{aligned} \qquad (19)$$

KINEMATICS

Rapidities are obtained as:

$$y_i = \log\left(\frac{x_i\sqrt{S}}{\sqrt{\boldsymbol{k}_i^2}}\right) \leftrightarrow x_i = \sqrt{\frac{\boldsymbol{k}_i^2}{S}} \cdot e^{y_i}\,, i = +,-,J\,. \qquad (20)$$

The longitudinal momentum fractions x_1, x_2 entering the quark and gluon distributions are

$$\begin{aligned} x_1 &= \sqrt{\frac{\boldsymbol{k}_+^2}{S}}e^{y_+} + \sqrt{\frac{\boldsymbol{k}_-^2}{S}}e^{y_-} + \sqrt{\frac{\boldsymbol{k}_J^2}{S}}e^{y_J}\,, \\ x_2 &= \sqrt{\frac{\boldsymbol{k}_+^2}{S}}e^{-y_+} + \sqrt{\frac{\boldsymbol{k}_-^2}{S}}e^{-y_-} + \sqrt{\frac{\boldsymbol{k}_J^2}{S}}e^{-y_J}\,. \end{aligned} \qquad (21)$$

The invariant mass of the dilepton system is

$$M^2 = m_{\perp+}^2 + m_{\perp-}^2 + 2m_{\perp+}m_{\perp-}\cosh(y_+ - y_-) - \boldsymbol{q}^2\,, \;\; m_{\perp\pm} = \sqrt{\boldsymbol{k}_\pm^2 + m_\pm^2}\,. \qquad (22)$$

FOURIER TRANSFORM OF DIPOLE - NUCLEON CROSS SECTION

The dipole cross section is related to the unintegrated glue as

$$\sigma(x,\boldsymbol{r}) = \frac{4\pi}{N_c}\int \frac{d^2\boldsymbol{\kappa}}{\boldsymbol{\kappa}^4}\alpha_S \mathcal{F}(x,\boldsymbol{\kappa})\Big\{1-\exp(i\boldsymbol{\kappa}\boldsymbol{r})\Big\}\,. \tag{23}$$

The parametrizations of Albacete et al. are presented in the form

$$\sigma(x,\boldsymbol{r}) = \sigma_0\cdot N(x,\boldsymbol{r})\,, \tag{24}$$

with $N(x,\boldsymbol{r})\to 1$ at large $\boldsymbol{r}$. We can therefore easily obtain, that

$$\frac{\alpha_S\mathcal{F}(x,\boldsymbol{\kappa})}{\boldsymbol{\kappa}^4} = \frac{\sigma_0 N_c}{4\pi}\int\frac{d^2\boldsymbol{r}}{(2\pi)^2}\exp(-i\boldsymbol{\kappa}\boldsymbol{r})\Big[1-N(x,\boldsymbol{r})\Big]\,, \tag{25}$$

or

$$\mathcal{F}(x,\boldsymbol{\kappa}) = \frac{\sigma_0 N_c}{8\pi^2}\frac{\boldsymbol{\kappa}^2}{\alpha_S(\boldsymbol{\kappa}^2)}\int_0^\infty r dr J_0(\kappa r)\Big[1-N(x,\boldsymbol{r})\Big], \tag{26}$$

where $J_0(x)$ is the Bessel function. The Fourier-Bessel (or Hankel-) transform (26) can pose severe numerical problems, if values at large κ^2 are required. For the evaluations of these integrals we use

UGDFs used

We use the following UGDFs:

- Kimber-Martin-Ryskin UGDF,
  transverse momentum in the last step of evolution
- Kutak-Staśto UGDF,
  includes nonlinear effects
- Albacete, Armesto, Milhano, Salgado
  - solving BK evolution equation and Fourier transform.
- Golec-Biernat UGDF,
  saturation inspired parametrization of photon-nucleon cross section.

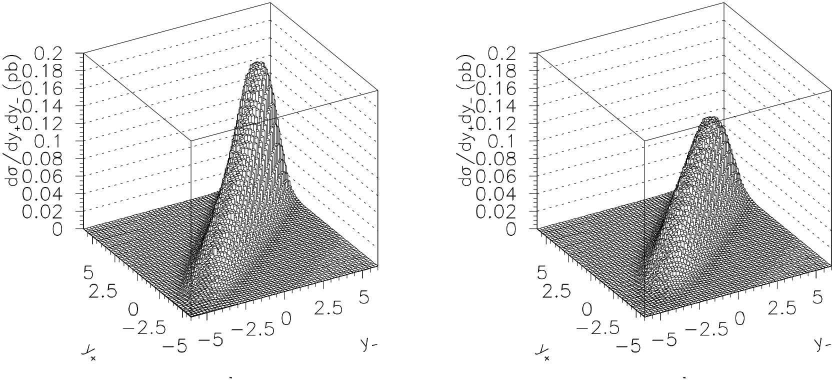
Parton distributions

In the present calculations we use MSTW08 distributions to generate the KMR unintegrated gluon distributions. Here we use numerical implementation by Maciuła and Szczurek used e.g. in the production of charm and double charm.
For the quark and antiquark distributions we use MSTW08 leading-order distributions. For most of the calculations we used M_{ll}^2 both as a factorization and renormalization scales. We have also tried:

$$\begin{aligned} \mu_R^2 &= \max\left(\kappa_\perp^2, q_\perp^2 + \varepsilon^2\right) \, , \\ \mu_F^2 &= q_\perp^2 + \varepsilon^2 \, . \end{aligned} \tag{27}$$

The corresponding results turned out to be almost identical.

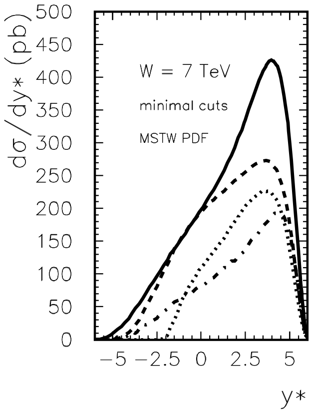
FULL RAPIDITY RANGE



RYSUNEK: Two-dimensional (y_+, y_-) distribution for $\sqrt{s}$ = 7 TeV and $k_{T+}, k_{T-} > 3$ GeV for MSTW08 PDF and KMR (left) and KS (right) UGDFs.

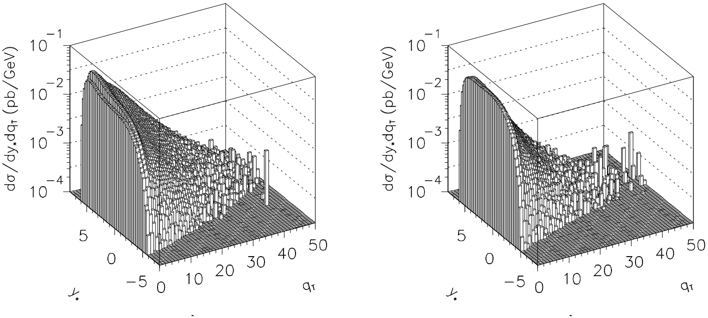
The rapidities of both leptons are strongly correlated i.e. $y_+ \approx y_-$.

FULL RAPIDITY RANGE



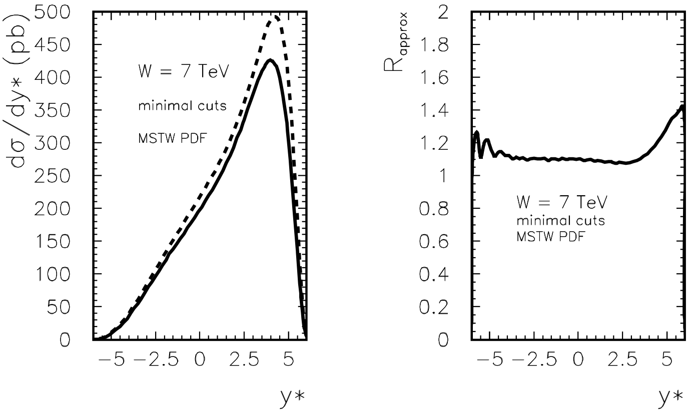
RYSUNEK: Distribution in rapidity of the dileptons for $\sqrt{s}$ = 7 TeV and $k_{T+}, k_{T-} > 3$ GeV for MSTW08 PDF and different UGDFs: KMR (solid), KS (dashed), AAMS (dotted) and GBW (dash-dotted).

FULL RAPIDITY RANGE



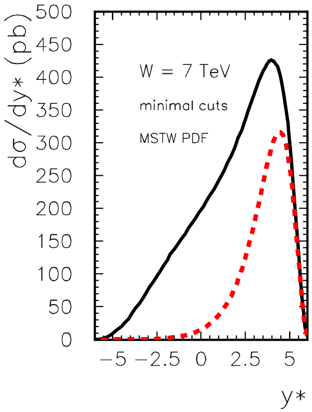
RYSUNEK: Two-dimensional (y_*, q_T) distribution for $\sqrt{s}$ = 7 TeV and $k_{T+}, k_{T-} > 3$ GeV for MSTW08 PDF and KMR (left) and KS (right) UGDF.

Full rapidity range



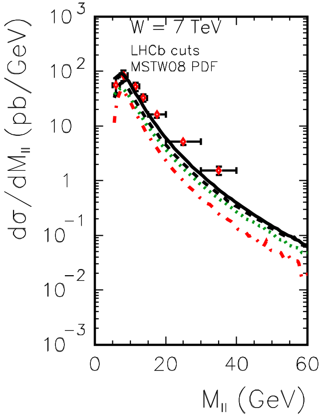
Rysunek: Distribution in y_* for exact (solid) and approximate (dashed) formula for calculating x_1 and x_2 for $\sqrt{s}$ = 7 TeV and $k_{T+}, k_{T-} > 3$ GeV for MSTW08 PDF and KMR UGDF. In the right panel we show the ratio of the two distributions.

Full rapidity range



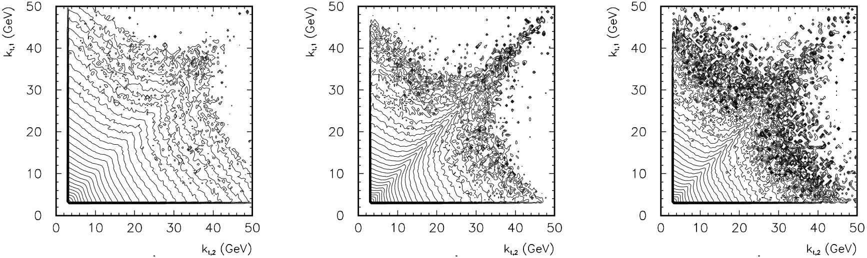
Rysunek: Distribution in rapidity of the dileptons for $\sqrt{s}$ = 7 TeV and $k_{T+}, k_{T-} > 3$ GeV for MSTW08 valence quark distributions and KMR UGDFs. The dashed line is the contribution from valence quarks only.

FORWARD REGION - LHCB



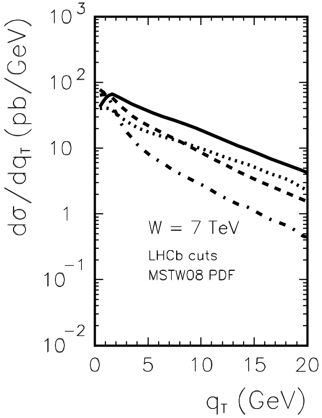
RYSUNEK: Invariant mass distribution (only the dominant component) for the LHCb cuts: $2 < y_+, y_- < 4.5$, $k_{T+}, k_{T-} > 3$ GeV for different UGDFs: KMR (solid), Kutak-Stasto (dashed), AAMS (dotted) and GBW (dash-dotted).

FORWARD REGION - LHCB



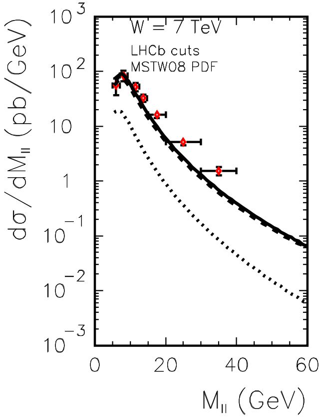
RYSUNEK: Two-dimensional (k_{T+}, k_{T-}) distribution for $\sqrt{s}$ = 7 TeV and $k_{T+}, k_{T-} > 3$ GeV for MSTW08 PDF and KMR (left), KS (middle) and AAMS (right) UGDFs.

FORWARD REGION - LHCB



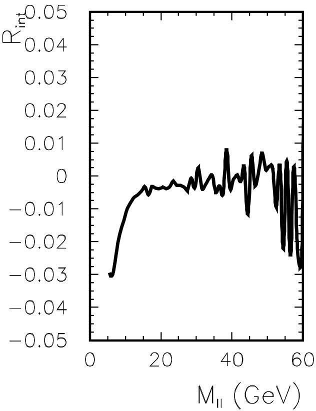
RYSUNEK: Dilepton transverse momentum distribution (only the dominant component) for the LHCb cuts: $2 < y_+, y_- < 4.5$, $k_{T+}, k_{T-} > 3$ GeV for different UGDFs: KMR (solid), Kutak-Stasto (dashed), AAMS (dotted) and GBW (dash-dotted).

FORWARD REGION - LHCB



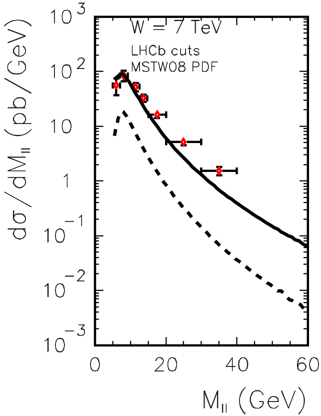
RYSUNEK: The T and L contributions to the dilepton invariant mass distribution for the LHCb kinematics: $2 < y_+, y_- < 4.5$, $k_{T+}, k_{T-} > 3$ GeV. KMR UGDF was used here.

Forward region - LHCb



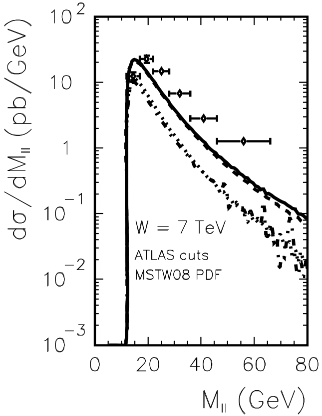
Rysunek: The R_{int} as a function of M_{ll} for the LHCb kinematics: $2 < y_+, y_- < 4.5$, $k_{T+}, k_{T-} > 3$ GeV. KMR UGDF was used here. The fluctuations are due to insufficient statistics of our Monte Carlo calculation.

FORWARD REGION - LHCB



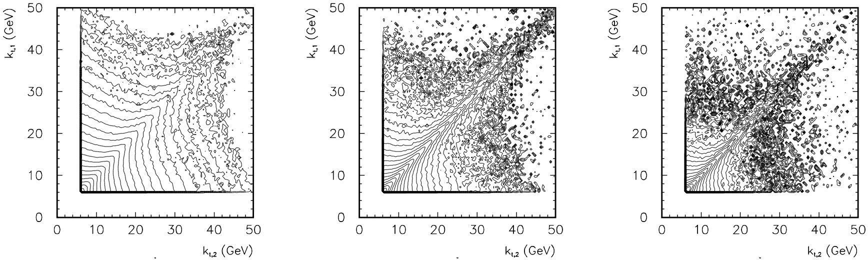
RYSUNEK: Contributions of the second-side component for the LHCb kinematics: $2 < y_+, y_- < 4.5$, $k_{T+}, k_{T-} > 3$ GeV. KMR UGDF was used here.

MIDRAPIDITY REGION - ATLAS



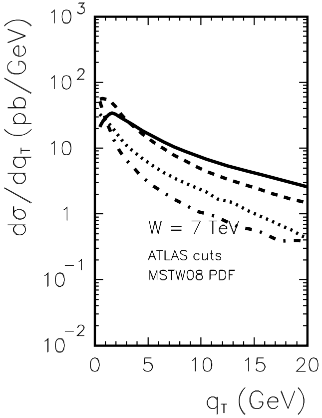
RYSUNEK: Invariant dilepton mass distribution for the ATLAS kinematics: -2.4 $< y_+, y_- <$ 2.4, $k_{T+}, k_{T-} >$ 6 GeV. Here both $gq/\bar{q}$ and $q/\bar{q}g$ contributions have been included.

MIDRAPIDITY REGION - ATLAS



RYSUNEK: Lepton transverse momentum correlations for the ATLAS kinematics: -2.4 $< y_+, y_- <$ 2.4, $k_{T+}, k_{T-} >$ 6 GeV. The left panel is for the KMR UGDF, the middle panel for the KS UGDF and the right panel for the AAMS UGDF.

Midrapidity region - ATLAS



Rysunek: Transverse momentum distribution of dileptons for the ATLAS kinematics: -2.4 $< y_+, y_- <$ 2.4, $k_{T+}, k_{T-} >$ 6 GeV for MWST08 PDF and for different UGDFs: KMR (solid), KS (dashed), AAMS (dotted) and GBW (dash-dotted).

Conclusions

- Forward production of low-mass dileptons has been discussed
- Correponding momentum space formula has been derived and presented
- In contrast to the dipole formalism correct treatment of kinematics and can be applied to the analysis of real experiment
- We have obtained four terms instead of two terms in the traditional dipole approach.
- A program which includes $2 \to 3$ subprocesses has been written. Correlation between a jet and leptons can be calculated
- Calculation of differential cross section for experimental conditions have been performed.
- General tendencies have been shown.
- The results have been compared with LHCb and ATLAS data.
- Critical remarks to dipole model applications have been made

Conclusions

- The saturation inspired UGDFs fail to describe LHCb and ATLAS data
- KMR UGDF (relation to DGLAP approach) is much better
- Some strenght at large M_{ll} is missing (lack of meson cloud)
- Both side contributions have to be included (even for LHCb) in contrast to calculations in dipole model in the literature
- Contribution of different terms (L, T, etc) strongly depends on kinematics
- New interference terms rather small
- Meson cloud effects missing here as well as in dipole approach
- No clear hints of saturation at small M_{ll}

Thank You

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