UINTEGRATED GLUON DISTRIBUTION AND SATURATION EFFECT IN P-P AT LHC

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in collaboration with

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and

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OUTLINE

1. Soft p-p collisions
2. Gluon distribution in proton
3. Modified unintegrated gluon distribution
4. Saturation of gluon density at low transfer
5. Summary

The inclusive spectrum is presented in the following form:

$$\rho(x=0, p_t) = \rho_q(x=0, p_t) + \rho_g(x=0, p_t)$$

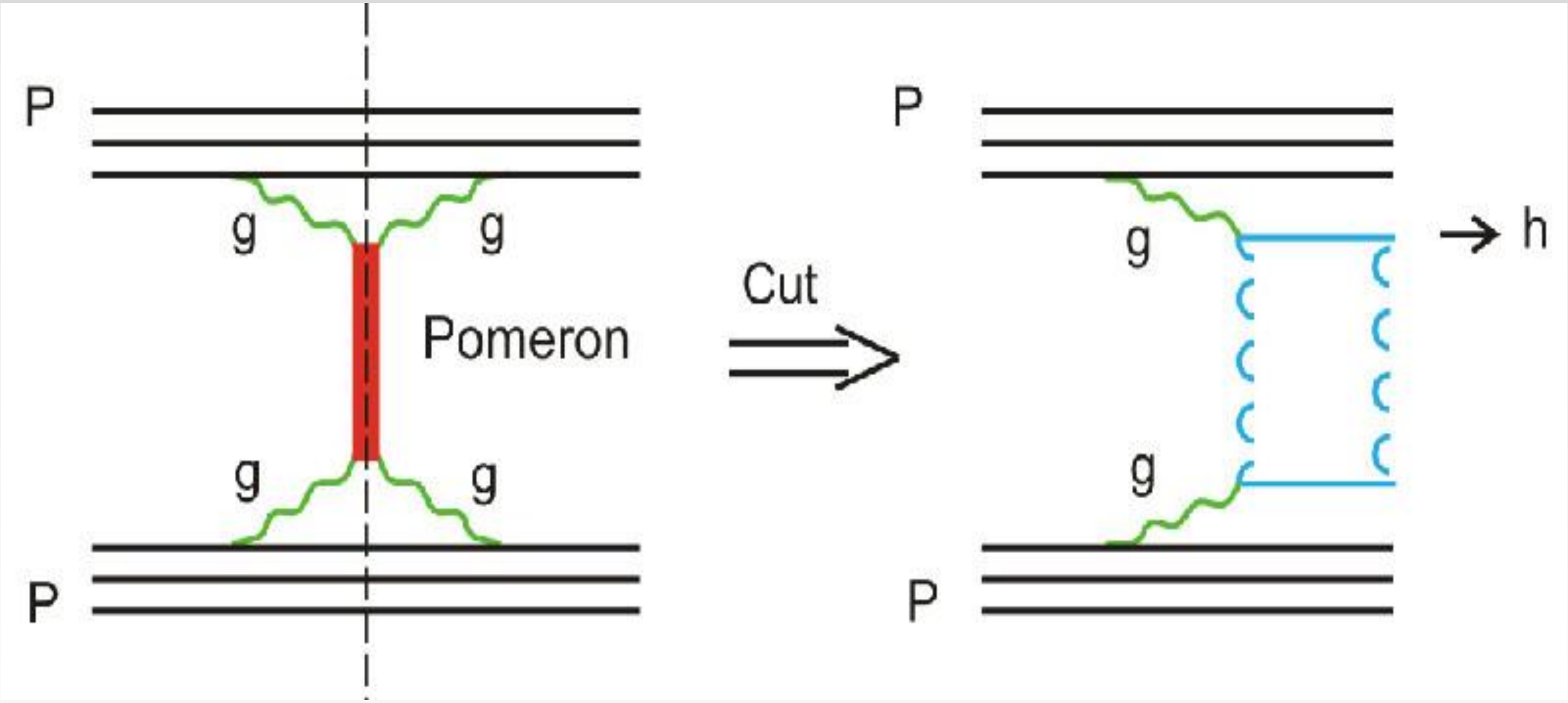
Here $\rho_q = g\left(\frac{s}{s_0}\right)^{\Delta} \varphi_q; \varphi_q(0, p_t) = A_q \exp(-b_q p_t)$

$$\rho_g = g\left[\left(\frac{s}{s_0}\right)^{\Delta} - \sigma_{nd}\right]\varphi_g; \varphi_g(0, p_t) = \sqrt{p_t} A_g \exp(-b_g p_t)$$

$A_q = 11.91 \pm 0.39$, $b_q = 7.29 \pm 0.11$ $g \approx 21$ mb

$A_g = 3.76 \pm 0.13$ $b_g = 3.51 \pm 0.02$ $\Delta \approx 0.12$

V.A. Bednyakov, A.V. Grinyuk, G.L., M. Poghosyan, Int. J.Mod.Phys. A 27 (2012) 1250012. hep-ph/11040532 (2011); hep-ph/1109.1469 (2011); Nucl.Phys. B 219 (2011) 225.



One-Pomeron exchange (left) and the cut one-Pomeron exchange (right); P-proton, g-gluon, h-hadron produced in PP

In the light cone dynamics the proton has a general decomposition:

$|uud\rangle, |uudg\rangle, |uudq\bar{q}\rangle, \ldots$ S.J.Brodsky, C.Peterson, N.Sakai, Phys.Rev. D 23 (1981) 2745.

The cut one-pomeron exchange

$$\rho(x, p_{ht}) = F(x_+, p_{ht}) F(x_-, p_{ht})$$

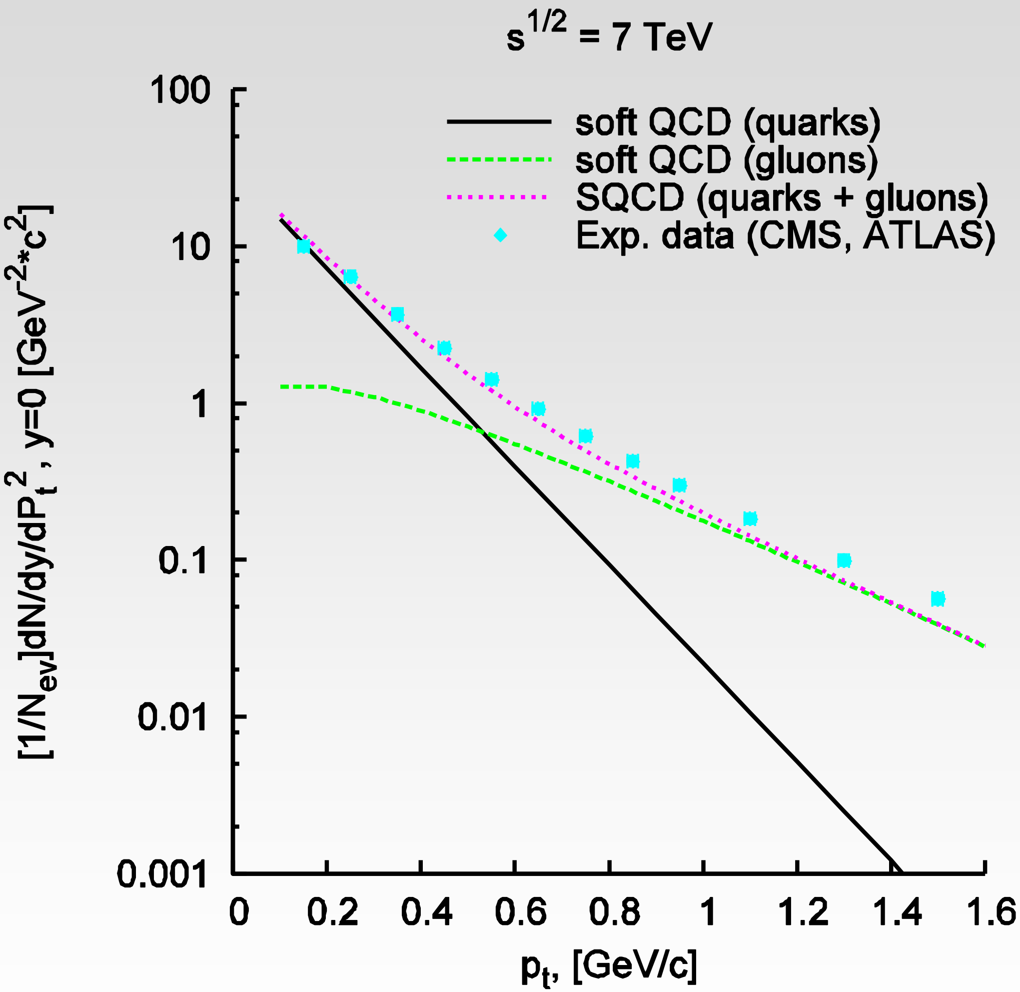
Here

$$F(x_+, p_{ht}) = \int dx_1 \int d^2 k_{1t} \, f_{Pq}(x_1, k_{1t}) G_q^h\left(\frac{x_+}{x_1}, p_{ht} - k_{1t}\right)$$

where

$$G_q^h(z, k_t) = z D_q^h(z, k_t) \qquad f_q = g \otimes P_{g-q\bar{q}}$$

where $P_{g-q\bar{q}}$ is the splitting function of a gluon to the quark-antiquark pair



s^1/2 = 7 TeV
soft QCD (quarks)
soft QCD (gluons)
SQCD (quarks + gluons)
Exp. data (CMS, ATLAS)
[1/N_ev]dN/dy/dP_t^2, y=0 [GeV^-2*c^2]
p_t, [GeV/c]
100
10
1
0.1
0.01
0.001
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

UN-INTEGRATED GLUON DISTRIBUTION IN PROTON

$$xA\left(x,k_t^2,Q_0^2\right)=\frac{3\sigma_0}{4\pi^2\alpha_s}R_0^2(x)\,k_t^2\exp\left(-R_0^2(x)\,k_t^2\right) ,$$

where $R_0=C_1(x/x_0)^{\lambda/2}$, $C_1=1/\mathrm{GeV}$

K.Golec-Biernat & M.Wuesthoff, Phys.Rev. D60, 114023 (1999); Phys.Rev. D59, 014017 (1998)

H.Jung, hep-ph/0411287, Proc. DIS'2004 Strbske Pleco, Slovakia

$$xg(x,k_t,Q_0)=C_0 C_3 (1-x)^{b_g}\left(R_0^2(x)k_t^2+C_2\left(R_0(x)k_t\right)^a\right)$$
$$\exp\left(-R_0(x)k_t-d\left(R_0(x)k_t\right)^3\right),$$

where

$$C_0=3\sigma_0/\left(4\pi^2\alpha_s\left(Q_0^2\right)\right)$$

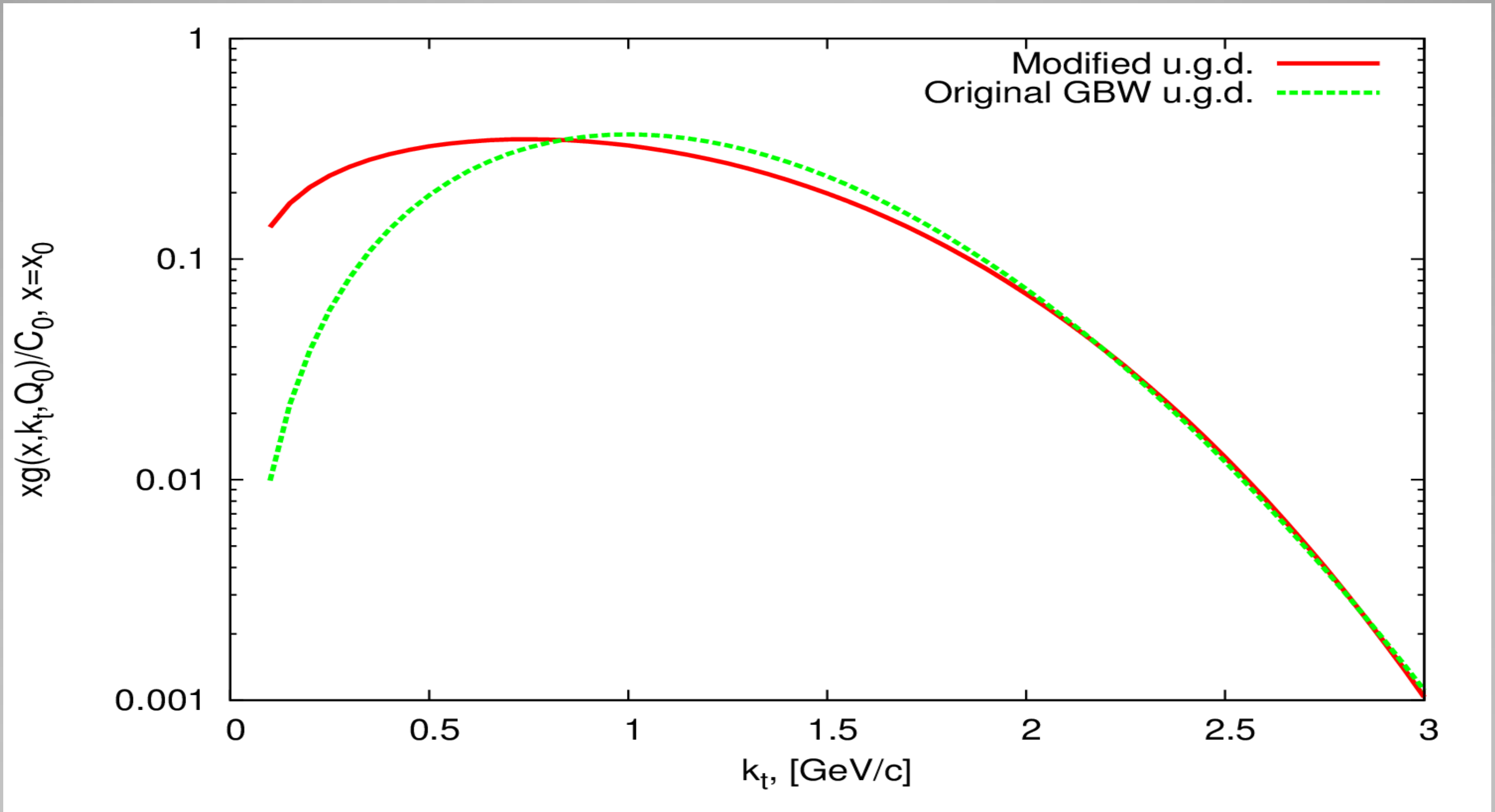
The coefficient C_3 is found from the relation

$$xg(x,Q_0^2)=\int_0^{Q_0^2} xg(x,k_t^2,Q_0^2)\,dk_t^2$$

A.Grinyuk, H.Jung, G.L., A.Lipatov, N.Zotov, hep-ph/1203.0939; Proc.MPI-11, DESY, Hamburg, 2012.

At $k_t -> 0$ our UGD goes to zero as k_t^a where $a<1$

It has been confirmed by B.I.Ermolaev, V.Greco, S.I.Troyan, Eur.Phys.J. C 72 (2012) 1253; hep-ph/1112.1854.

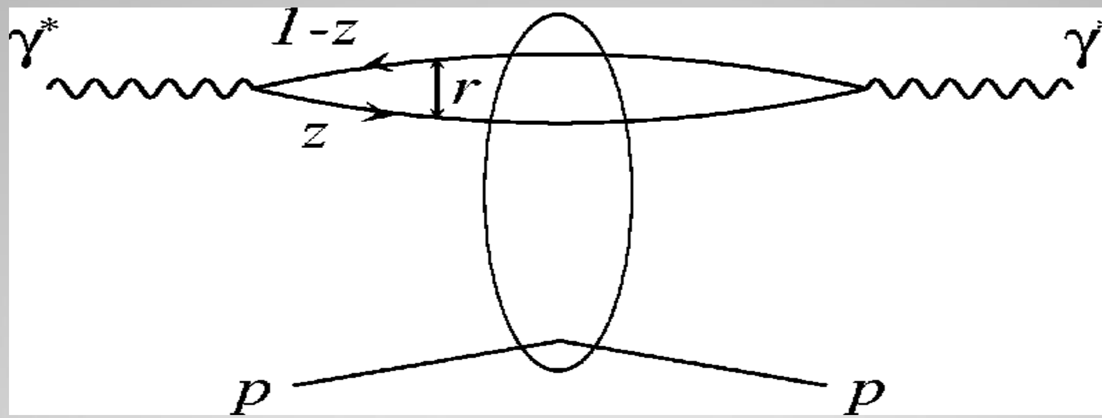


Green line is the GBW u.g.d. K. Golec-Biernat & M. Wuesthoff, Phys.Rev.D60, 114023 (1999).

Red line is the modified u.g.d. A.Grinyuk, H.Jung, G.L., A.Lipatov, N.Zotov, hep-ph/1203.0939; Proc.MPI-11, DESY, Hamburg, 2012.

K. Golec-Biernat, M Wuesthoff , Phys.Rev. D60, 114023 (1999); D59, 014017 (1998)

Saturation dynamics



$$\sigma_{dipole}^{GBW}(x,r) = \sigma_0 \left\{ 1 - \exp\left(-\frac{r^2}{4R_0^2} \right) \right\}$$

$R_0 = GeV^{-1}(x/x_0)^{\lambda/2}$ at $x < x_0$ we have $\sigma_{dipole} \approx \sigma_0$

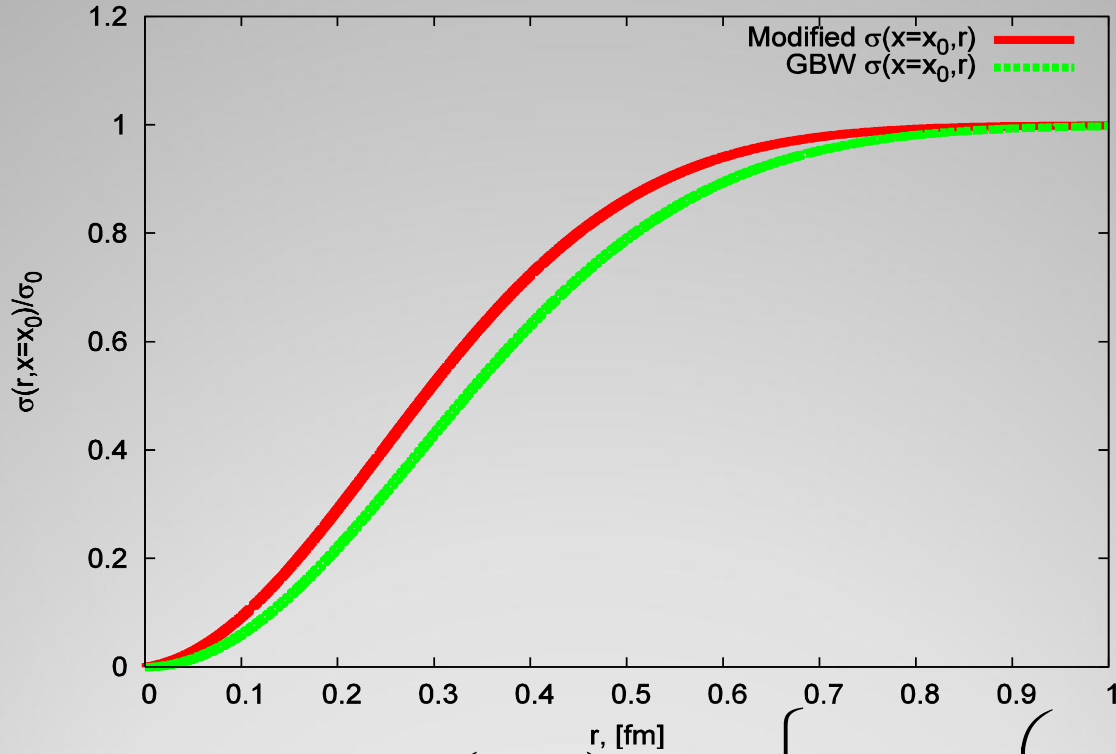
Saturation becomes when $r \sim 2R_0$. It leads to $\sigma_T \sim \sigma_0$ when $QR_0 < 1$ or $Q < 1/R_0$

Effective dipole cross section and unintegrated gluon distribution

$$\sigma_{dipole}(x,r)=\frac{4\pi}{3}\int\frac{dk_t^2}{k_t^2}\left[1-J_0(k_t,r)\right]\alpha_s xg(x,k_t)$$

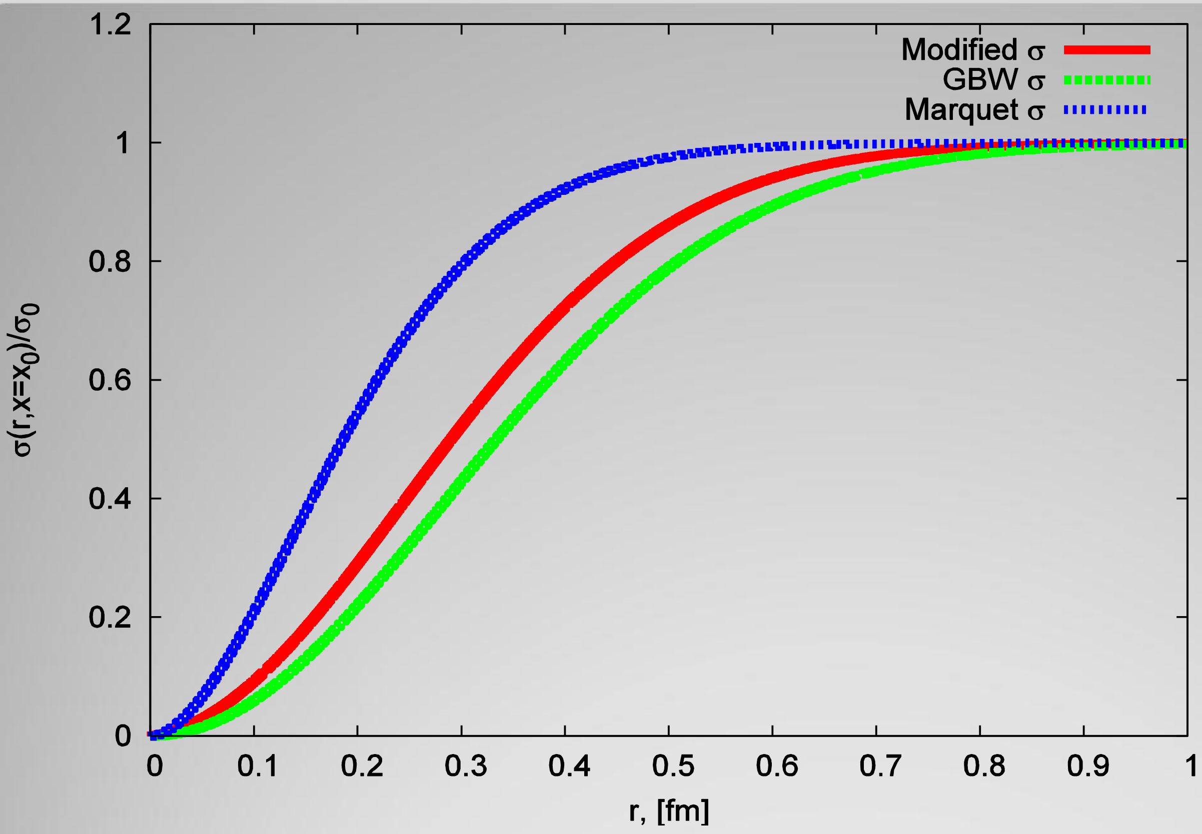
Here α_s is the QCD running constant, J_0 is the Bessel function of the zero order.

Effective dipole cross section



Green line: $\sigma^{GBW}_{dipole}(x,r) = \sigma_0 \left\{ 1 - \exp\left(-\frac{r^2}{4R_0^2(x)} \right) \right\}$

Red line: $\sigma^{GBW}_{dipole}(x,r) = \sigma_0 \left\{ 1 - \exp\left(-\frac{a_1 r}{R_0(x)} - \frac{a_2 r^2}{R_0^2(x)} \right) \right\}$

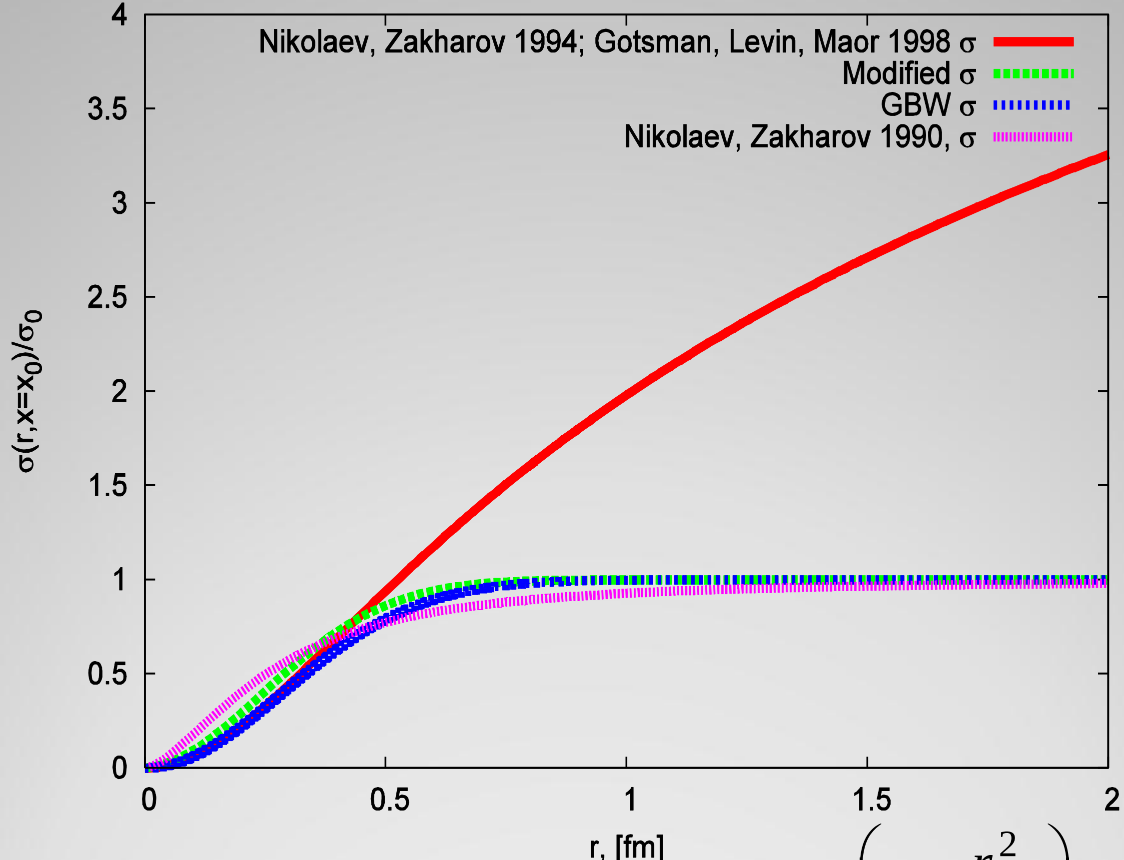


Javier L. Albacete, Cyrille Marquet, arXiv:1001.137 [hep-ph]

Blue line corresponds to

$$\sigma_{dipole}^{AM} = \sigma_0 \left\{ 1 - \exp\left[-\frac{r^2}{4R_0^2} \ln\left(\frac{1}{\Lambda r} + e \right) \right] \right\}; \Lambda = 0.24 GeV = 1.2\, fm^{-1}; R_0 = 1 GeV^{-1} = 0.2\, fm$$

Effective dipole cross section

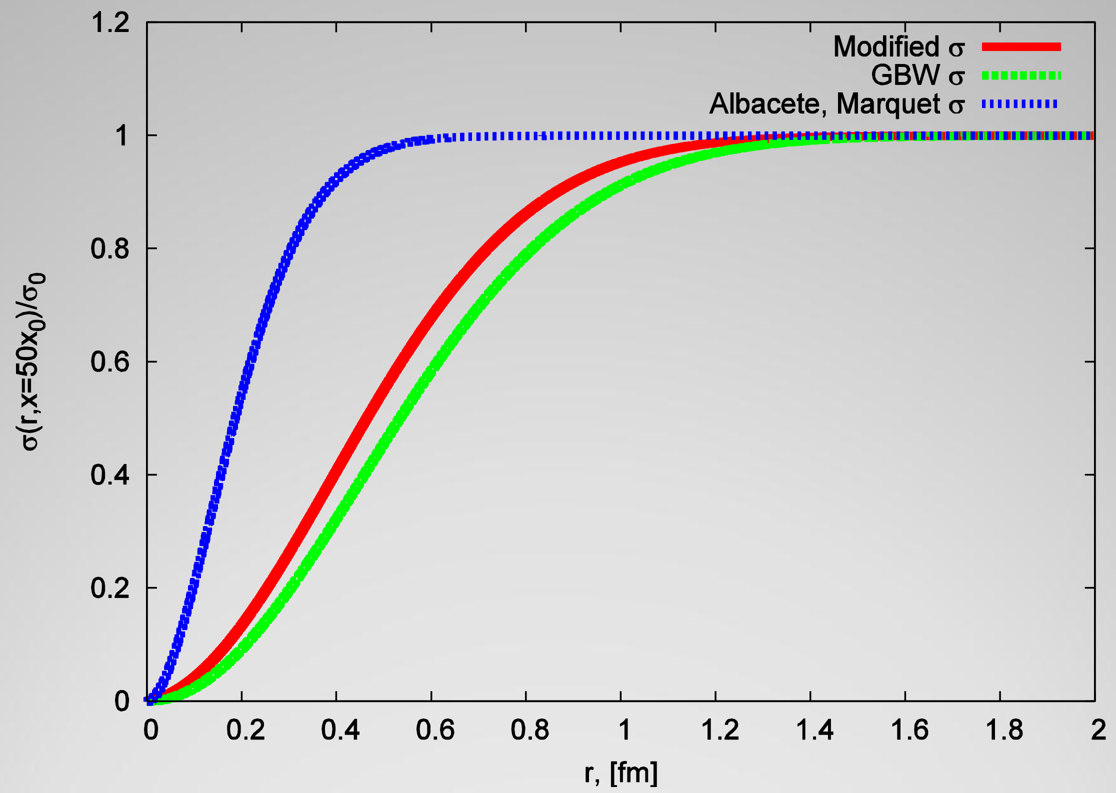


Red line corresponds to $\sigma_{dipole} = \sigma_0 \ln\left(1 + \frac{r^2}{4R_0^2}\right)$

SUMMARY

1. The unintegrated gluon distribution in proton at low intrinsic transverse momenta is calculated and their parameters were found from the best fit to the LHC data.
2. At large intrinsic transverse momenta it coincides to the distributions found by GBW, H.Jung and others and at low ones it differs sizably.
3. Using the modified U.G.D. we study the saturation of the dipole-nucleon cross section at large transverse distance r between q and $\bar{q}$ in the dipole.
4. We show that this cross section is saturated more faster if we use the modified U.G.D. In comparison to the conventional U.G.D of type GBW.
5. We found that the saturation scale Q is larger that the one obtained within the GBW model.
6. LHC data in the soft kinematical region allow us to verify this saturation scale

THANK YOU VERY MUCH FOR YOUR ATTENTION !



Modified σ
GBW σ
Albacete, Marquet σ
σ(r,x=50x0)/σ0
r, [fm]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Kt-factorization

Photo-production cross section

$$\sigma = \int \frac{dz}{z} d^2 k_t \, \sigma_{part}\left(\frac{x}{z}, k_t^2\right) F\left(z, k_t^2\right)$$

Here $F\left(z, k_t^2\right)$ is the un-integrated parton density function,
$\sigma_{part}\left(x/z, k_t^2\right)$ is the partonic cross section.

Classification scheme:

$xF\left(x, k_t^2\right)$ is used by BFKL

$xA\left(x, k_t^2, \bar{Q}^2\right)$ describes the CCFM type UGD with an additional factorization scale $\bar{Q}$ (such as $\alpha_s\left(\bar{Q}^2\right) \leq 1$)

$xG\left(x, k_t^2\right)$ describes the DGLAP type UGD

Longitudinal structure function within the kt-factorization

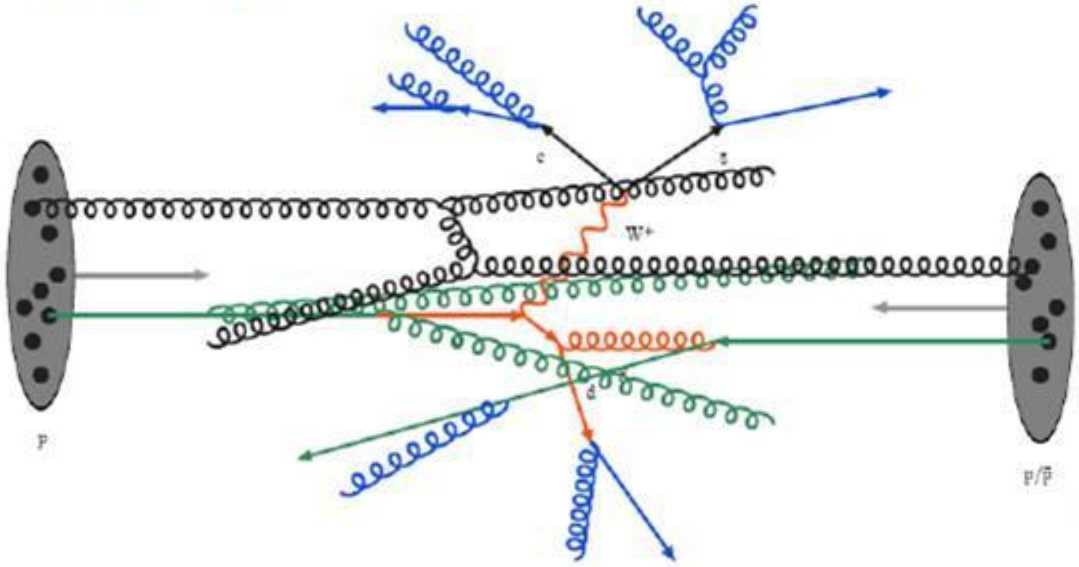
$$F_L(x,Q^2)=\int_x^1 \frac{dz}{z}\int_0^{Q^2} dk_t^2 \sum_{i=u,d,s} e_i^2 C_L^g\left(\frac{x}{z},Q^2,m_i^2,k_t^2\right)\phi_g(z,k_t^2),$$

$$\phi_g(x,k_t^2)=xg(x,k_t^2), \quad xg(x,Q^2)=xg(x,Q_0^2)+\int_{Q_0^2}^{Q^2} dk_t^2\phi_g(x,k_t^2)$$

A.V. Kotikov, A.V. Lipatov, N.P. Zotov, Eur.Phys.J., C27 92003)219.
H. Jung, A.V. Kotikov, A.V. Lipatov, N.P. Zotov, DIS 2007, hep-ph/07063793.

Structure of an event

- Multiple parton-parton interactions



DIAGRAMS in *pp* collisions within QGSM

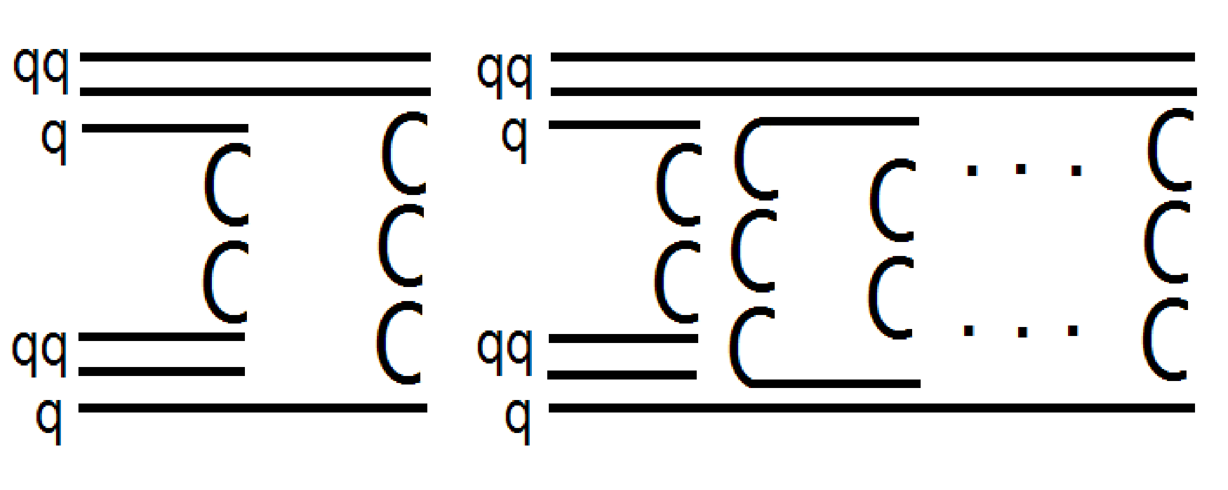


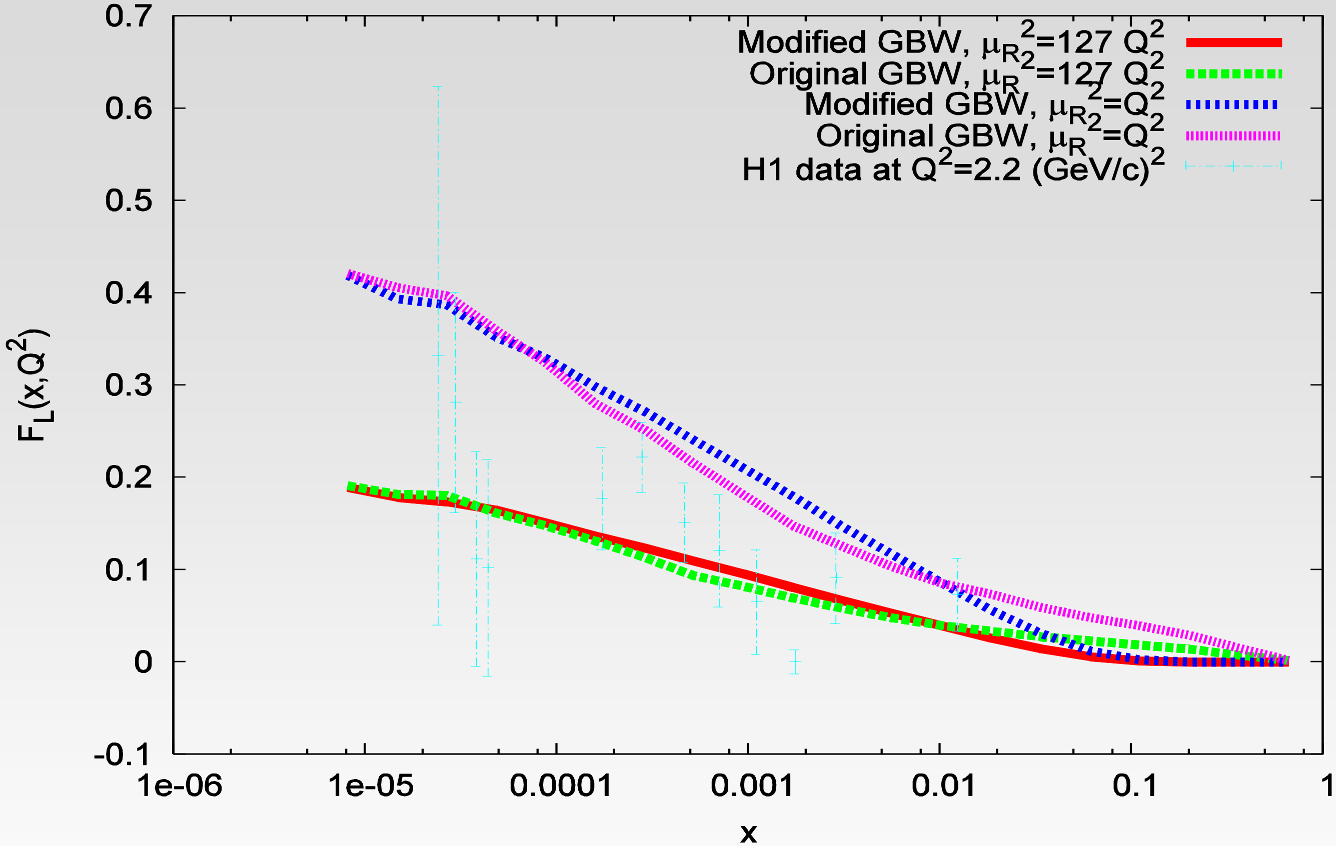
Fig. 1. The one-cylinder graph (at the left) and the multi-cylinder graph (at the right) for the inclusive *pp* → hX process.

QGSM

A.B.Kaidalov, Phys.Lett., B116, 459 (1982)
A.B.Kaidalov, K.A.Ter-Martirosyan, Phys.Lett., B117, 247 (1982)

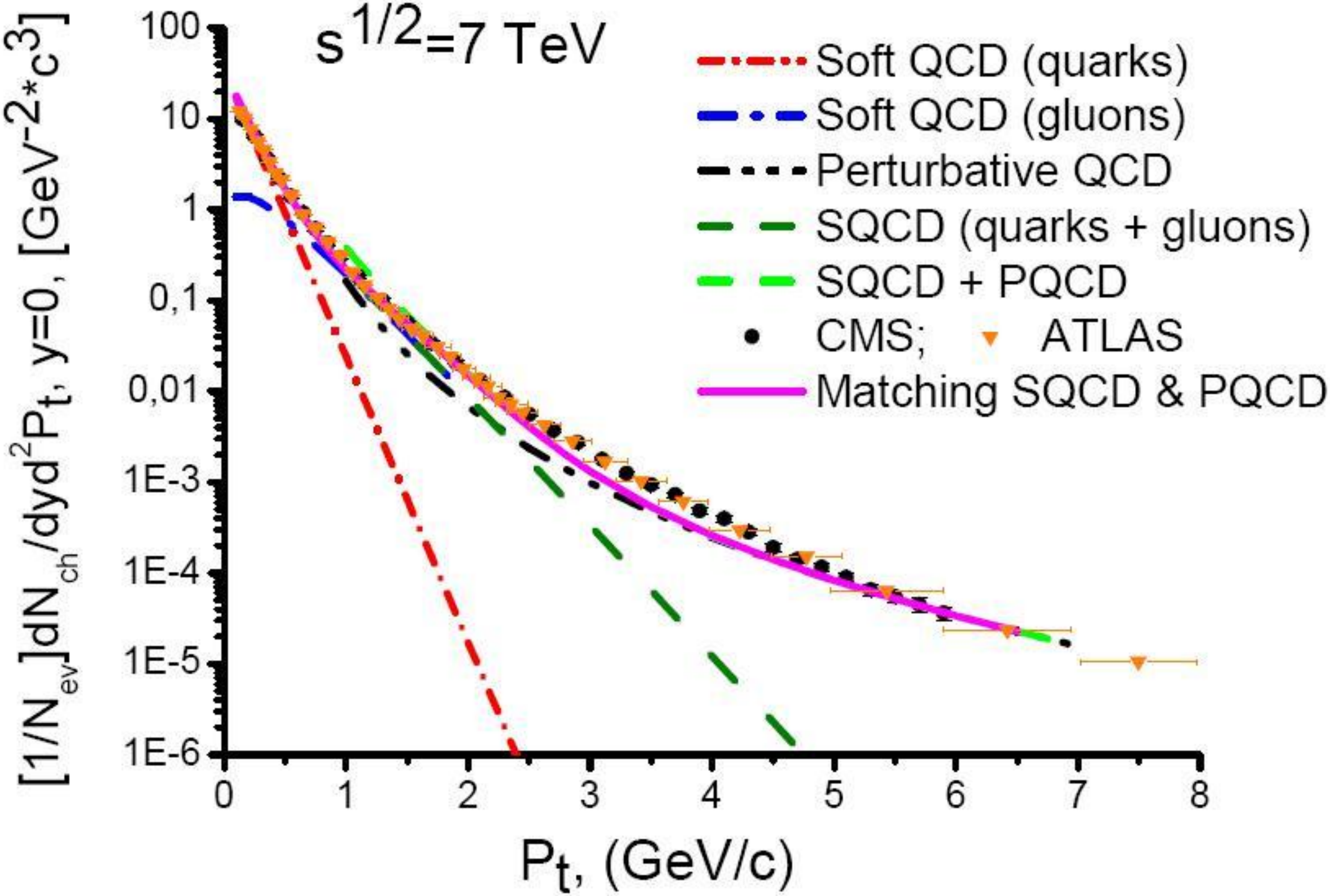
DPM

A.Capella, J.Tran Thanh Van, Phys.Lett., B114, 450 (1982)



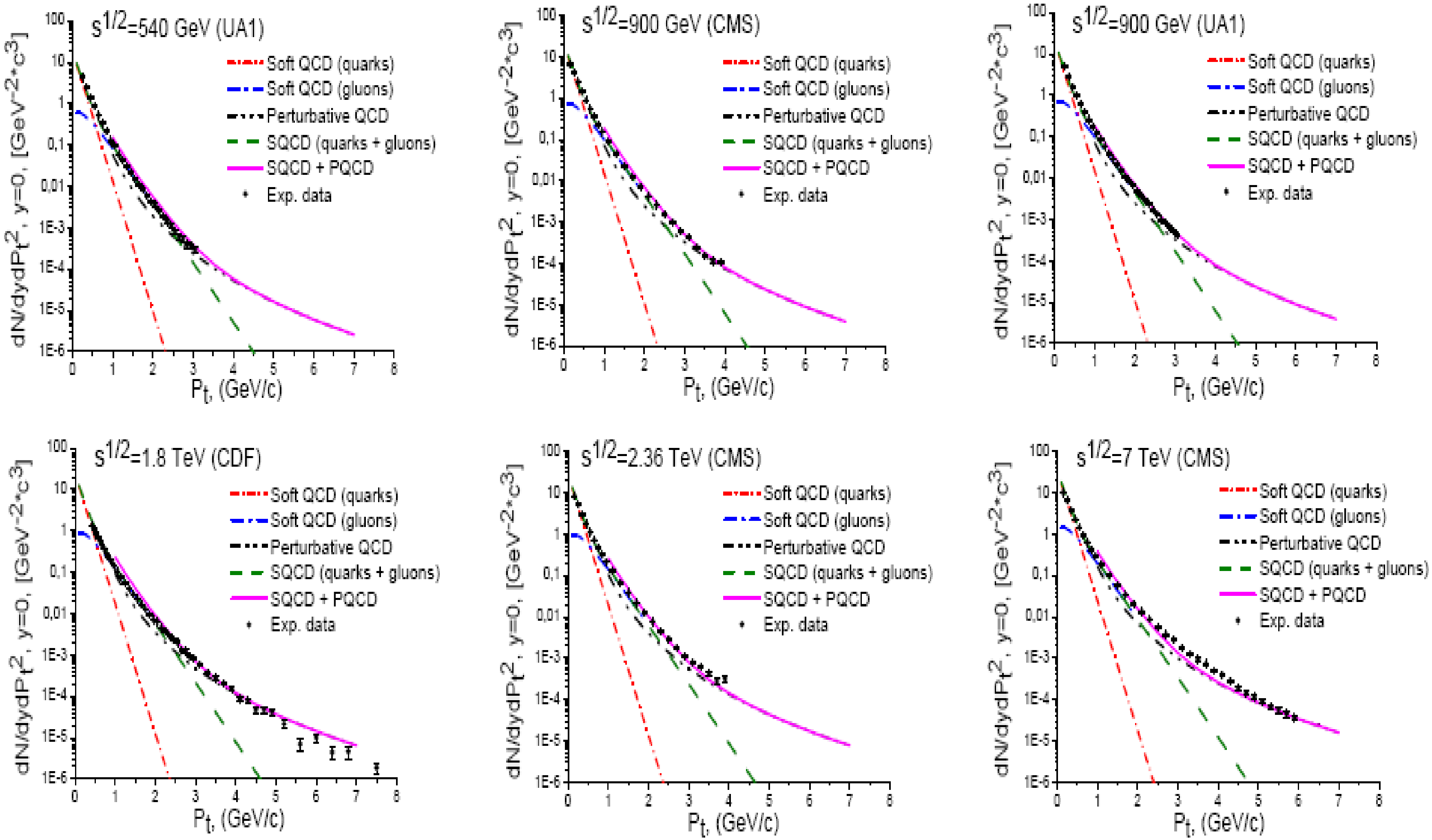
The x-dependence of F_L at $Q^2=2.2(GeV/c)^2$ assuming

$\mu_R^2=KQ^2$ and $\mu_R^2=Q^2$, where $K=127$



$s^{1/2}$=7 TeV
Soft QCD (quarks)
Soft QCD (gluons)
Perturbative QCD
SQCD (quarks + gluons)
SQCD + PQCD
CMS; ATLAS
Matching SQCD & PQCD
$[1/N_{ev}]dN_{ch}/dyd^2P_t$, y=0, $[GeV^{-2}*c^3]$
100
10
1
0,1
0,01
1E-3
1E-4
1E-5
1E-6
0 1 2 3 4 5 6 7 8
P_t, (GeV/c)

2012


s1/2=540 GeV (UA1)
s1/2=900 GeV (CMS)
s1/2=900 GeV (UA1)
s1/2=1.8 TeV (CDF)
s1/2=2.36 TeV (CMS)
s1/2=7 TeV (CMS)
Soft QCD (quarks)
Soft QCD (gluons)
Perturbative QCD
SQCD (quarks + gluons)
SQCD + PQCD
Exp. data
dN/dydPt2, y=0, [GeV-2*c3]
Pt, (GeV/c)

2012

Inclusive hadron production in central region and the AGK cancellation

According to the AGK, the n-Pomeron contributions to the inclusive hadron spectrum at y=0 are cancelled and only the one-Pomeron contributes. This was proved asymptotically, i.e., at very high energies.

Using this AGK we estimate the inclusive spectrum of the charged hadrons produced in p-p at y=0 as a function of the transverse momentum including the quark and gluon components in the proton.

$$\rho_q(x=0,p_t) = \phi_q(0,p_t)\sum_{n=1}^{\infty} n\sigma_n(s) = g s^{\Delta}\phi_q(0,p_t)$$

$$\rho_g(x=0,p_t) = \varphi_g(0,p_t)\sum_{n=2}(n-1)\sigma_n(s) =$$

$$\varphi_g(0,p_t)\left(g s^{\Delta} - \sigma_{nd}\right)$$

2012

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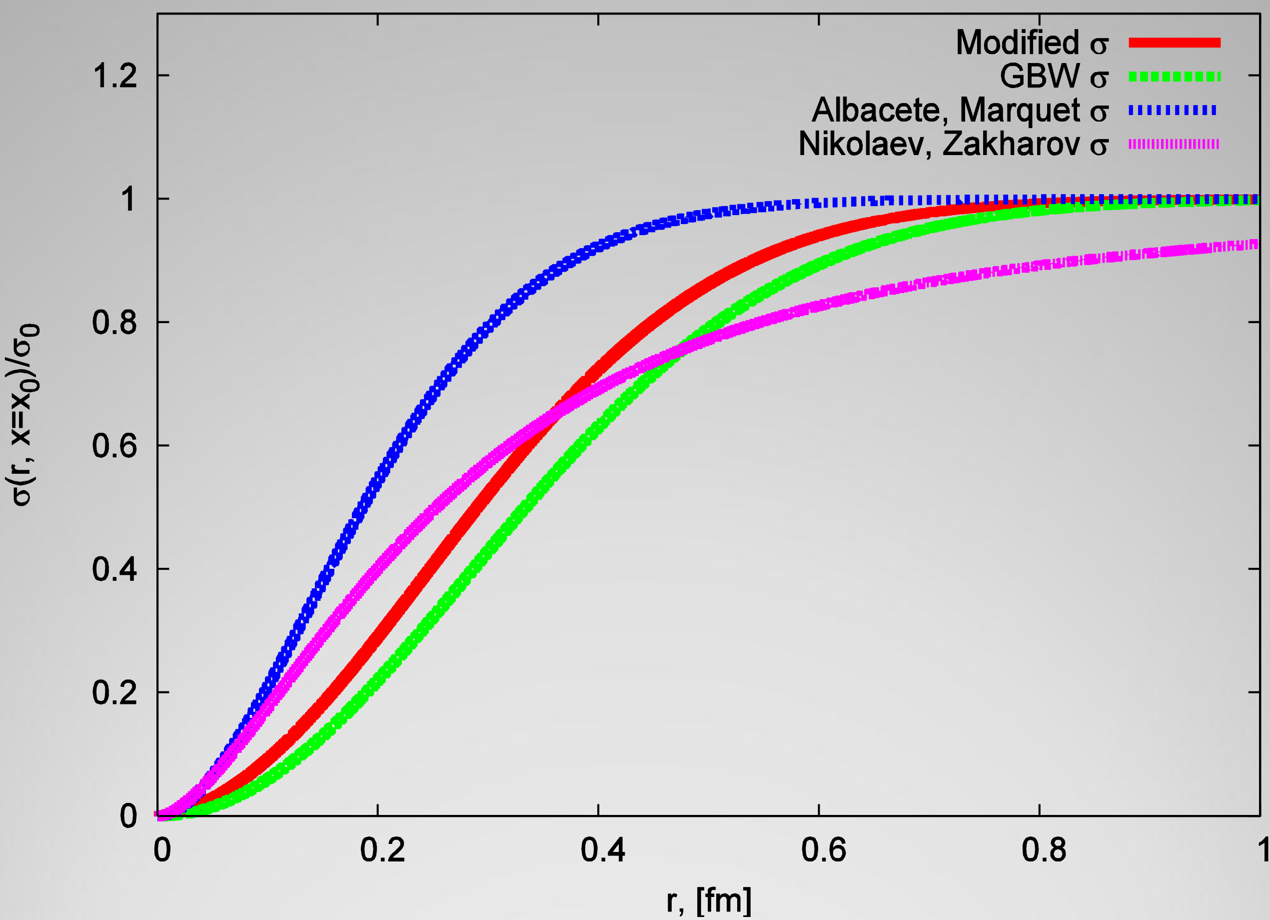
$$\rho_g(x=0,p_t)=\varphi_g(0,p_t)\sum_{n=2}(n-1)\sigma_n(s)=$$

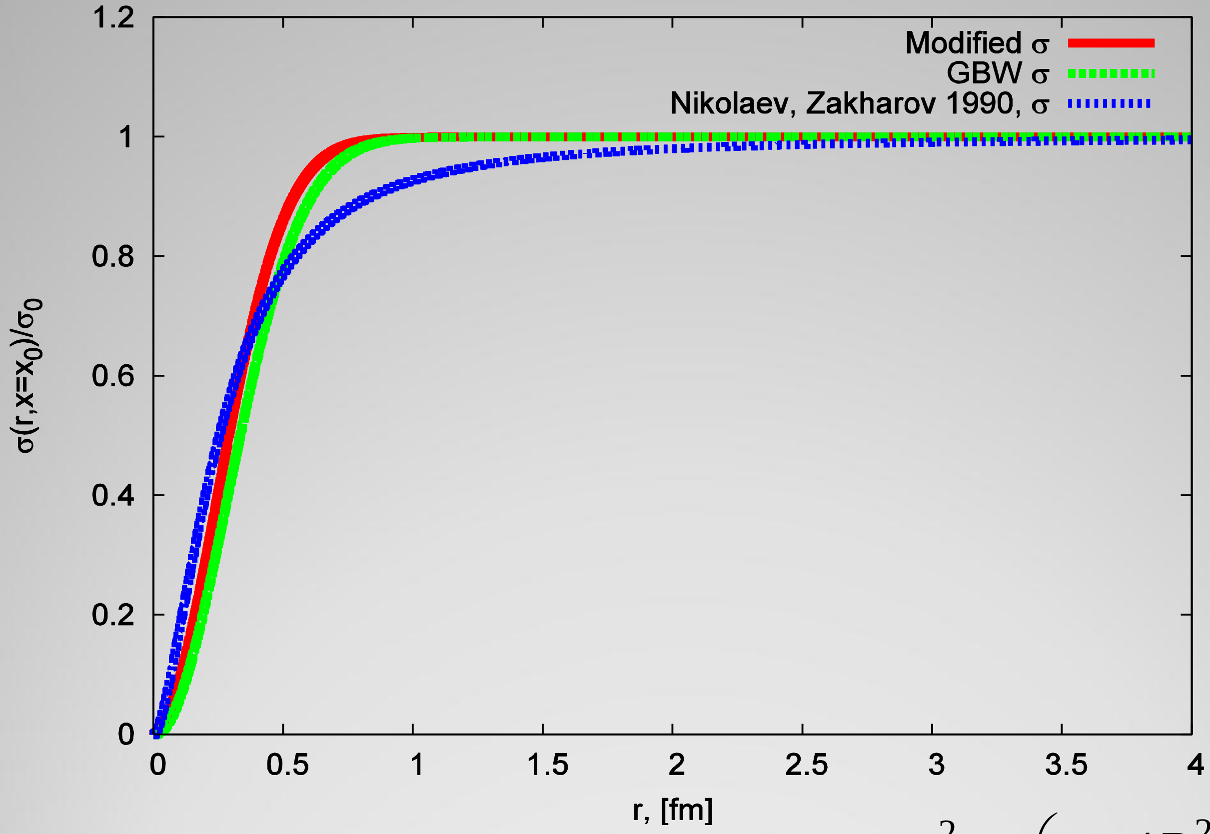
$$\varphi_g(0,p_t)\left(gs^{\Delta}-\sigma_{nd}\right)$$

2012



Modified σ
GBW σ
Albacete, Marquet σ
Nikolaev, Zakharov σ
σ(r, x=x0)/σ0
r, [fm]
0
0.2
0.4
0.6
0.8
1
1.2

Effective dipole cross section



N.Nikolaev, B.Zakharov, Z.Phys.C49, 607 (1990)

Blue line corresponds to $\sigma_{dipole} = \sigma_0 \frac{r^2}{4R_0^2} \ln\left(1 + \frac{4R_0^2}{r^2}\right)$