Diffractive production of charm quark/antiquark pairs at RHIC and LHC

Marta Łuszczak

Institut of Physics

University of Rzeszow

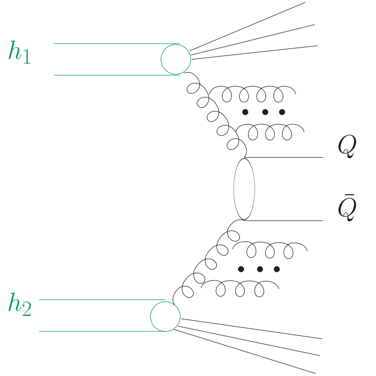
September 10-15, 2012
Lanzarote, Spain

Plan of the talk

- Introduction
- Parton distributions
- Results
  - k_t-factorization
  - gluon distributions at small-x region
  - γg and $g\gamma$ subprocesses
  - $\gamma\gamma$ subprocesses
  - single and central diffraction
- Conclusions

Production of heavy quarks

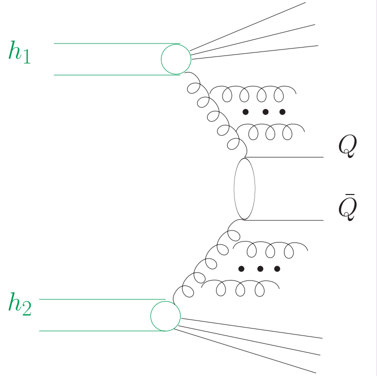
$h_1 + h_2 \longrightarrow Q + \bar{Q} + X$:



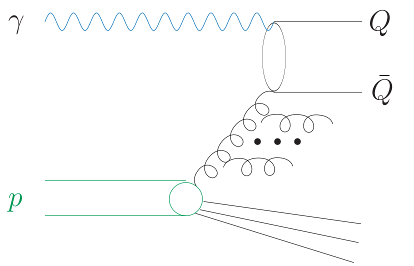
$\gamma + p \longrightarrow Q + \bar{Q} + X$:

Production of heavy quarks

$h_1 + h_2 \rightarrow Q + \bar{Q} + X$:

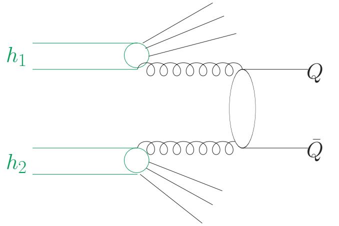


$\gamma + p \rightarrow Q + \bar{Q} + X$:

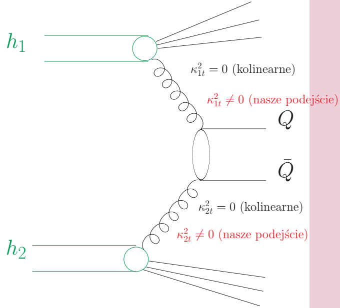


Dominant mechanism

LO collinear approach



k_t-factorization



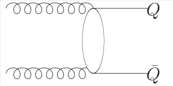
Formalism of collinear - factorization

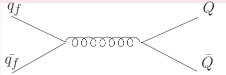
$$\frac{d\sigma}{dy_1 dy_2 d^2 p_t} = \frac{1}{16\pi^2 \hat{s}^2} \sum_{i,j} x_1 p_i(x_1,\mu^2)\; x_2 p_j(x_2,\mu^2)\; \overline{|\mathcal{M}_{ij}|^2}$$

$p_{1t} = p_{2t} = p_t$

$$x_1 = \frac{m_t}{\sqrt{s}} \left(\exp(y_1) + \exp(y_2)\right),$$

$$x_2 = \frac{m_t}{\sqrt{s}} \left(\exp(-y_1) + \exp(-y_2)\right)$$





Formalism of k_t-factorization

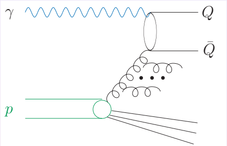
$$\frac{d\sigma}{dy_1 dy_2 d^2p_{1,t} d^2p_{2,t}} = \sum_{i,j} \int \frac{d^2\kappa_{1,t}}{\pi} \frac{d^2\kappa_{2,t}}{\pi} \frac{1}{16\pi^2 (x_1 x_2 s)^2} \overline{|\mathcal{M}_{ij}|^2}$$
$$\delta^2 \left(\vec{\kappa}_{1,t} + \vec{\kappa}_{2,t} - \vec{p}_{1,t} - \vec{p}_{2,t}\right) f_i(x_1, \kappa_{1,t}^2)\ f_j(x_2, \kappa_{2,t}^2)$$

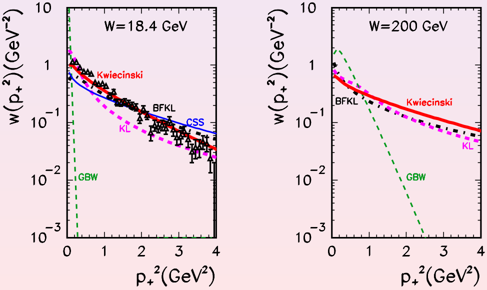
$$m_t = \sqrt{{p_t}^2 + m^2}$$

$$x_1 = \frac{m_{1,t}}{\sqrt{s}} \exp(y_1) + \frac{m_{2,t}}{\sqrt{s}} \exp(y_2),$$
$$x_2 = \frac{m_{1,t}}{\sqrt{s}} \exp(-y_1) + \frac{m_{2,t}}{\sqrt{s}} \exp(-y_2).$$

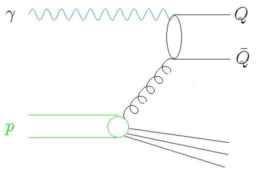
see A. Szczurek talk

$\gamma p \longrightarrow c\bar{c}$ (k_t-factorization)





How important are photon initiated processes in hadronic collisions?



Then photon is a parton of proton.

Martin-Roberts-Stirling-Thorne 2004 include photons.

MRSTQ parton distributions

The factorization of the QED-induced collinear divergences leads to QED-corrected evolution equations for the parton distributions of the proton.

$$\frac{\partial q_i(x,\mu^2)}{\partial \log \mu^2} = \frac{\alpha_S}{2\pi}\int_x^1 \frac{dy}{y}\Big\{P_{qq}(y)\; q_i(\frac{x}{y},\mu^2) + P_{qg}(y)\; g(\frac{x}{y},\mu^2)\Big\}$$

$$+ \frac{\alpha}{2\pi}\int_x^1 \frac{dy}{y}\Big\{\tilde{P}_{qq}(y)\; e_i^2 q_i(\frac{x}{y},\mu^2) + P_{q\gamma}(y)\; e_i^2 \gamma(\frac{x}{y},\mu^2)\Big\}$$

$$\frac{\partial g(x,\mu^2)}{\partial \log \mu^2} = \frac{\alpha_S}{2\pi}\int_x^1 \frac{dy}{y}\Big\{P_{gq}(y)\; \sum_j q_j(\frac{x}{y},\mu^2) + P_{gg}(y)\; g(\frac{x}{y},\mu^2)\Big\}$$

$$\frac{\partial \gamma(x,\mu^2)}{\partial \log \mu^2} = \frac{\alpha}{2\pi}\int_x^1 \frac{dy}{y}\Big\{P_{\gamma q}(y)\; \sum_j e_j^2\; q_j(\frac{x}{y},\mu^2) + P_{\gamma\gamma}(y)\; \gamma(\frac{x}{y},\mu^2)\Big\}$$

MRSTQ parton distributions

In addition to usual P_{qq}, P_{gq}, P_{qg}, P_{gg} spliting functions new spliting functions apper.

$$\tilde{P}_{qq} = C_F^{-1} P_{qq},$$

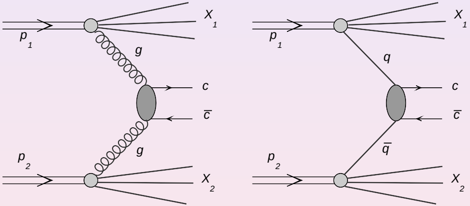
$$\mathrm{P}_{\gamma q} = C_F^{-1} P_{gq},$$
$$\mathrm{P}_{q\gamma} = T_R^{-1} P_{qg},$$
$$\mathrm{P}_{\gamma\gamma} = -\frac{2}{3} \sum_i e_i^2 \, \delta(1-y)$$

momentum is conserved:

$$\int_0^1 dx \, x \left\{ \sum_i q_i(x,\mu^2) + g(x,\mu^2) + \gamma(x,\mu^2) \right\} = 1$$

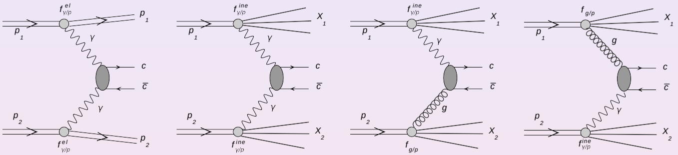
Standard diagrams

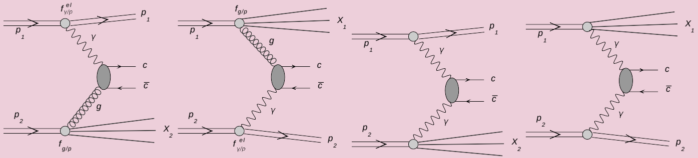
- Standard diagrams



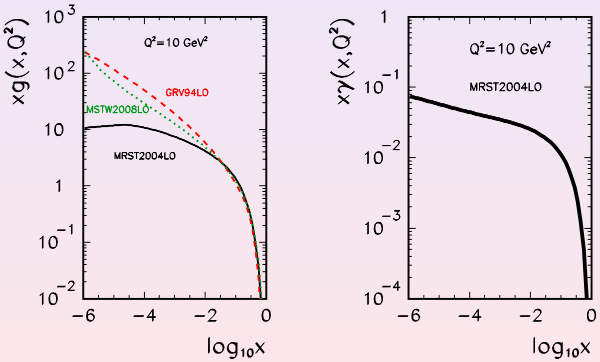
Photon included diagrams

- Photon included diagrams

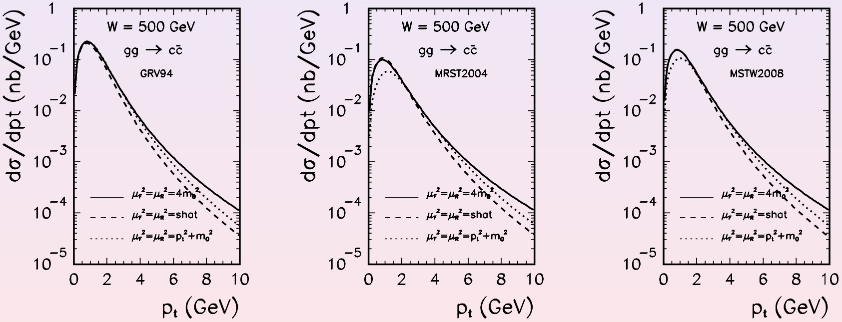




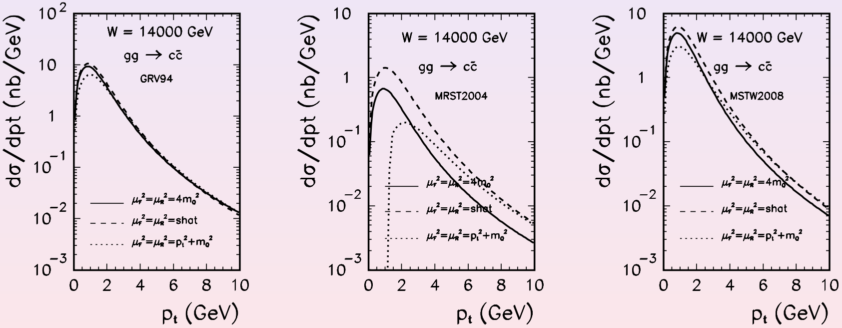
Collinear LO gluon and photon distributions



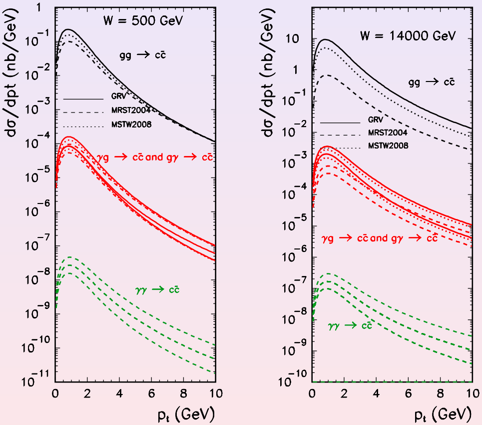
Distribution in quark/antiquark transverse momentum at $\sqrt{s} = 500$ GeV



Distribution in quark/antiquark transverse momentum at $\sqrt{s} = 14$ TeV

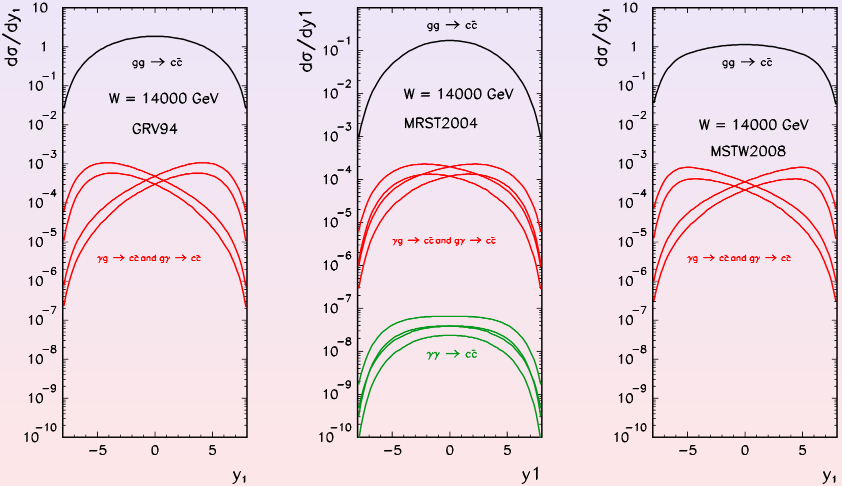


Distribution in the transverse momentum

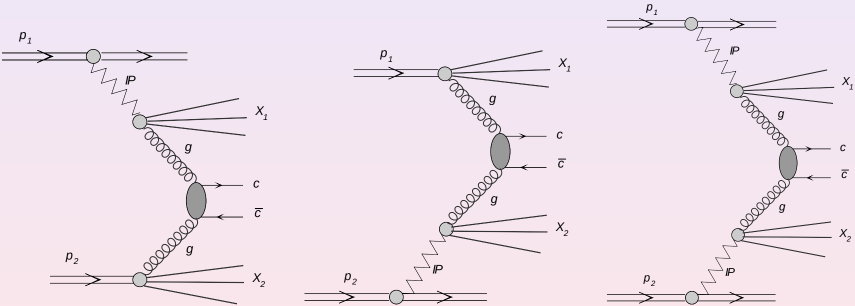


Luszczak, Maciula, Szczurek, Phys. Rev. **D84** (2011) 4018

Distribution in the rapidity



Single and central diffraction



Luszczak, Maciula, Szczurek, Phys. Rev. **D84** (2011) 4018

Formalism

In this approach (Ingelman-Schlein model) one assumes that the Pomeron has a well defined partonic structure, and that the hard process takes place in a Pomeron–proton or proton–Pomeron (single diffraction) or Pomeron–Pomeron (central diffraction) processes.

$$\frac{d\sigma_{SD}}{dy_1 dy_2 dp_t^2} = K \frac{\left|M\right|^2}{16\pi^2 \hat{s}^2} \left[\left(x_1 q_f^D(x_1, \mu^2)\, x_2 \bar{q}_f(x_2, \mu^2) \right) \right.$$

$$\left. + \left(x_1 \bar{q}_f^D(x_1, \mu^2)\, x_2 q_f(x_2, \mu^2) \right) \right],$$

$$\frac{d\sigma_{CD}}{dy_1 dy_2 dp_t^2} = K \frac{\left|M\right|^2}{16\pi^2 \hat{s}^2} \left[\left(x_1 q_f^D(x_1, \mu^2)\, x_2 \bar{q}_f^D(x_2, \mu^2) \right) \right.$$

$$\left. + \left(x_1 \bar{q}_f^D(x_1, \mu^2)\, x_2 q_f^D(x_2, \mu^2) \right) \right]$$

Formalism

The 'diffractive' quark distribution of flavour f can be obtained by a convolution of the flux of Pomerons $f_{\mathbf{P}}(x_{\mathbf{P}})$ and the parton distribution in the Pomeron $q_{f/\mathbf{P}}(\beta, \mu^2)$:

$$q_f^D(x, \mu^2) = \int dx_{\mathbf{P}}\, d\beta\, \delta(x - x_{\mathbf{P}}\beta) q_{f/\mathbf{P}}(\beta, \mu^2)\, f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_x^1 \frac{dx_{\mathbf{P}}}{x_{\mathbf{P}}}\, f_{\mathbf{P}}(x_{\mathbf{P}}) q_{f/\mathbf{P}}(\frac{x}{x_{\mathbf{P}}}, \mu^2)\,.$$

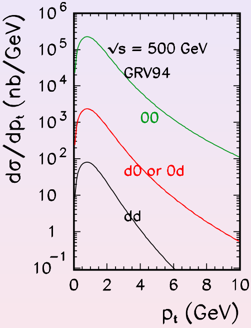
The flux of Pomerons $f_{\mathbf{P}}(x_{\mathbf{P}})$:

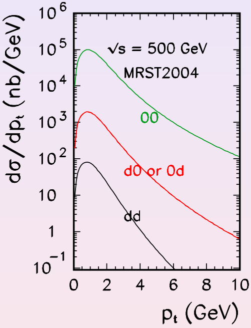
$$f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_{t_{min}}^{t_{max}} dt\, f(x_{\mathbf{P}}, t)\,,$$

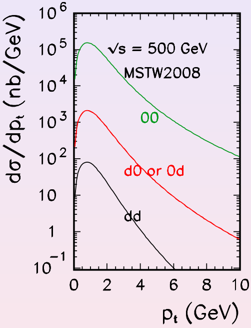
with t_{min}, t_{max} being kinematic boundaries.

Both pomeron flux factors $f_{\mathbf{P}}(x_{\mathbf{P}}, t)$ as well as quark/antiquark distributions in the pomeron were taken from the H1 collaboration analysis of diffractive structure function at HERA.

Results





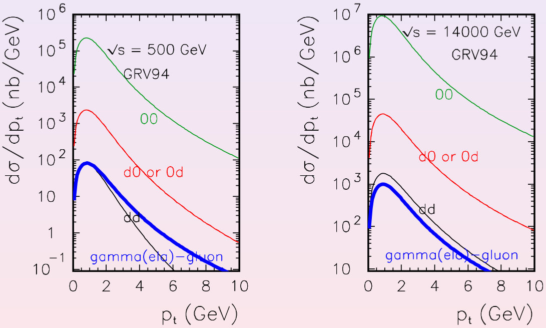


Absorption has been included by multiplying cross section by gap survival factors (violation of Regge factorization):

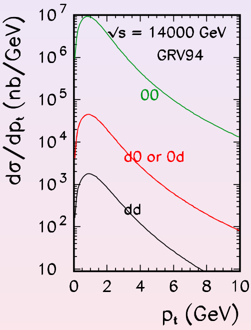
for RHIC: dd*0.06; d0 or 0d*0.13

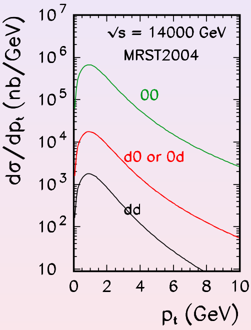
for LHC: dd*0.02; d0 or 0d*0.05

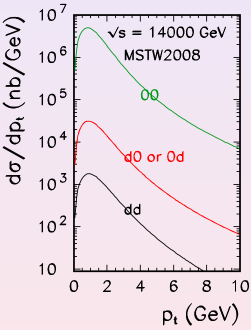
Results


√s = 500 GeV
GRV94
00
d0 or 0d
dd
gamma(ela)−gluon
dσ/dp_t (nb/GeV)
p_t (GeV)
√s = 14000 GeV
GRV94
00
d0 or 0d
dd
gamma(ela)−gluon
dσ/dp_t (nb/GeV)
p_t (GeV)

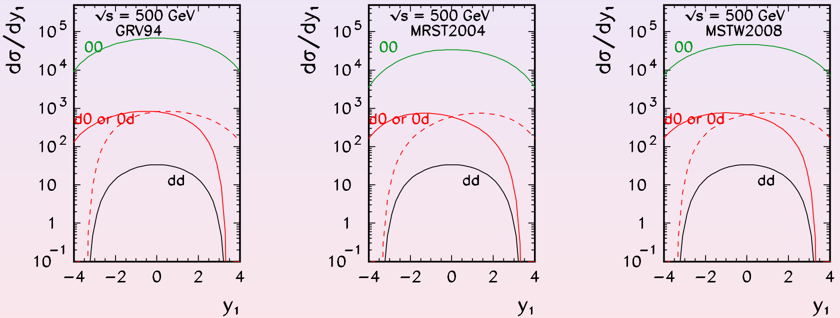
Results


$\sqrt{s}$ = 14000 GeV
GRV94
00
d0 or 0d
dd
$d\sigma/dp_t$ (nb/GeV)
p_t (GeV)

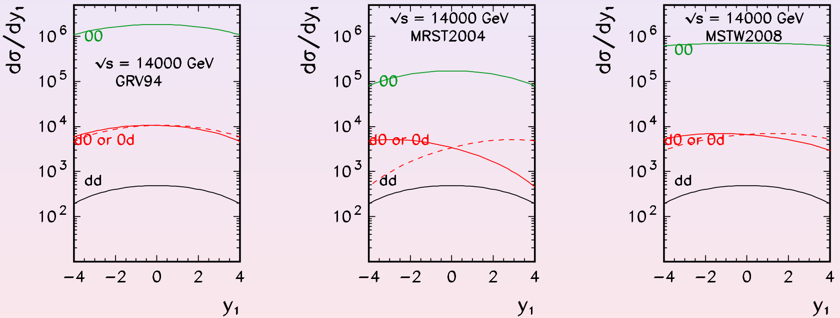

$\sqrt{s}$ = 14000 GeV
MRST2004
00
d0 or 0d
dd
$d\sigma/dp_t$ (nb/GeV)
p_t (GeV)


$\sqrt{s}$ = 14000 GeV
MSTW2008
00
d0 or 0d
dd
$d\sigma/dp_t$ (nb/GeV)
p_t (GeV)

Results


dσ/dy₁
√s = 500 GeV
GRV94
00
d0 or 0d
dd
y₁
√s = 500 GeV
MRST2004
00
d0 or 0d
dd
y₁
√s = 500 GeV
MSTW2008
00
d0 or 0d
dd
y₁

Results


dσ/dy₁
10 6
10 5
10 4
10 3
10 2
00
√s = 14000 GeV
GRV94
d0 or 0d
dd
−4 −2 0 2 4
y₁
dσ/dy₁
√s = 14000 GeV
MRST2004
00
d0 or 0d
dd
y₁
dσ/dy₁
√s = 14000 GeV
MSTW2008
00
d0 or 0d
dd
y₁

Different approaches

Alves, Levin and Santoro,
Phys. Rev. D**55**, 2683 (1997)
- diffractive production of heavy quark/antiquark with UGDF.

Yuan and Chao,
Phys. Rev. D**60**, 094012 (1999)
-two gluon exchange parametrization of the Pomeron model

Different approaches

The lowest order perturbative QCD diagrams for partonic process $gp \longrightarrow q\bar{q}p$:

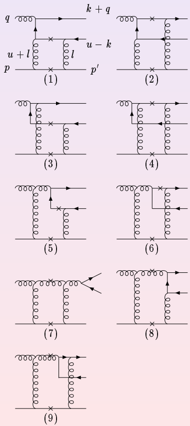
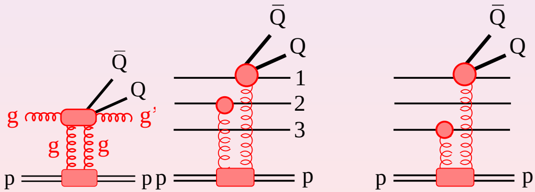


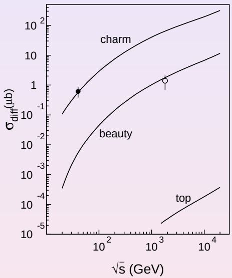
Fig.2

The light-cone dipole approach

Diffractive production of heavy flavors was also calculated within the light-cone dipole approach:
B.Z. Kopeliovich, I.K. Potashnikova, Ivan Schmidt, A.V.Tarasov, Phys. Rev. **D76** (2007) 034019



The light-cone dipole approach



- The experimental point is the results of the measurement of the cross section of diffractive production of D^*-mesons in the E690 experiment at Fermilab at $\sqrt{s} = 40 GeV$ and corrected by KPST for branching fraction.
- $\sigma_{diff}(c\bar{c}) = [0.61 \pm 0.12(stat) \pm 0.11(syst)]\mu b$
- our result for $\sigma_{diff}(c\bar{c}) = 0.97\mu b$

Conclusions

- Huge sensitivity to gluon distribution and scales for W=14000 GeV.
- We have calculated cross section for many new photon included processes. They are small but there are many of them.
- Some γg processes have similar characteristic as usual single diffractive processes, but turned out to be much smaller.
- The cross sections for single and central diffraction have been calculated.The *SD* cross section smaller by 2 orders of magnitude than the dominant gg term.