MPI@UPC in pQCD.

B.Blok (Technion, Haifa)
(based on joint work with M. Strikman, in preparation)

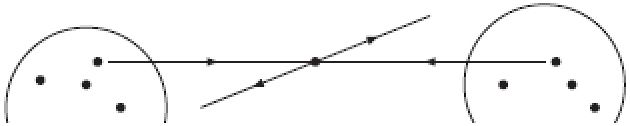
Introduction

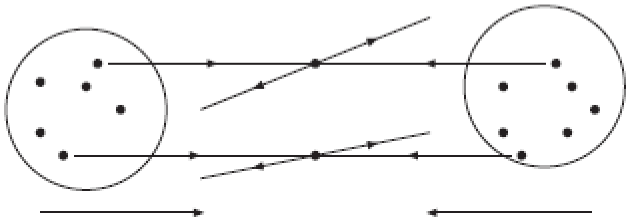
The subject of this talk: the two dijet production

In ultraperipheral collisions at LHC and photon-proton collisions at HERA-how to use UPC and γp to uncover properties of MPI.

The conventional jet production at colliders is two to two production

$$\frac{d\sigma^{(2\to 2)}}{d\hat{t}} \propto \frac{\alpha_s^2}{Q^4}.$$





Here the cross sections are not sensitive to nucleon structure-it comes through $D(x,Q^2)$-the nucleon structure functions.

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Next source of jets -double parton interactions, i.e. more than one participating partons from one of participating nucleons or from both leading to multiple jet production (There are also higher coorrections, leading to 2 to 4 processes, etc, we do not consider them here (see below)).

Questions:1) can they be seen/distinguished? Can they be calculated? (parton model, pQCD?), can reliable predictions for experimentalists be made?

Problem: the cross sections observed in pp collisions in Tevatron and now at LHC where 2-3.5 times larger than predicted in naïve parton model calculations

(such calculations where first done by Treleani and Paver (1985) and Mufti (1985))

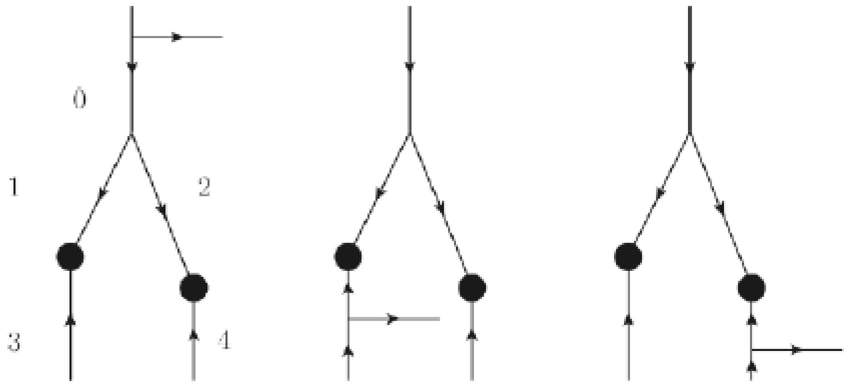
Recently-new pQCD formalism for MPI was developed:

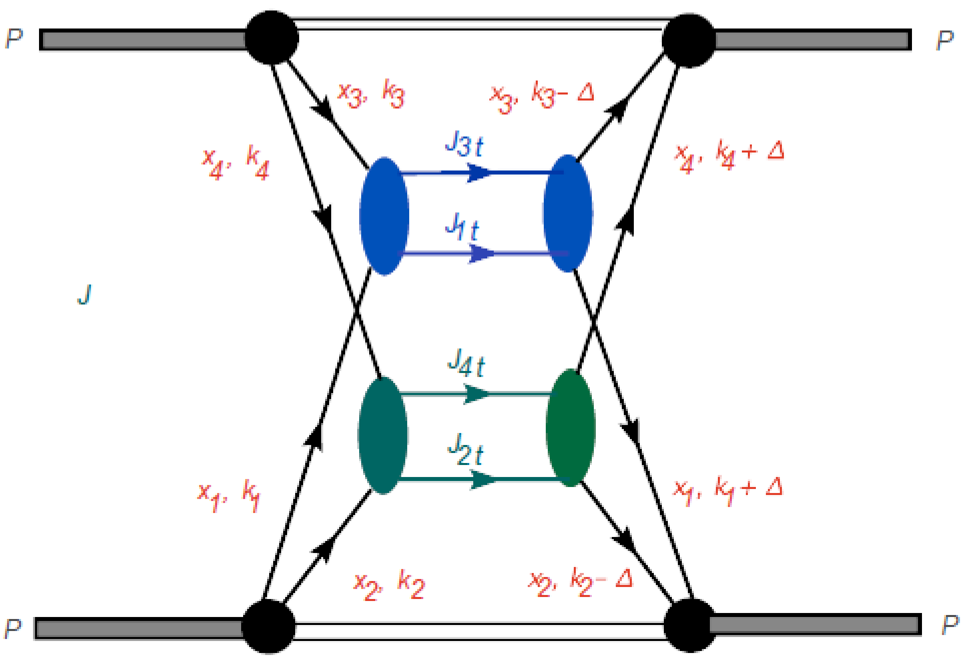
B.Blok, Yu.Dokshitzer, L. Frankfurt ,M. Strikman, Phys.Rev. D83 (2011) 071501 Eur.Phys.J. C72 (2012) 1963, and "Perturbative QCD correlations in MultiParton collisions, arXiv1306.3673, to be published in Eur.Phys. J. C

See also related recent work by Ryskin and Snigirev, Gaunt and Stirling, Manohar and Wierwadjana, Gaunt…..
Alternative attempt to develop pQCD approach to MPI based on TMD is currently perceived by M. Diehl and his collaborators. There was also extensive work on MPI In pA collisions-see Strikman and Treleani, Blok,Strikman and Wiedemann, d'Enterria and Snigirev, Treleani, Salvini, Calucci,…
There are also experimental measurements by CMS and D0 at Tevatron .and new experimental measurements by LHCb, CMS, ATLAS-in pp collisions (i.e. CMS, JHEP 1403(2014) 032; 1312(2013)030,

New basic ideas:1) new universal objects 2 parton GPD $D(x_1, x_2, p_1^2, p_2^2, \vec{\Delta})$

2) DGLAP/parton ladder splitting mechanism-3 to 4, numerically gives the same order contribution as parton model 4 to 4 mechanism.





G. 1: Kinematics of double hard collision - momenta of t

For the first time we can see QCD nonlinear effects.

However, the calculations-not free of theoretical uncertainties, mostly due to dependence on physical parameter Q, that describes when we can start using pQCD to describe parton splitting, i.e. describes separation between soft and hard physics. So-need to check in enviroment free of theoretical uncertainties.

3) The characteristic property of these two partons-they are on the same/close impact parameters, thus giving direct source of short range correlations between partos.As a result, such 3 to 4 mechanism may be important to understanding low x dynamics, nondiagonal interactions/cross talk between ladders (Gaunt, Bartels/Ryskin) and other QCD phenomena. UPC-i.e. photon proton interactions may give a clear test for such mechanism: two charm quarks created by photon are born at the same impact parameter, very closely resembling 3 to 4 in pp,pA collisions, but free from possible soft contributions in the vertex.

Let us briefly review MPI in pp collisions.

The most interesting property of MPI-they can be seen in the back-to-back kinematics.

Indeed, they are not the leading twist process.

The 2 to 4 processes give a contribution to cross section

$$\frac{d\sigma^{(2\to4)}}{d\hat{t}_1 d\hat{t}_2} \propto \frac{\alpha_s^4}{Q^6}$$

On the other hand $$\frac{d\sigma^{(4\to4)}}{d\hat{t}_1 d\hat{t}_2} \propto R^{-2}\cdot\left(\frac{\alpha_s^2}{Q^4}\right)^2 \propto \frac{\alpha_s^4}{R^2\,Q^8};$$

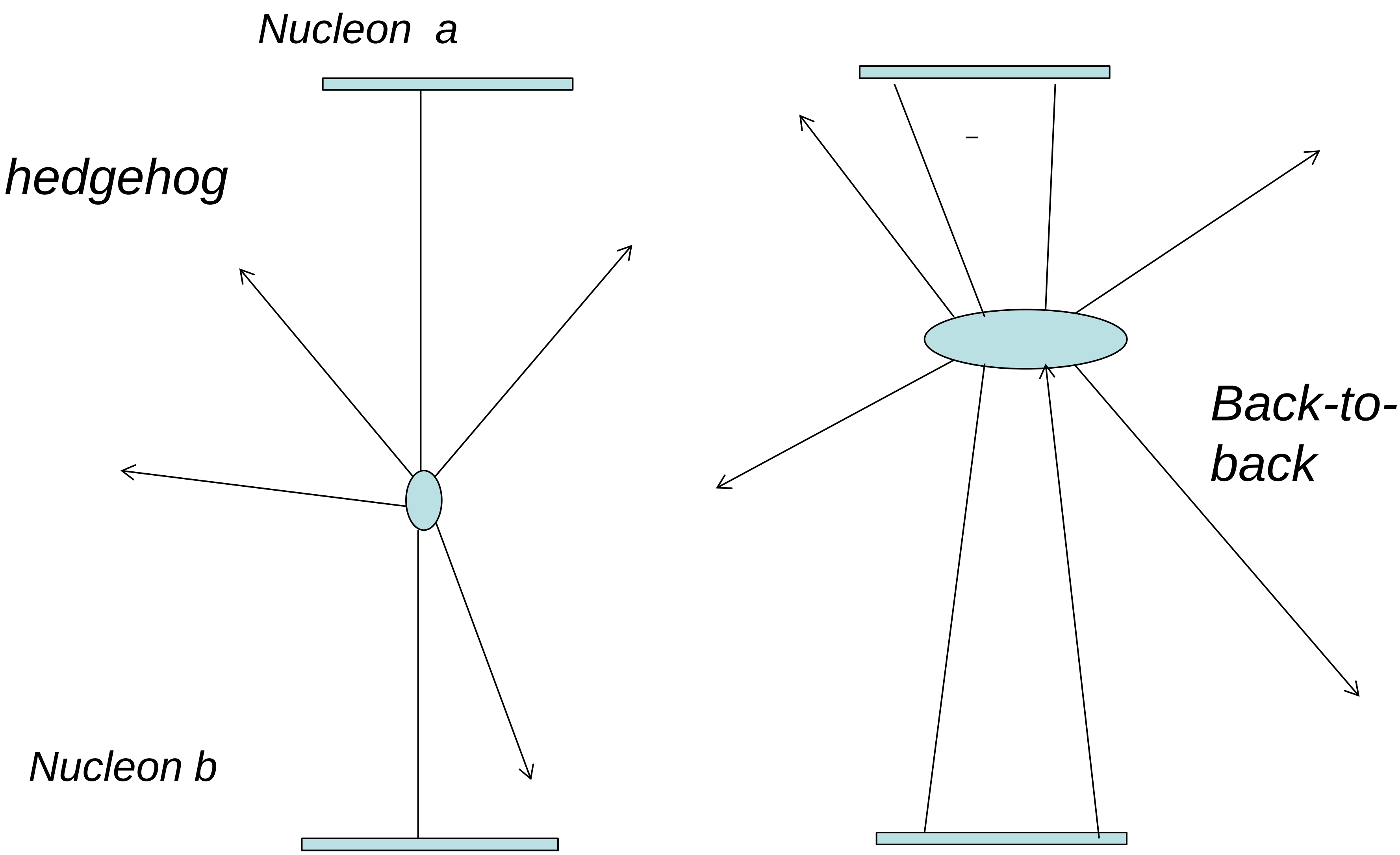
i.e. they can be seen as a higher twist process.

the scale R is given by

$R^2 = 1/\langle\Delta^2\rangle$ the characteristic distance between the two partons in the hadron wave function.

$$
\begin{aligned}
d\sigma^{(4\to4)} \;&\propto\; \frac{\alpha_{\rm s}^2}{\delta_{13}^2\,\delta_{24}^2}\, d^2 j_{3\perp} d^2 j_{4\perp}\cdot d\Sigma, \\
&\qquad\qquad \delta_{13}^2 \ll Q^2, \quad \delta_{24}^2 \ll Q^2; \\
d\sigma^{(3\to4)} \;&\propto\; \frac{\alpha_{\rm s}^2}{\delta'^2\,\delta^2}\, d^2 j_{3\perp} d^2 j_{4\perp}\cdot d\Sigma, \\
&\qquad\qquad \delta'^2 \ll \delta^2 \ll Q^2,\; \delta^2 = \delta_{13}^2 \simeq \delta_{24}^2.
\end{aligned}
$$

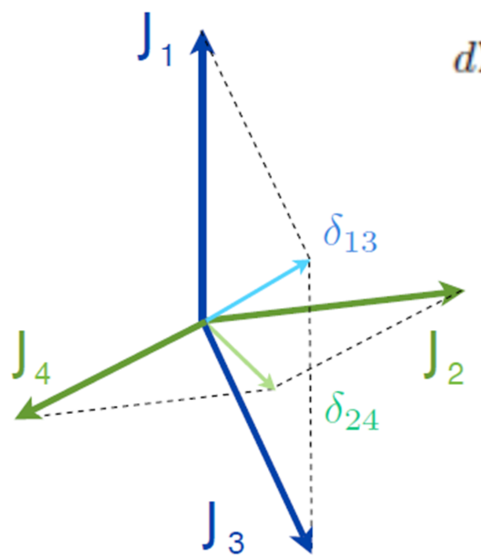
In back-to back kinematics they are double collinear enhanced (and 2 to 4 are not)


Nucleon a
hedgehog
Back-to-back
Nucleon b

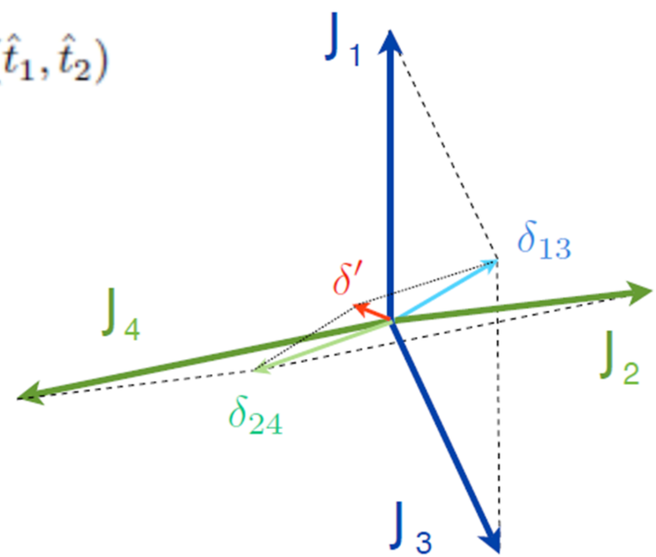
back-to-back kinematics

$\delta_{13}^2, \delta_{24}^2 \ll J_{i\perp}^2$

$\delta'^2 \ll \delta_{13}^2 \simeq \delta_{24}^2 \ll J_{i\perp}^2$



$d\Sigma(\hat{t}_1, \hat{t}_2)$



$$\boxed{d\sigma^{(4\to 4)} \propto \frac{\alpha_s^2}{\delta_{13}^2\,\delta_{24}^2}\, d^2 j_{3\perp} d^2 j_{4\perp} \cdot d\Sigma}$$

$$\boxed{d\sigma^{(3\to 4)} \propto \frac{\alpha_s^2}{\delta'^2\,\delta^2}\, d^2 j_{3\perp} d^2 j_{4\perp} \cdot d\Sigma}$$

The four jet cross-section in the parton model.

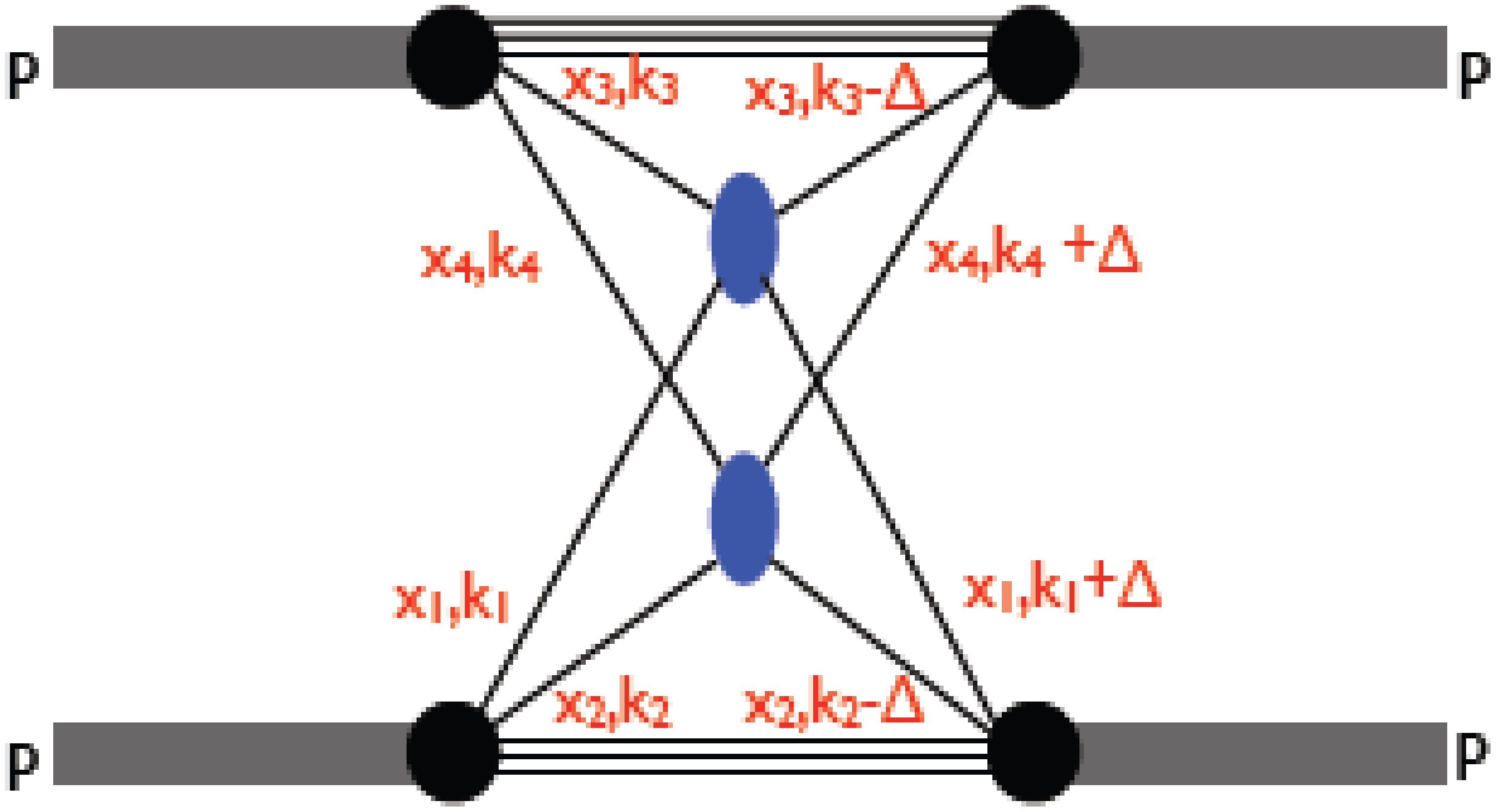
The four jet cross-section can be directly calculated in momentum space and is given by the formula:

$$\sigma_4(x_1, x_2, x_3, x_4) = \int \frac{d^2\vec{\Delta}}{(2\pi)^2} D_a(x_1, x_2, p_1^2, p_2^2, \vec{\Delta}) \times D_b(x_3, x_4, p_1^2, p_2^2, -\vec{\Delta}) \times \frac{d\sigma^{13}}{d\hat{t}_1} \frac{d\sigma^{24}}{d\hat{t}_2} d\hat{t}_1 d\hat{t}_2. \quad (2)$$

Experimentalists often denote:

$$\sigma_4 = \sigma_1 \sigma_2 / \pi R_{\text{int}}^2,$$

Coordinate representations calculations first-in Treleani Paver (1985), Mekhfi (1985)



p
p
p
p
x3,k3
x3,k3-Δ
x4,k4
x4,k4 +Δ
x1,k1
x1,k1+Δ
x2,k2
x2,k2-Δ

Treleani,Paver (1985),M. Mekfi (1985)

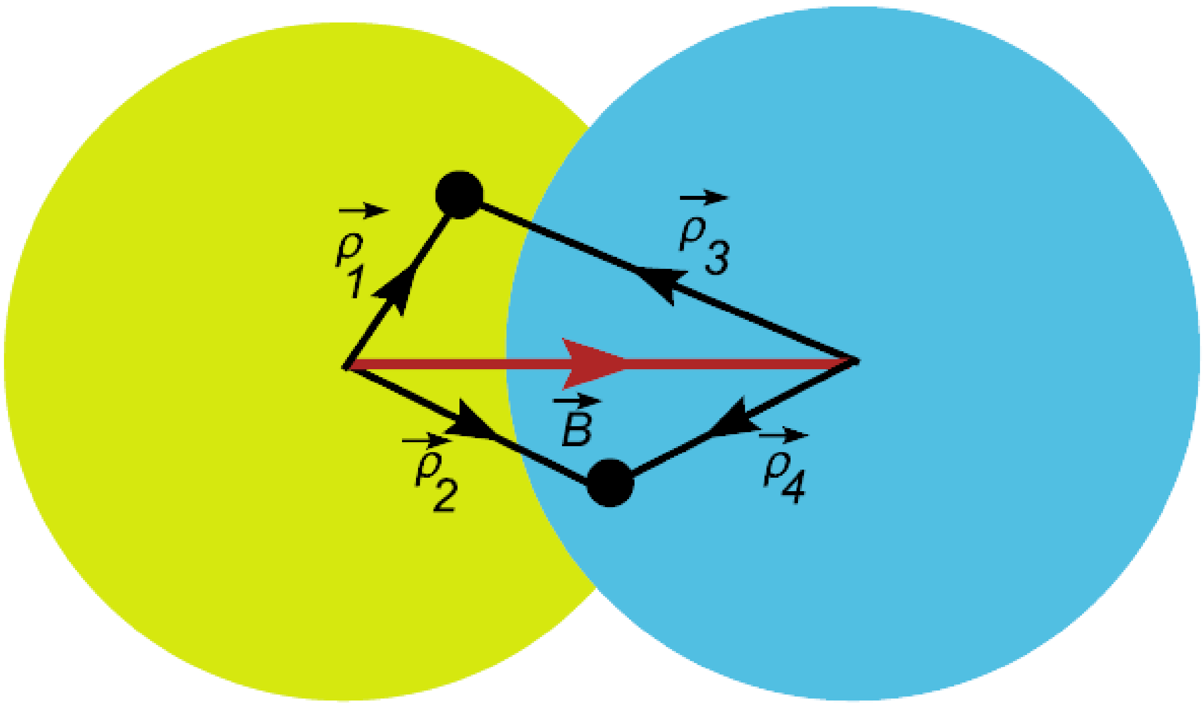


FIG. 2 (color online). Geometry of two hard collisions in impact parameter picture.

It follows from the discussion above that the area can be written explicitly in terms of these new two particle GPDs as

$$\frac{1}{\pi R_{\rm int}^2} = \int \frac{d^2\vec{\Delta}}{(2\pi)^2} \frac{D(x_1, x_2, -\vec{\Delta})D(x_3, x_4, \vec{\Delta})}{D(x_1)D(x_2)D(x_3)D(x_4)},$$

This formula is valid for inclusive dijet production. When the momentum fraction are different, the exclusive production DDT formula can be easily obtained. This

formula expresses the interaction area in the model independent way as the single integral over the transverse momenta.

The new GPDs can be explicitly expressed through the light cone wave functions of the hadron as

$$D\ (x_1, x_2, p_1^2, p_2^2, \overrightarrow{\Delta}) = \sum_{n=3}^{\infty} \int \frac{d^2k_1}{(2\pi)^2} \frac{d^2k_2}{(2\pi)^2} \theta(p_1^2 - k_1^2)$$

$$\times\ \theta(p_2^2 - k_2^2) \int \prod_{i \neq 1,2} \frac{d^2k_i}{(2\pi)^2} \int_0^1 \prod_{i \neq 1,2} dx_i$$

$$\times\ \psi_n(x_1, \vec{k}_1, x_2, \vec{k}_2, .., \vec{k}_i, x_i..)$$

$$\times\ \psi_n^+(x_1, \overrightarrow{k_1} + \overrightarrow{\Delta}, x_2, \overrightarrow{k_2} - \overrightarrow{\Delta}, x_3, \vec{k}_3, ...)$$

$$\times\ (2\pi)^3 \delta(\sum_{i=1}^{i=n} x_i - 1) \delta(\sum_{i=1}^{i=n} \vec{k}_i). \qquad (5)$$

Here psi are the light cone wave functions of the nucleon in the initial and final states.

The approximation of independent particles.

Suppose the multiparton wave faction factorise, i.e. we neglect possible interparton correlations and recoil effects. Then it's straightforward to see that the two particle GPDs factorise and acquire a form:

$$D(x_1, x_2, p_1^2, p_2^2, \vec{\Delta}) = G(x_1, p_1^2, \vec{\Delta})G(x_2, p_2^2, \vec{\Delta}),$$

The one-particle GPD-s G are conventionally written in the dipole form:

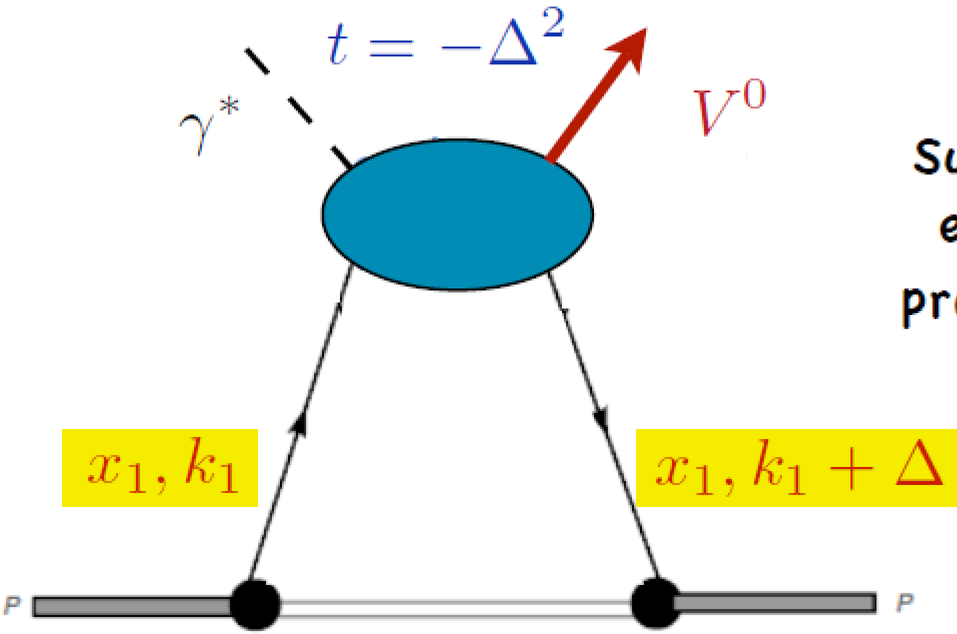
$$G_N(x, Q^2, \vec{\Delta}) = G_N(x, Q^2)F_{2g}(\Delta)$$

G - the usual 1-parton distribution (determining DIS structure functions)

F - the two-gluon form factor of the nucleon

the dipole fit : $$F_{2g}(\Delta) \simeq \frac{1}{\left(1 + \Delta^2/m_g^2\right)^2}$$

$m_g^2(x \sim 0.03, Q^2 \sim 3\text{GeV}^2)$
$\simeq 1.1\text{GeV}^2$



G P D

Such an amplitude describes exclusive photo-(/electro-) production of vector mesons at HERA !

$$\frac{1}{\pi R_{\text{int}}^2} = \int \frac{d^2\Delta}{(2\pi)^2} F_{2g}^4(\Delta) = \frac{m_g^2}{28\pi}.$$

$$R_{\text{int}}^2 = 7/2 r_g^2, \qquad r_g^2/4 = dF_{2g}(t)/dt_{t=0}.$$

Let us note that this result coincides with the one obtained in a geometric picture (Frankfurt,Strikman and Weiss 2003)
However the latter computation involved a complicated 6 dimensional integral that potentially could lead to large numerical uncertainties

The dependence of r^2_g on Q^2 and x is given by the approximate formula that takes into account the DGLAP evolution:

$$\langle\rho^2\rangle(x,Q^2) = \langle\rho^2\rangle(x,Q_0^2)\left(1 + A\ln\frac{Q^2}{Q_0^2}\right)^{-a},$$

$$\langle\rho^2\rangle = \frac{8}{m_g^2}.$$

where

$$Q_0^2 = 3\,\mathrm{GeV}^2, \quad A = 1.5, \quad a = 0.0090\ln\frac{1}{x}.$$

The similar analysis for quark sea leads to slightly bigger transverse area (Strikman and Weiss 2009). Recoil may be important for large x_i but also leads to smaller total cross section, i.e. to larger R_{int}

Then we see the problem: the approximation of independent particles leads to the cross section two times smaller than the experimental one (Frankfurt,Strikman and Weiss 2004), *The experimental result is 15 mb, while the use of the electromagnetic radius of the nucleon leads to this area being 60 mb while we obtain in independent particle approximation 34 mb*

Even more naïve way-take $\sigma_{eff} = 1/\pi R^2$

(most MC generators do)

Perturbative QCD and differential cross sections

Two basic ideas (relative to conventional one dijet processes-2 to2 in our notations):

1. Double collinear enhancement in total cross sections-i.e. double pole enhancement in differential two dijet cross sections.

2. new topologies-in addition to conventional pQCD bremsstralung-parton/ladder splitting .

a) 4 to 4

b) 3 to 4

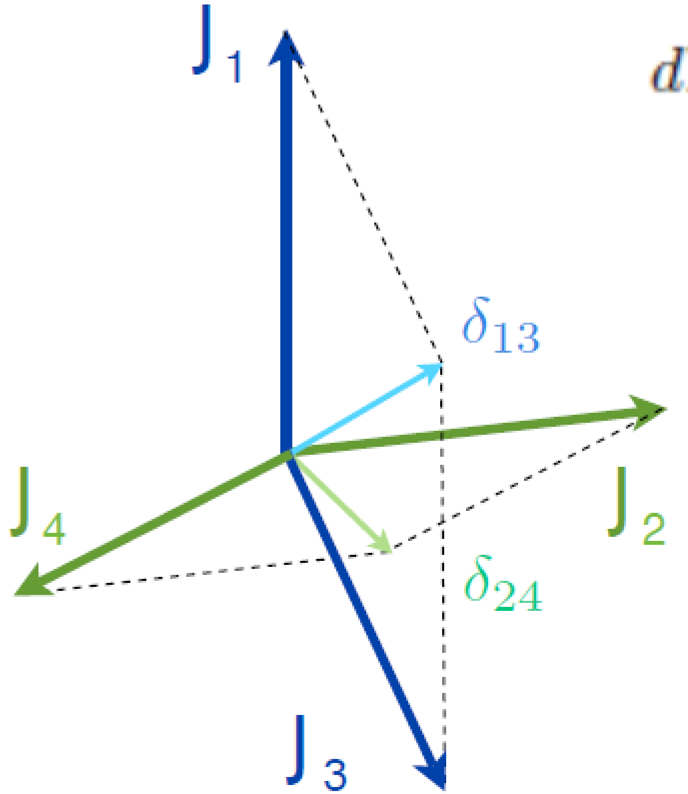
But no 2 to 4

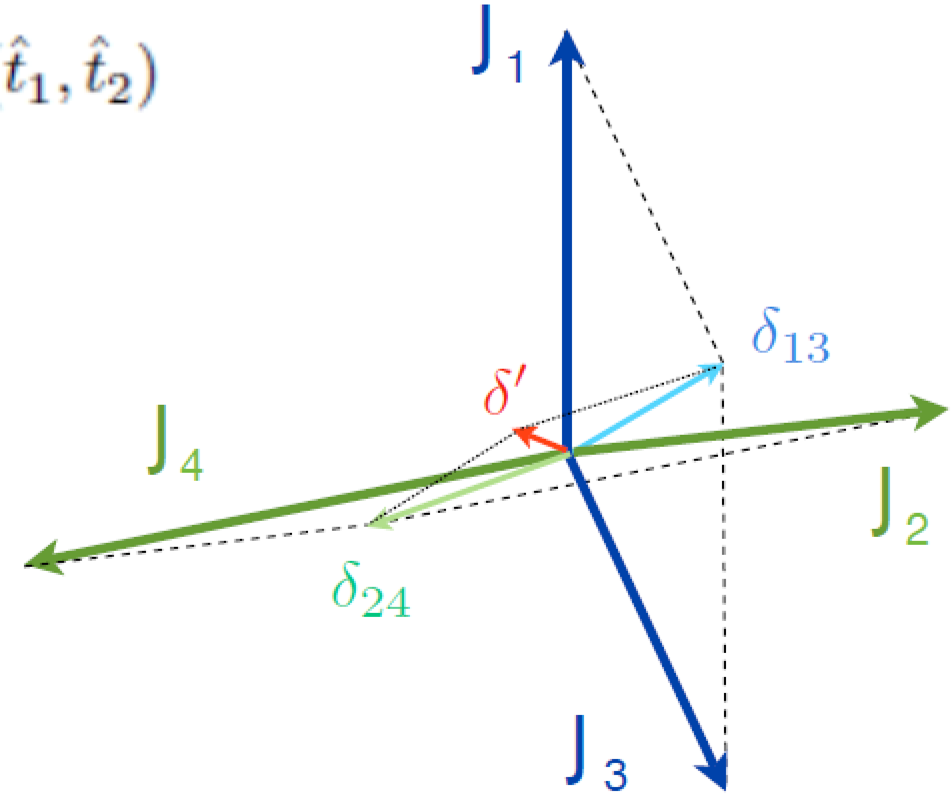
back-to-back kinematics

$$\delta_{13}^2, \delta_{24}^2 \ll J_{i\perp}^2$$

$$\delta'^2 \ll \delta_{13}^2 \simeq \delta_{24}^2 \ll J_{i\perp}^2$$

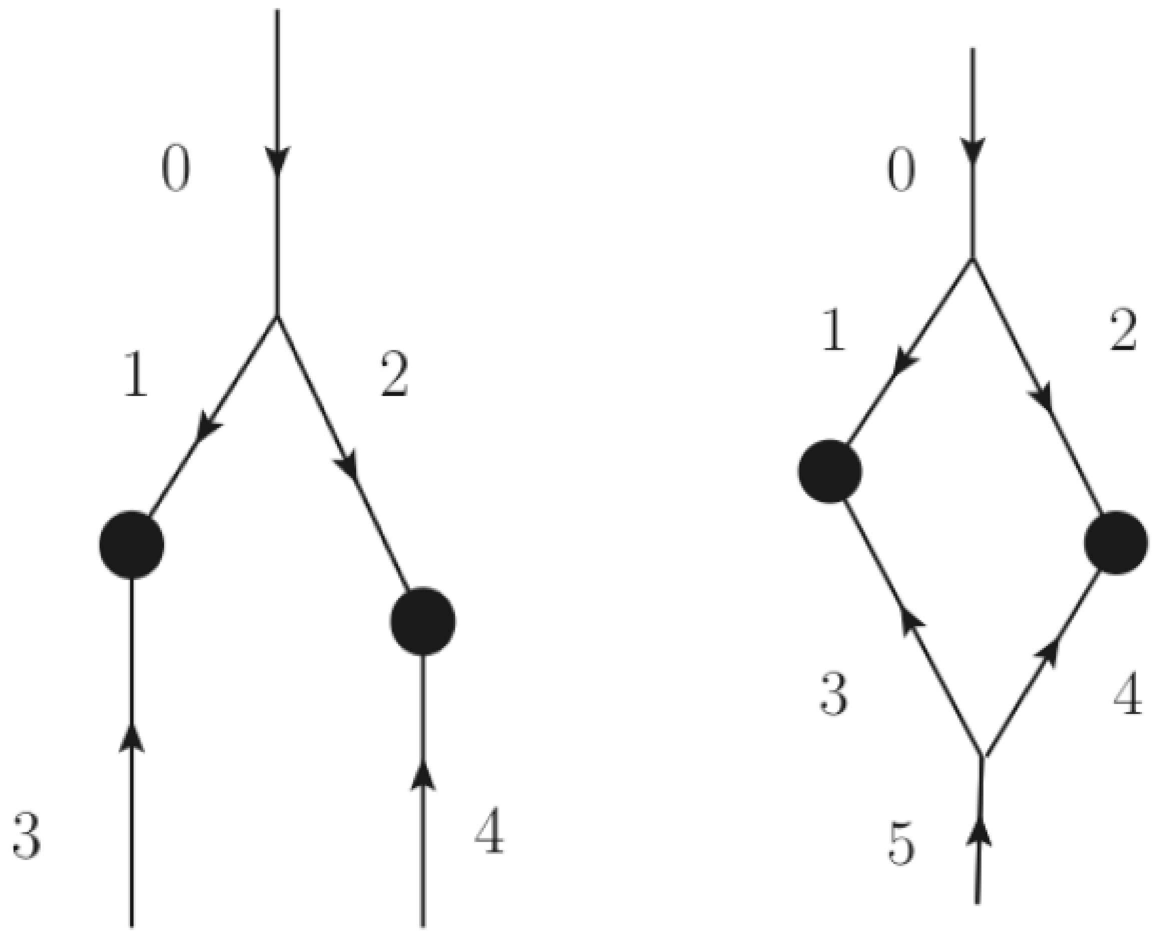
$$d\Sigma(\hat{t}_1, \hat{t}_2)$$





$$\boxed{d\sigma^{(4\to 4)} \propto \frac{\alpha_s^2}{\delta_{13}^2\,\delta_{24}^2}\, d^2 j_{3\perp} d^2 j_{4\perp} \cdot d\Sigma}$$

$$\boxed{d\sigma^{(3\to 4)} \propto \frac{\alpha_s^2}{\delta'^2\,\delta^2}\, d^2 j_{3\perp} d^2 j_{4\perp} \cdot d\Sigma}$$


0
1
2
3
4
0
1
2
3
4
5

Three to Four

There are two types of three to four contributions: The first-when there is radiation after the split, the second-when there is not. This leads to two different types of singularities: $1/\delta'^2$ $1/\delta_{13}^2$

$$\delta' = \delta_{13} + \delta_{24} \qquad\qquad \delta_{13}^2 \ll \delta_{24}^2 \simeq \delta'^2.$$

and vice versa –we call this type of singularity short split, and singularities-$1/\delta_{13}^2$ $1/\delta_{24}^2$

that we call a long split. The first type of pole/log terms is present only in three to four

terms, while the second is the same as in 4 to 4

terms.

$$\pi^2 \frac{d\sigma_1^{(3\to 4)}}{d^2\delta_{13}\, d^2\delta_{24}} = \frac{d\sigma_{\rm part}}{d\hat{t}_1\, d\hat{t}_2} \cdot \frac{\partial}{\partial \delta_{13}^2} \frac{\partial}{\partial \delta_{24}^2} \Big\{ {}_{[1]}D_a^{1,2}(x_1, x_2; \delta_{13}^2, \delta_{24}^2) \cdot {}_{[2]}D_b^{3,4}(x_3, x_4; \delta_{13}^2, \delta_{24}^2)$$
$$\times \; S_1\left(Q^2, \delta_{13}^2\right) S_3\left(Q^2, \delta_{13}^2\right) \cdot S_2\left(Q^2, \delta_{24}^2\right) S_4\left(Q^2, \delta_{24}^2\right) \Big\}.$$

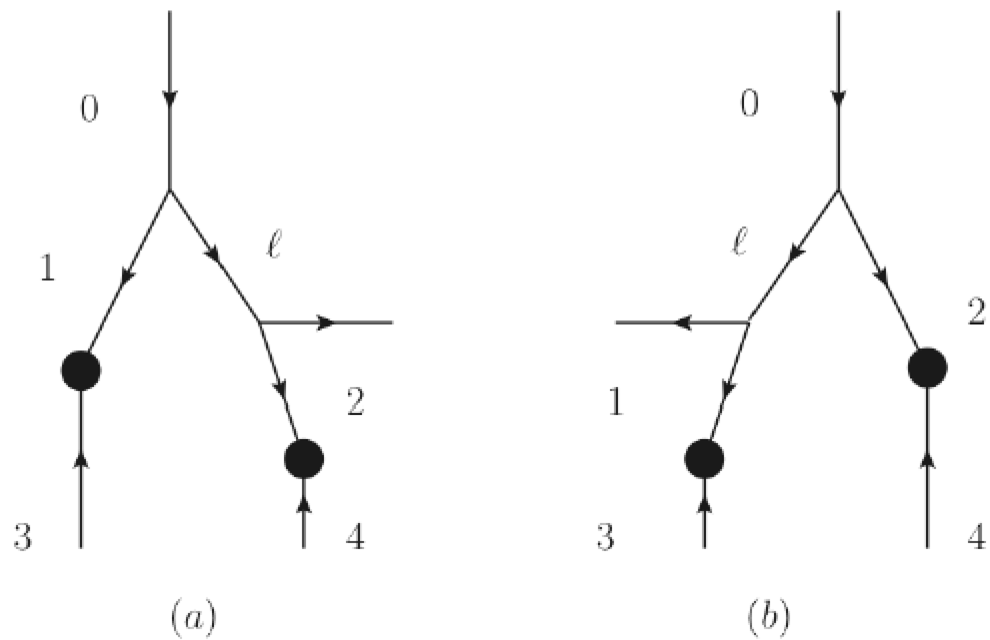


FIG. 3: Three-to-four amplitudes with extra emission from inside the splitting fork

$$\frac{d\sigma}{d^2\delta_{13}d^2\delta_{24}} \propto \frac{\alpha_{\rm s}}{\delta^2}\delta(\vec{\delta}_{13}+\vec{\delta}_{24}), \quad \delta^2 \equiv \delta_{13}^2 = \delta_{24}^2.$$

$$\frac{d\sigma}{d^2\delta_{13}d^2\delta_{24}} \propto \frac{\alpha_{\rm s}^2}{\delta^2\,\delta'^2}, \quad \delta'^2 \ll \delta^2 \equiv \delta_{13}^2 \simeq \delta_{24}^2.$$

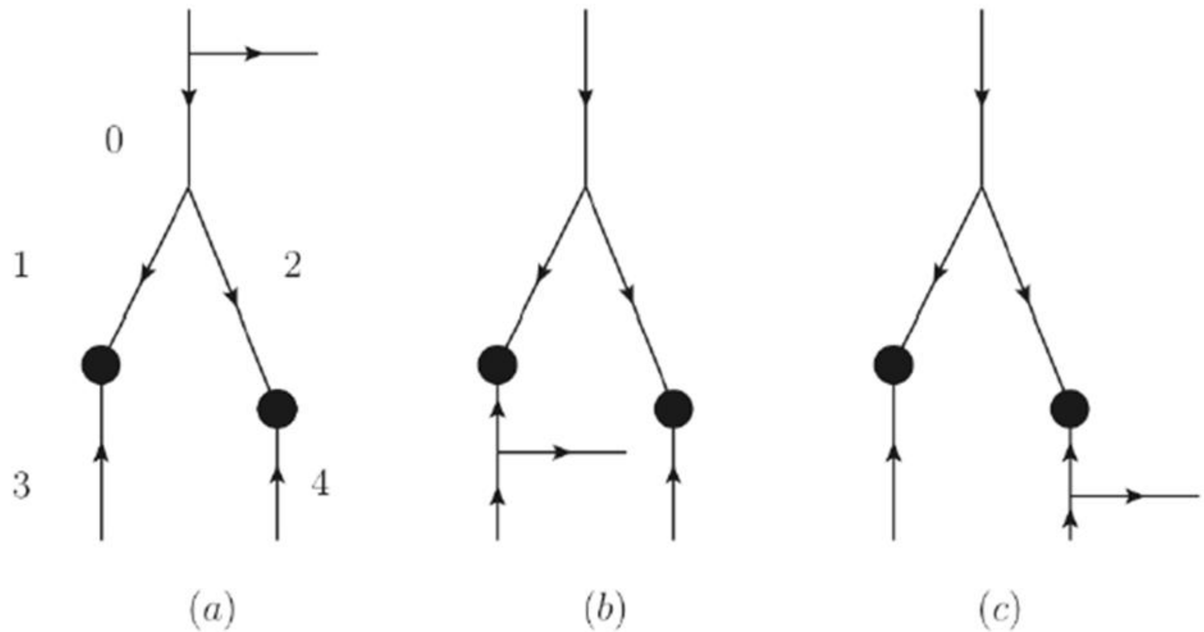


FIG. 4: $3 \to 4$ with real parton emission off the external lines

The short splits however lead to very different expression:

$$\frac{\pi^2\, d\sigma_2^{(3\to4)}}{d^2\delta_{13}\, d^2\delta_{24}} = \frac{d\sigma_{\rm part}}{d\hat{t}_1\, d\hat{t}_2} \cdot \frac{\alpha_s(\delta^2)}{2\pi\,\delta^2} \sum_c P_c^{1,2}\left(\frac{x_1}{x_1+x_2}\right) S_1(Q^2,\delta^2)\, S_2(Q^2,\delta^2)$$
$$\times \frac{\partial}{\partial\delta'^2}\left\{ S_c(\delta^2,\delta'^2)\frac{G_a^c(x_1+x_2;\delta'^2,Q_0^2)}{x_1+x_2} S_3(Q^2,\delta'^2) S_4(Q^2,\delta'^2) \times {}_{[2]}D_b^{3,4}(x_3,x_4;\delta'^2,\delta'^2)\right\}$$

- This expression contains GPD only of one of the hadrons. This contribution is not isotropic. It will depend on angle between two disbalances, with maximum, when they are opposite.

- Concequently, in the differential distributions we have 3 terms, corresponding to 4 to 4 and 3 to 4 (long and short):

$$\pi^2 \frac{d\sigma^{(4\to4)}}{d^2\delta_{13}\, d^2\delta_{24}} = \frac{d\sigma_{\rm part}}{d\hat{t}_1\, d\hat{t}_2} \cdot \frac{\partial}{\partial\delta_{13}^2} \frac{\partial}{\partial\delta_{24}^2} \Big\{ {}_{[2]}D_a^{1,2}(x_1,x_2;\delta_{13}^2,\delta_{24}^2) \times {}_{[2]}D_b^{3,4}(x_3,x_4;\delta_{13}^2,\delta_{24}^2)$$

$$\times\ S_1\left(Q^2,\delta_{13}^2\right) S_3\left(Q^2,\delta_{13}^2\right) \times S_2\left(Q^2,\delta_{24}^2\right) S_4\left(Q^2,\delta_{24}^2\right) \Big\}.$$

$$\pi^2 \frac{d\sigma_1^{(3\to4)}}{d^2\delta_{13}\, d^2\delta_{24}} = \frac{d\sigma_{\rm part}}{d\hat{t}_1\, d\hat{t}_2} \cdot \frac{\partial}{\partial\delta_{13}^2} \frac{\partial}{\partial\delta_{24}^2} \Big\{ {}_{[1]}D_a^{1,2}(x_1,x_2;\delta_{13}^2,\delta_{24}^2) \cdot {}_{[2]}D_b^{3,4}(x_3,x_4;\delta_{13}^2,\delta_{24}^2)$$

$$\times\ S_1\left(Q^2,\delta_{13}^2\right) S_3\left(Q^2,\delta_{13}^2\right) \cdot S_2\left(Q^2,\delta_{24}^2\right) S_4\left(Q^2,\delta_{24}^2\right) \Big\}.$$

- here S are the corresponding Sudakov formfactors . We see that 4 to 4 and long split 3 to 4 are expressed through convolution of 2GPD of two colliding hadrons – the expressions look
- quite similar to DDT formula

The total cross sections

$$\frac{d\sigma(x_1,x_2,x_3,x_4)}{d\hat{t}_1\,d\hat{t}_2} = \frac{d\sigma^{13}}{d\hat{t}_1}\,\frac{d\sigma^{24}}{d\hat{t}_2} \times \left\{ \frac{1}{S_4} + \frac{1}{S_3} \right\}.$$

$$\frac{1}{S_4} = \int \frac{d^2\vec{\Delta}}{(2\pi)^2}\ {}_{[2]}D_{h_1}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta})\ {}_{[2]}D_{h_2}(x_3,x_4;q_1^2,q_2^2;-\vec{\Delta}).$$

$$\frac{1}{S_3} = \int \frac{d^2\vec{\Delta}}{(2\pi)^2}\left[{}_{[2]}D_{h_1}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta})\,{}_{[1]}D_{h_2}(x_3,x_4;q_1^2,q_2^2) + {}_{[1]}D_{h_1}(x_1,x_2;q_1^2,q_2^2)\ {}_{[2]}D_{h_2}(x_3,x_4;q_1^2,q_2^2;\vec{\Delta})\right].$$

2 Parton GPD:perturbative structure.

- Two parton GPD can be also studied in pQCD. We immediately obtain that

$$
\begin{aligned}
D_a^{b,c}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta}) &= {}_{[2]}D_a^{b,c}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta}) \\
&+ {}_{[1]}D_a^{b,c}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta}).
\end{aligned}
$$

$$
\begin{aligned}
{}_{[2]}D_a^{b,c}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta}) &= S_b(q_1^2,Q_{\min}^2)S_c(q_2^2,Q_{\min}^2)\,{}_{[2]}D_a^{b,c}(x_1,x_2;Q_0^2,Q_0^2;\vec{\Delta}) \\
&+ \sum_{b'}\int_{Q_{\min}^2}^{q_1^2}\frac{dk^2}{k^2}\frac{\alpha_s(k^2)}{2\pi}S_b(q_1^2,k^2)\int\frac{dz}{z}P_{b'}^b(z)\,{}_{[2]}D_a^{b',c}\left(\frac{x_1}{z},x_2;k^2,q_2^2;\vec{\Delta}\right) \\
&+ \sum_{c'}\int_{Q_{\min}^2}^{q_2^2}\frac{dk^2}{k^2}\frac{\alpha_s(k^2)}{2\pi}S_c(q_2^2,k^2)\int\frac{dz}{z}P_{c'}^c(z)\,{}_{[2]}D_a^{b,c'}\left(x_1,\frac{x_2}{z};q_1^2,k^2;\vec{\Delta}\right).
\end{aligned}
$$

$$
Q_{\min}^2 = \max(Q_0^2,\Delta^2) \simeq Q_0^2+\Delta^2,
$$

$$
{}_{[1]}D_a^{b,c}(x_1,x_2;q_1^2,q_2^2;\vec{\Delta}) = \sum_{a',b',c'} \int_{Q^2_{\min}}^{\min(q_1^2,q_2^2)} \frac{dk^2}{k^2}\,\frac{\alpha_s(k^2)}{2\pi} \int \frac{dy}{y^2}\, G_a^{a'}(y;k^2,Q_0^2)
\times \int \frac{dz}{z(1-z)}\, P_{a'}^{b'[c']}(z)\; G_{b'}^{b}\left(\frac{x_1}{zy};q_1^2,k^2\right) G_{c'}^{c}\left(\frac{x_2}{(1-z)y};q_2^2,k^2\right).
$$

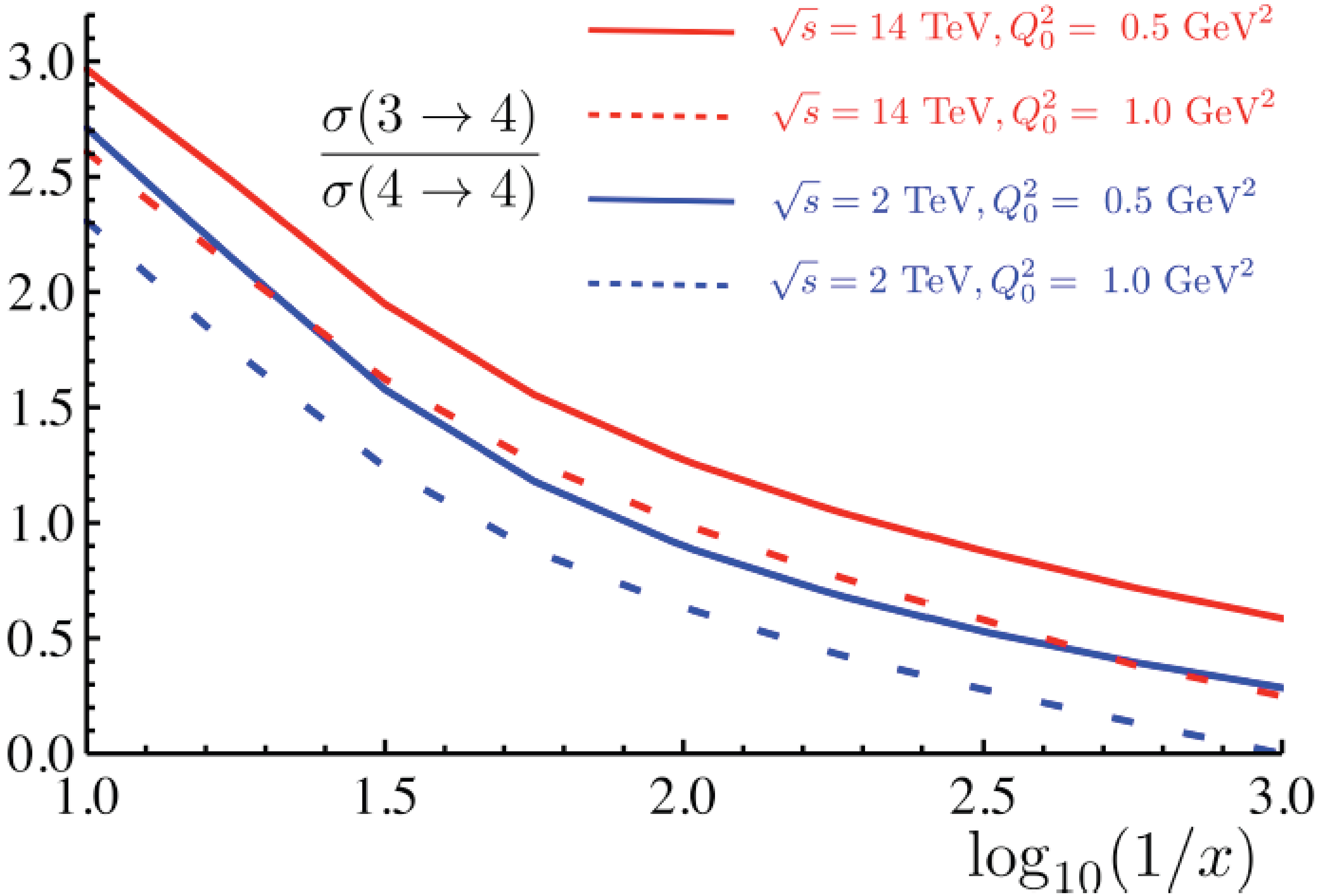
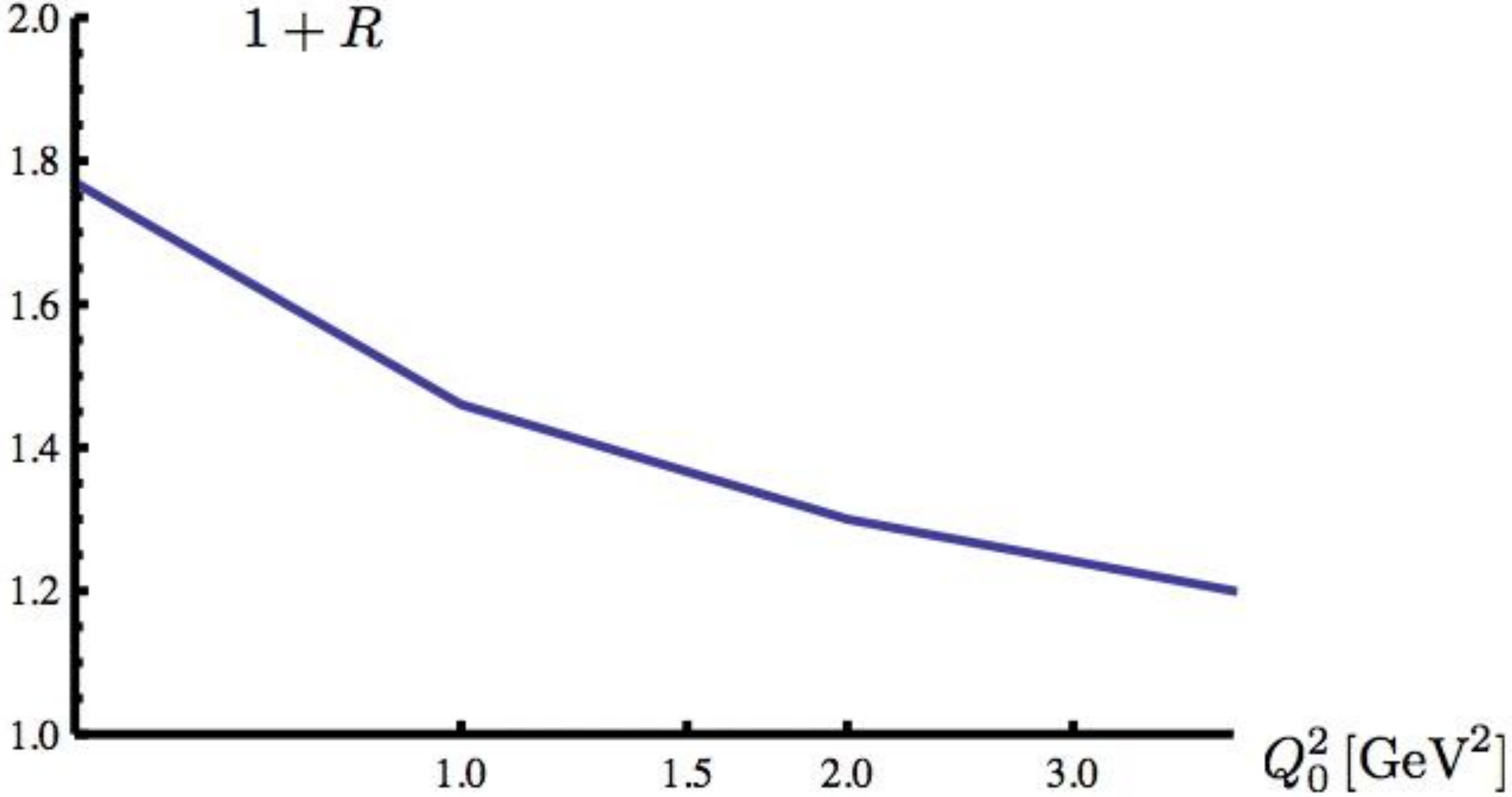
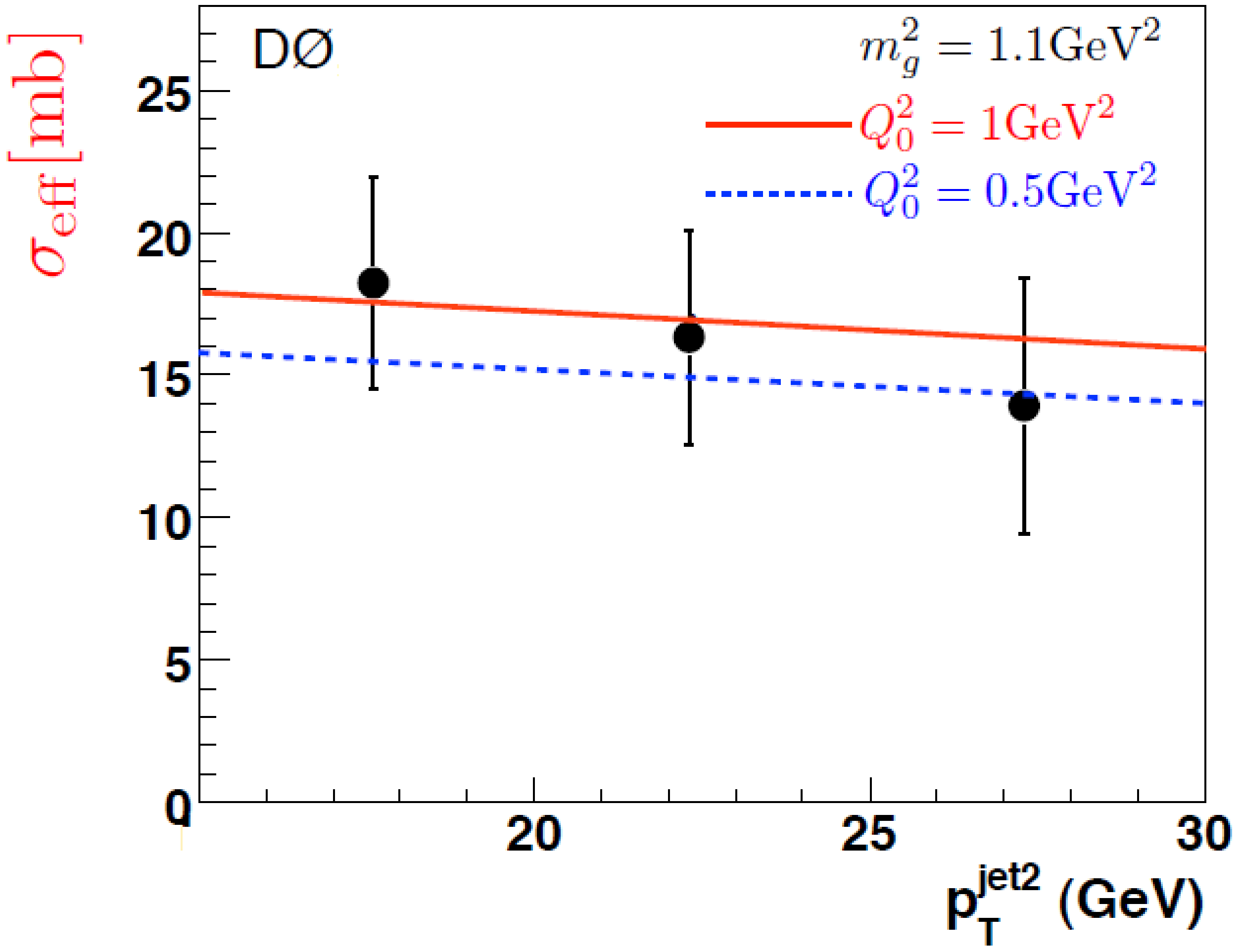


FIG. 3: The ratio of $3 \to 4$ to $4 \to 4$ contributions to $4g \to 4$ jets cross section ($x_i = x$) for Tevatron and LHC energies for two choices of the starting evolution scale Q_0^2; $Q^2 = x^2 s/4$.

The dependence on Q_0^2 (ladder split scale)



D0 physics (slightly larger energies)



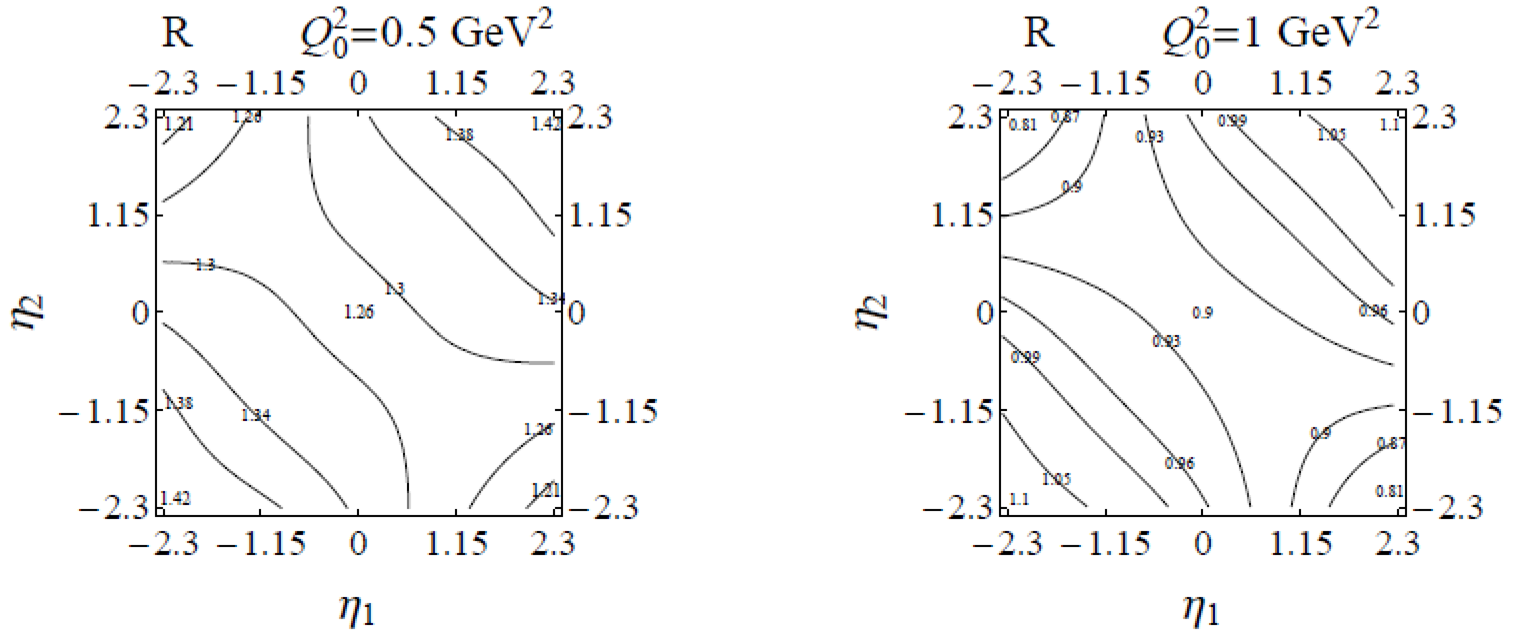


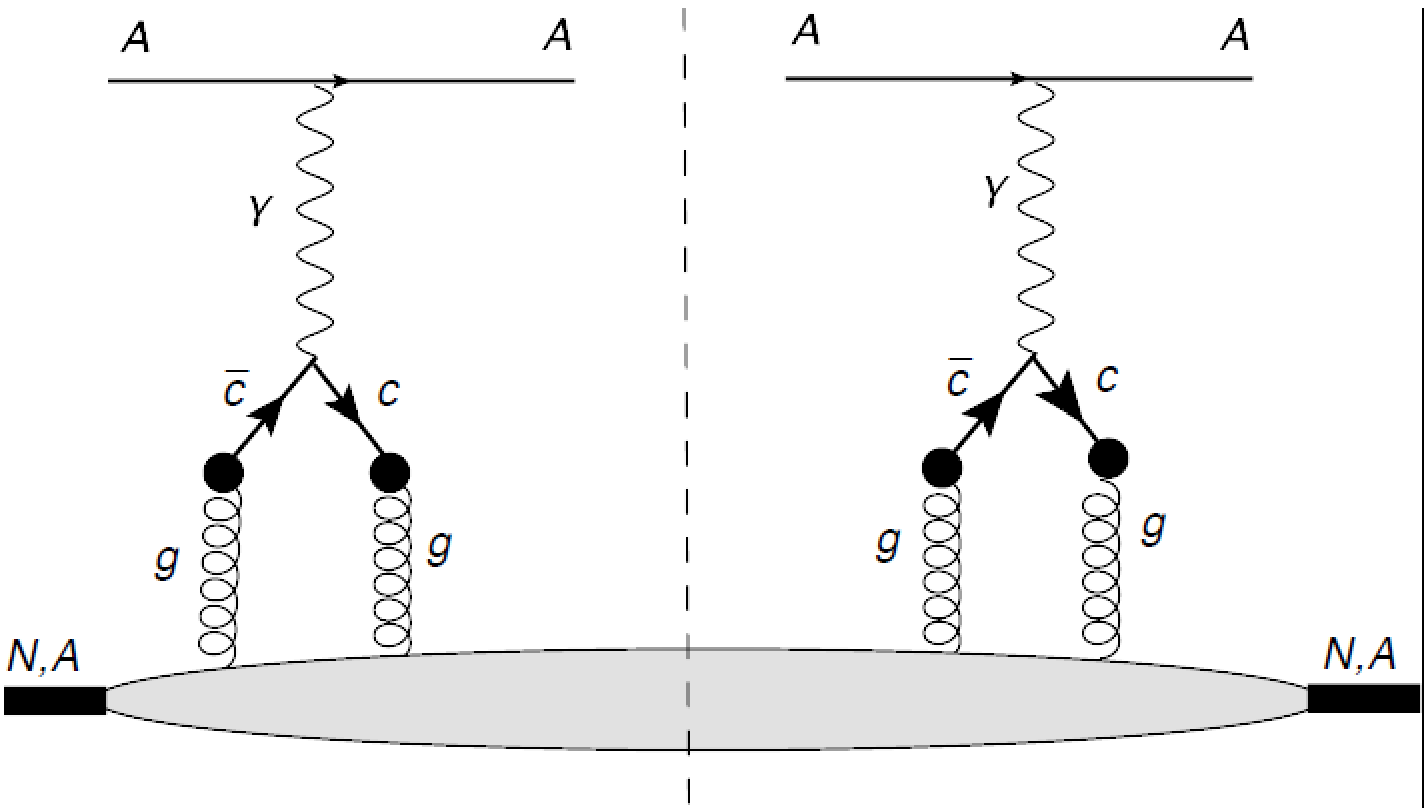
FIG. 7: Rapidity dependence of the R factor for two pairs of $p_\perp = 50\,\mathrm{GeV}$ jets produced in gluon-gluon collisions

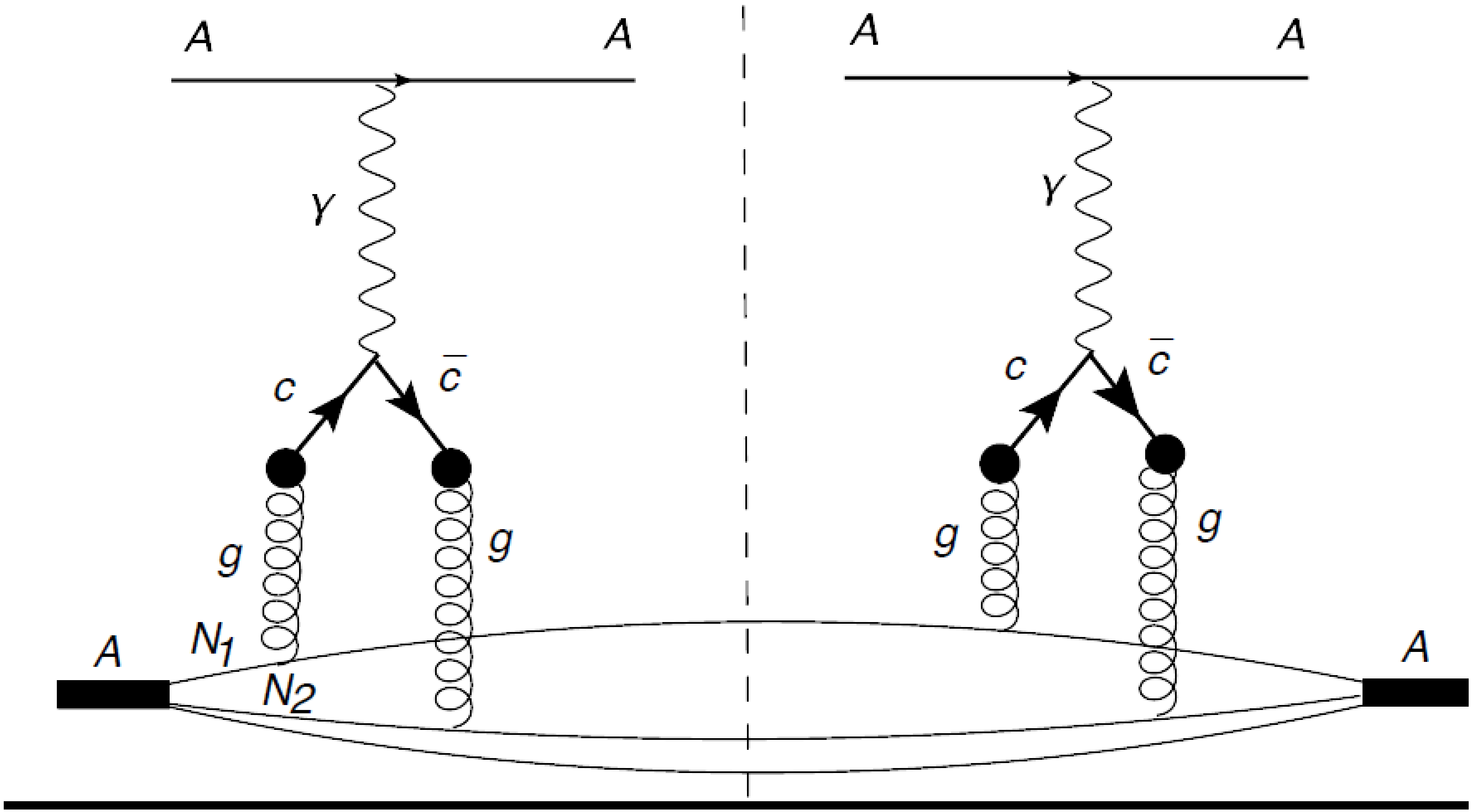
See arXiv:1306.3763 *for detailed predictions for different processes.*

UPC photon proton-give possibility of clean-free of soft QCD study of MPI. Kinematics: x1,x2 for charmed jets are large, i.e. we consider processes

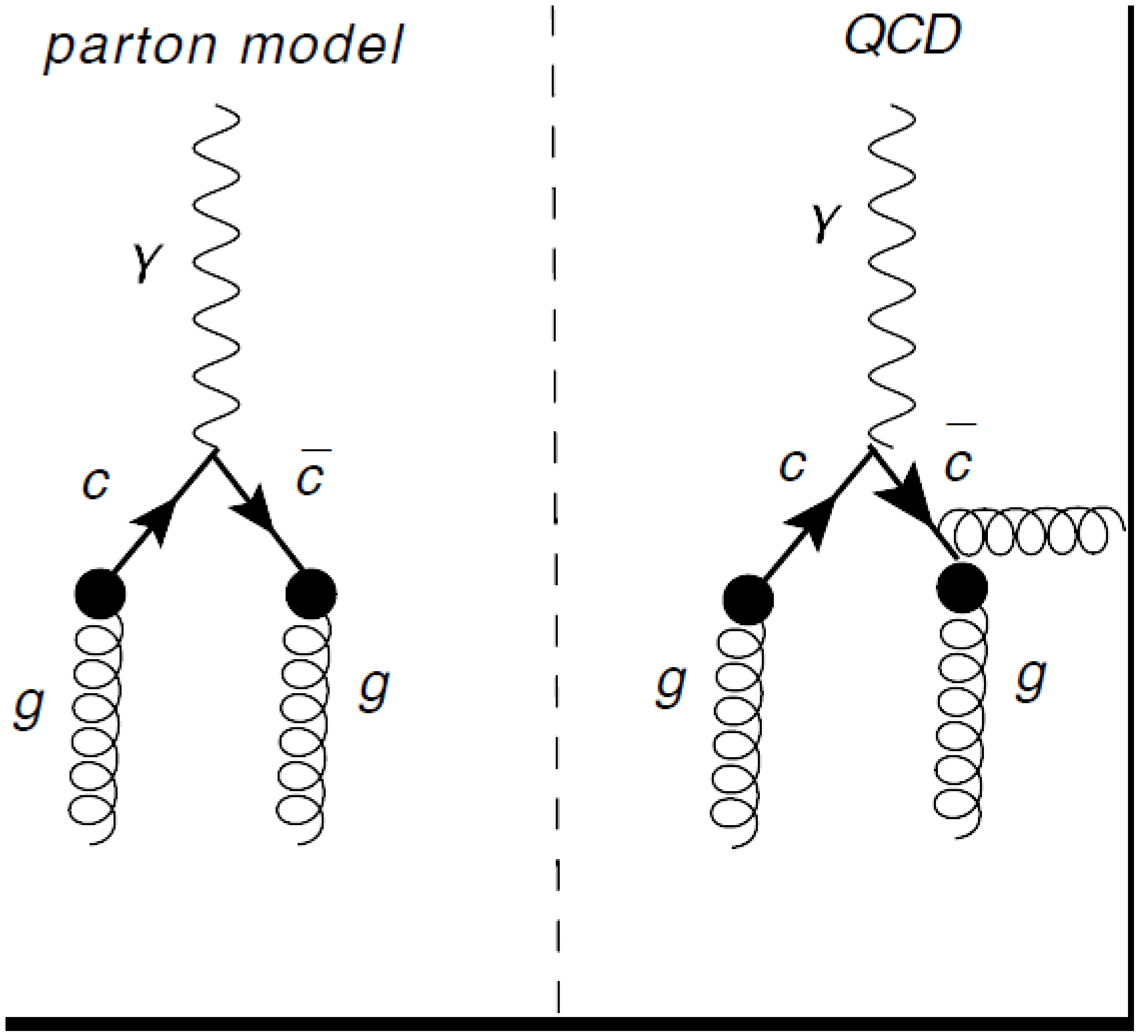
With direct photons, and large pseudorapidity gaps in each pair of dijets, 3—4, with pt 7-15 GeV (can be done due to photons).

This is very different kinematics from the processes with resolved photons MPI considered at HERA/LHC by Butterworth,Forshaw,Seymour (JIMMY) which are very similar to pp and conatain all the related uncertainties)





A
A
A
A
γ
γ
c
c̄
c
c̄
g
g
g
g
A
A
N1
N2



parton model
QCD
γ
c
c̄
g
g
γ
c
c̄
g
g

$$\pi^2 \frac{d\sigma_1^{(3\to4)}}{d^2\delta_{13}\, d^2\delta_{24}} = \frac{d\sigma_{\text{part}}}{d\hat{t}_1\, d\hat{t}_2} \cdot \frac{\partial}{\partial\delta_{13}^2} \frac{\partial}{\partial\delta_{24}^2} \Big\{ {}_{[1]}D_a^{1,2}(x_1, x_2; \delta_{13}^2, \delta_{24}^2) \cdot {}_{[2]}D_b^{3,4}(x_3, x_4; \delta_{13}^2, \delta_{24}^2)$$

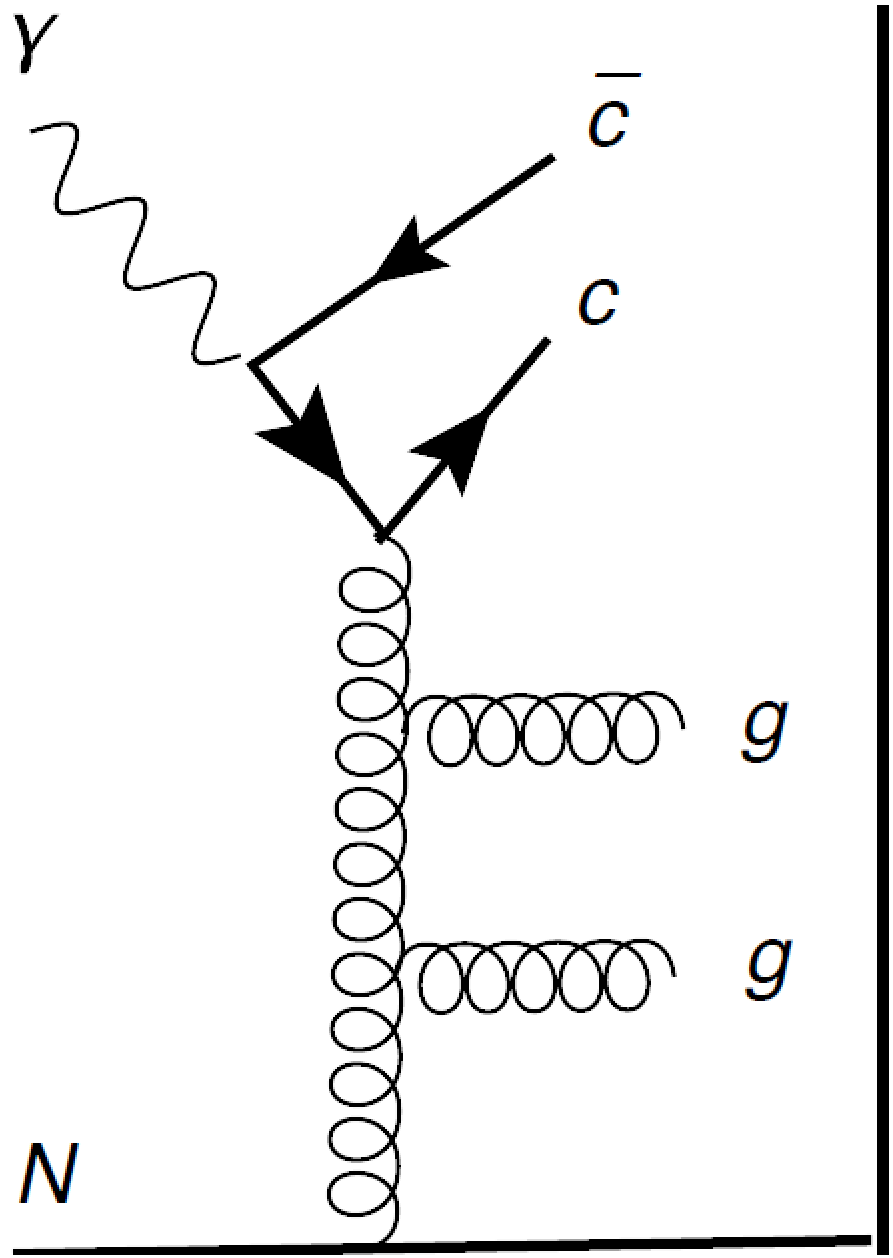
$$\times\ S_1\left(Q^2, \delta_{13}^2\right) S_3\left(Q^2, \delta_{13}^2\right) \cdot S_2\left(Q^2, \delta_{24}^2\right) S_4\left(Q^2, \delta_{24}^2\right) \Big\}.$$

$$_{[1]}D(x_1, x_2; q_1^2, q_2^2; \vec{\Delta}) = \int_{m_c^2+\Delta^2}^{\min(q_1^2, q_2^2)} \frac{dk^2}{k^2} \frac{\alpha_{em}}{4\pi} \times \int \frac{dz}{z(1-z)} R(z)\ G_{q'}^q\left(\frac{x_1}{z}; q_1^2, k^2\right) G_{q'}^q\left(\frac{x_2}{(1-z)}; q_2^2, k^2\right).$$

$$R(z) = z^2 + (1-z)^2$$

$$\sigma_{\gamma p\to 4j+X} = \int dp_{1t}^2 \int dp_{2t}^2 \int dk \int \frac{dx_1 dx_2 dx_3 dx_4}{x_1 x_2 x_3 x_4} \frac{dN}{dk} D(x_1, x_2, p_{1t}, p_{2t})$$

$$\frac{d\sigma_1}{dt_1} \frac{d\sigma_2}{dt_2} \times \frac{m_g^2}{12\pi^2} G(x_3, p_{1t}^2) G(x_4, p_{2t}^2)$$



γ
$\bar{c}$
c
g
g
N

Numerics: very preliminary

We consider AA and pA. for pt 7-15 GeV we have for luminosity 10^{27} $Cm^{-2}\,s^{-1}$ rate $5*10^{4}$ events for AA, where kinematics x1,x2>0.2- direct photons-is taken. For pA, with luminosity 10^{30} we have the same rates by the order of magnitude.

Conclusion:UPC at LHC, especially AA ones can give Invaluable information on MPI and nonlinear QCD effects-
Ladder splitting, and they are a unique tool to study short Range transverse correlations between partons, created at the same impact parameter .