

# QCD Reggeon Field Theory for DIS on Nuclei

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Small- $x$  Meeting, Lissabon, June 28 - July 1, 2006

- Goal: QCD reggeon field theory for DIS on nuclei
- Feynman diagrams in momentum space
- DIS: two hierarchies of equations
- General field theory structure

## Introduction

Interest in QCD reggeon field theory: HERA, RHIC, LHC.

Most of the discussion for nuclei (RHIC) is done in configuration space: hierarchies of evolution equations (Balitsky, JIMWLK), Pomeron loops etc.

Goal: Derive QCD reggeon field theory in momentum space.

Cross sections (semi-inclusive) need momentum space.

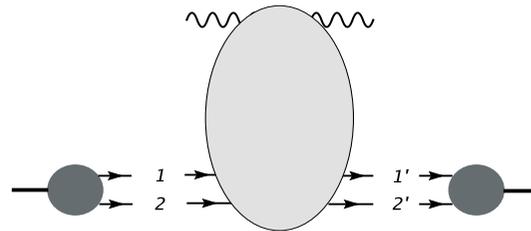
Some technical issues: central role of bootstrap equations.

Leading order: two hierarchies of equations (partially known).

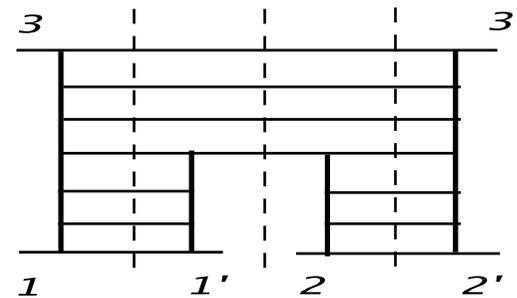
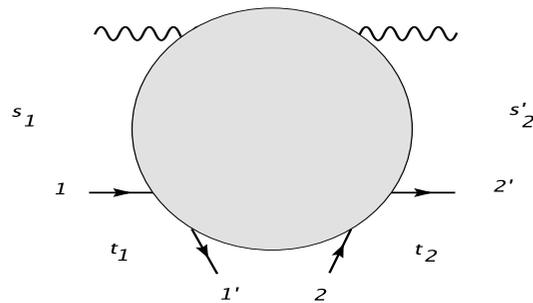
Beyond: reggeon field theory with (known) vertex functions.

Details: in a paper (to appear).

## Framework: DIS on a two-nucleon system

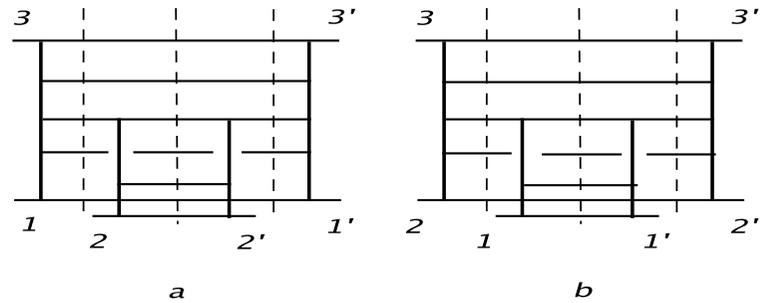


Two nucleons in loosely bound state, integration over longitudinal momentum transfer. Form factor effect limits integration over transverse momentum. **Use triple discontinuities.** In the kinematic region of interest:

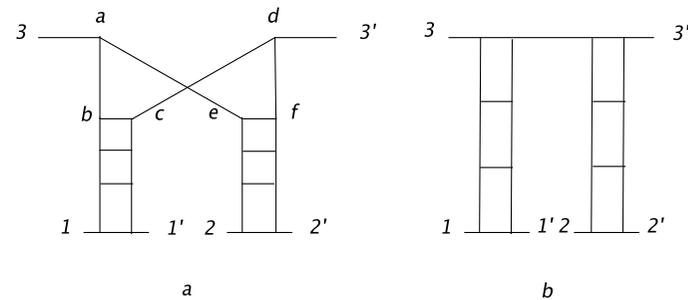


Use triple Regge formula, compute partial wave.

Cannot be all. Where is the double cut (AGK):



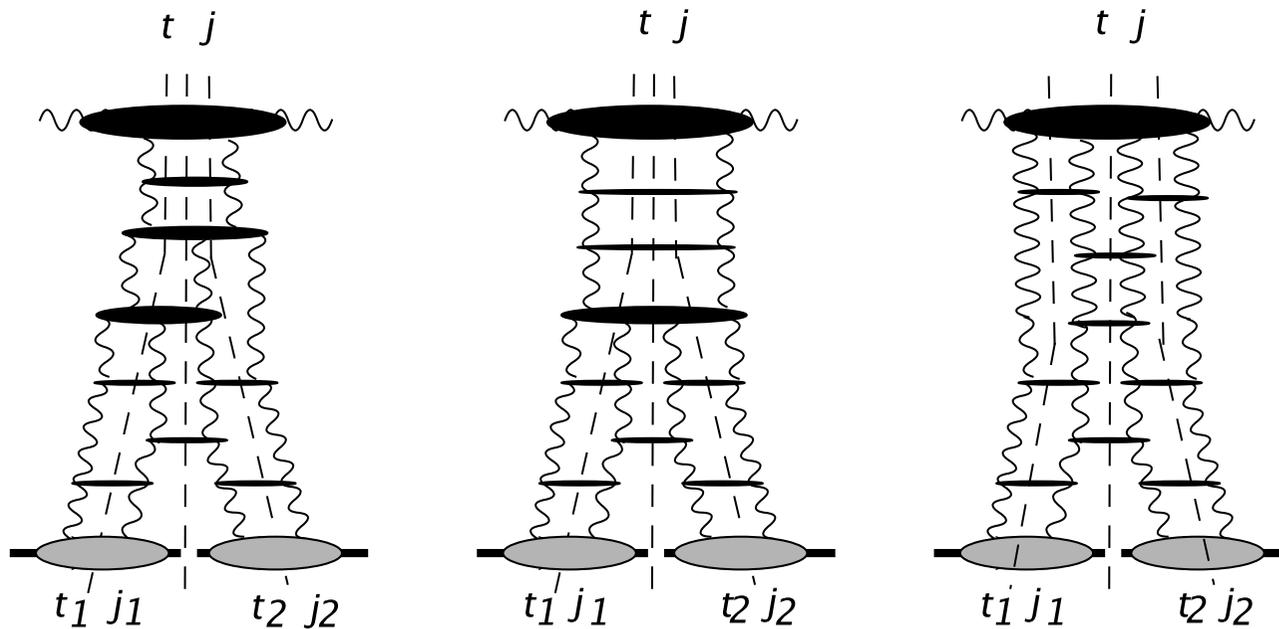
Do we need to add both contributions? No, there is an identity (AFS, Mandelstam):



Sufficient to keep the planar structure (for total cross section; not semi-inclusive).

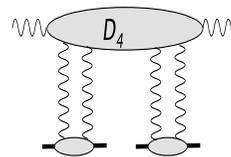
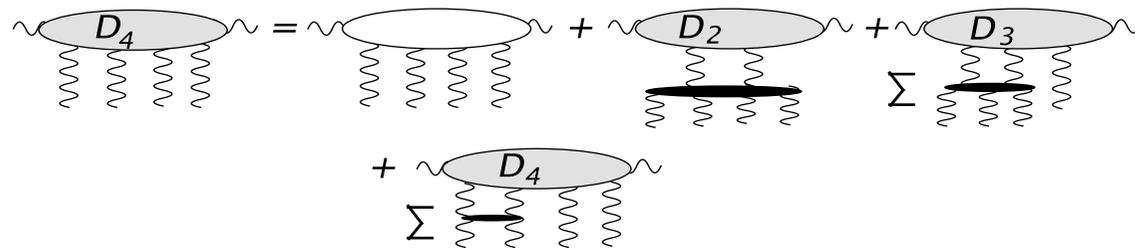
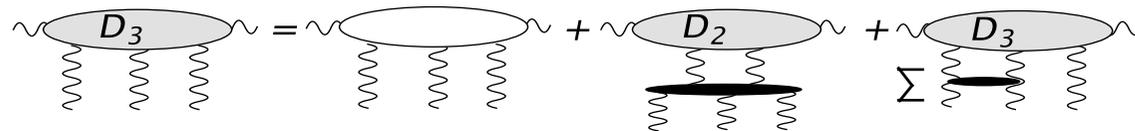
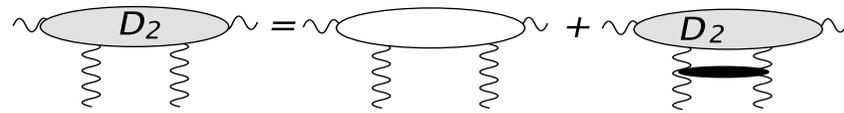
## QCD: sum production processes

Use BFKL amplitudes, compute unitarity integrals, integrate over 'diffractive mass':



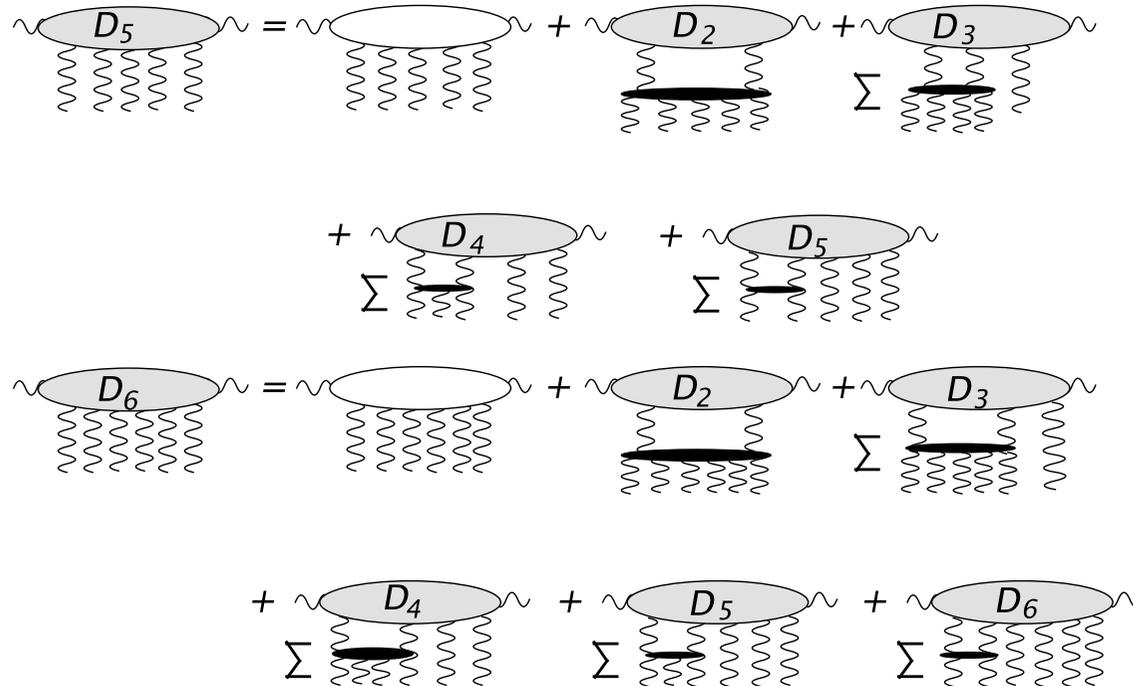
Vertical wavy lines = reggeized gluons, horizontal black lines = real gluon production. Contains elastic rescattering of the  $q\bar{q}$  pair. Generalized leading-log calculation!

Represent sums of diagrams in terms of integral equations ( $D_3$ : auxiliary function):



At the end: couple to the nucleons at the bottom

Generalization to scattering on 3 nucleons.



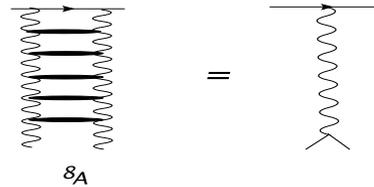
Contains rescattering of the  $q\bar{q}$  system, and rescattering of produced gluons ('eikonal').  
Hierarchy of equations:

$$D_n(\vec{k}_1, \dots, \vec{k}_n; \omega)_{a_1, \dots, a_n}$$

represent sums of production processes (not to be compared with Balitsky or JIMWLK).

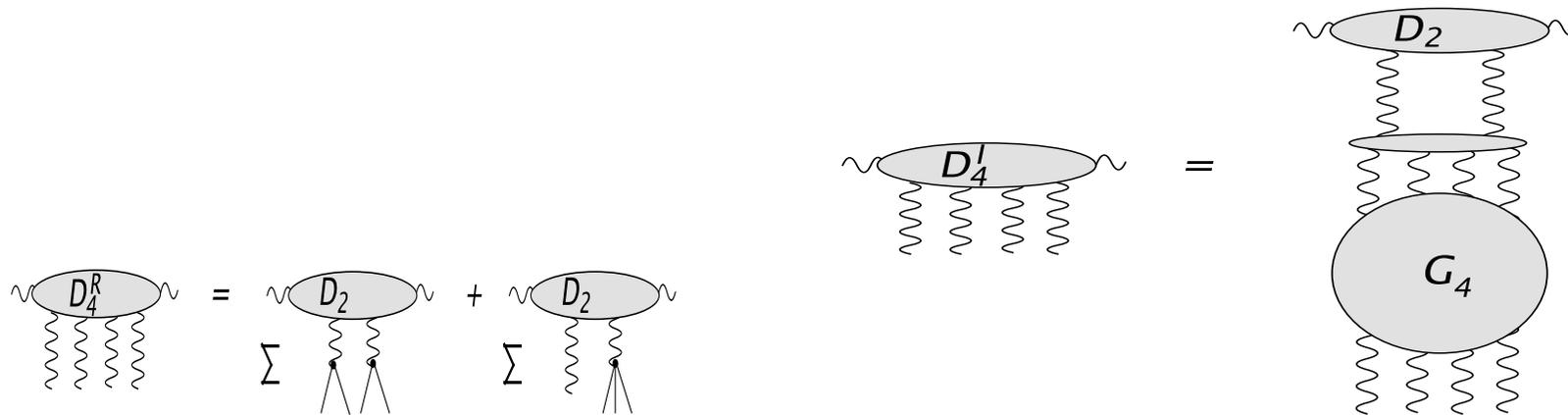
## Bootstrap: Reduction $D_n \rightarrow D_n^I$

The  $D_n$  functions contain reggeization: bootstrap



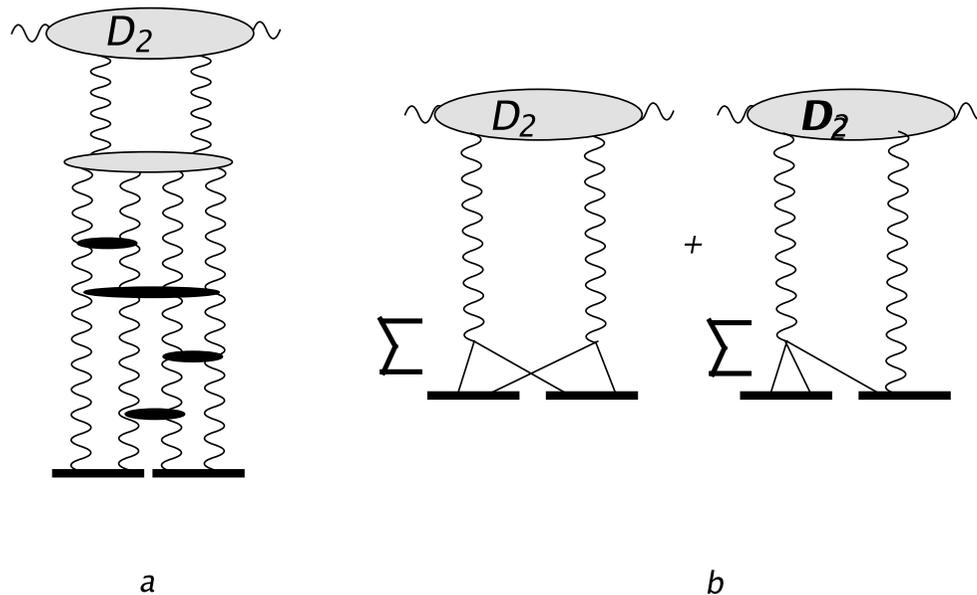
Task: remove such pieces from the  $D_n$ . 'Reduction' (JB, Wuesthoff, Ewerz).

$$D_4 = D_4^R + D_4^I$$



Vertex  $2 \rightarrow 4$  gluons (Fourier transform  $\rightarrow$  BK). Only 'enhanced' structure (not eikonal).  
 Advantage: correct symmetry in  $t$ -channel. Disadvantage: lose connection to individual final states, only for inclusive cross section.

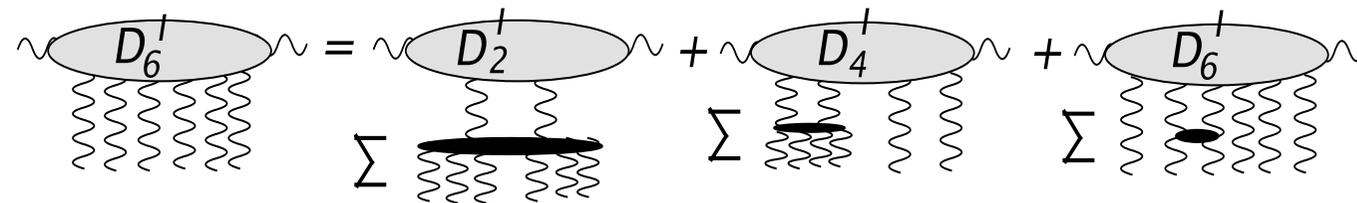
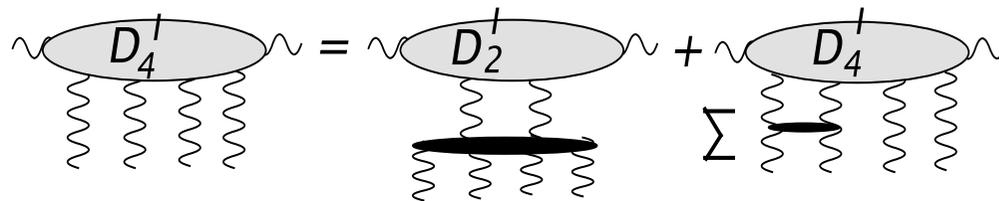
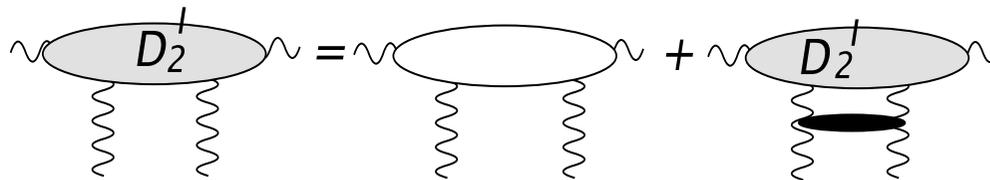
Coupling to nucleons: 'clusters' appear



Large- $N_c$  suppression is partially compensated by large  $A$  (combinatorics)!

Hierarchy of equations for 'irreducible functions':

$$D_{2n}^I(\vec{k}_1, \dots, \vec{k}_n; \omega)_{a_1, \dots, a_n}$$



In addition: the reggeizing pieces (obtained from the  $D_{2n}$  by attaching gluon splittings).  
 In this generalized leading log approximation: number of reggeized gluons never decreases.

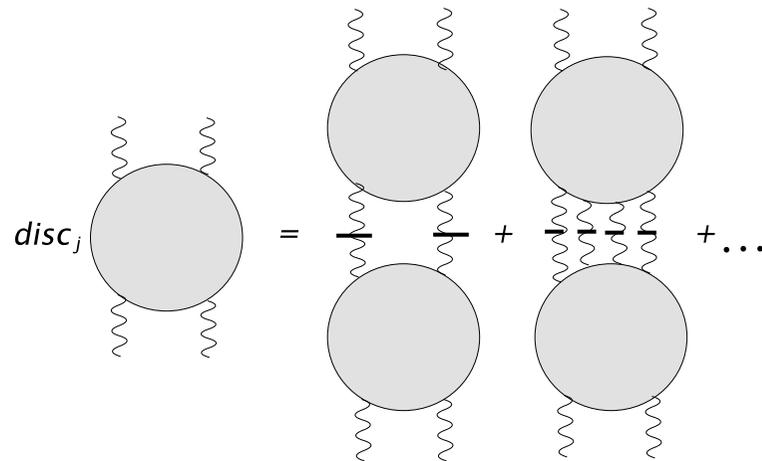
Several comments:

- equations for  $D_{2n}^I$  to be compared with Balitsky/JIMWLK (have the same evolution kernels)
- But: where are the reggeizing pieces? Consequences for DIS on nuclei.
- Connection with particle production: inclusive vs. semi-inclusive cross sections
- momentum space description has space-time interpretation
- So far: generalized leading-log approximation. Can be extended to NLO.  
First steps:  $2 \rightarrow 4$  vertex, (connected)  $3 \rightarrow 3$  vertex.  
Effective action (Lipatov).
- $D_{2n}$  in the large- $N_c$  limit: fan diagram structure
- Inclusive cross section: bootstrap has far-reaching consequences (JB,Salvadore,Vacca)

## Beyond: 'Pomeron loops'

Idea (Gribov, Pommeranchuk; White ): reggeon unitarity.

Green's function satisfy  $t$ -channel unitarity in angular momentum ( $\omega$ ):

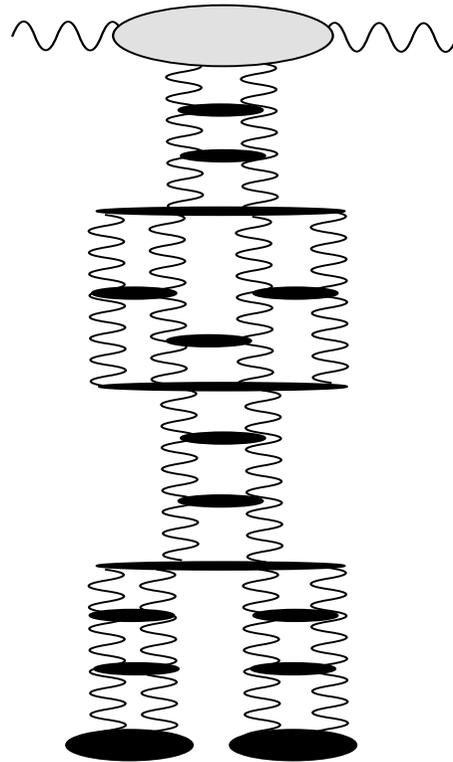


Solution: field theory of reggeized gluons

Interaction kernels known from  $D_{2n}^I$ .

Leads to 'loop diagrams', for example:

Compact formulation:  
either as action (**Braun**)  
or as evolution equations.  
Symmetry: target - projectile.



# Conclusions

What has been achieved:

- momentum space reggeon field theory for DIS on nuclei
- central role of bootstrap
- connection with  $s$ -channel particle production
- allows high order corrections

To be done:

- Solutions (evolution equations; in zero transverse dimensions)
- Connection with Balitsky, JIMWLK
- Extend to nucleus - nucleus