Theoretical remarks on Drell-Yan production at small x

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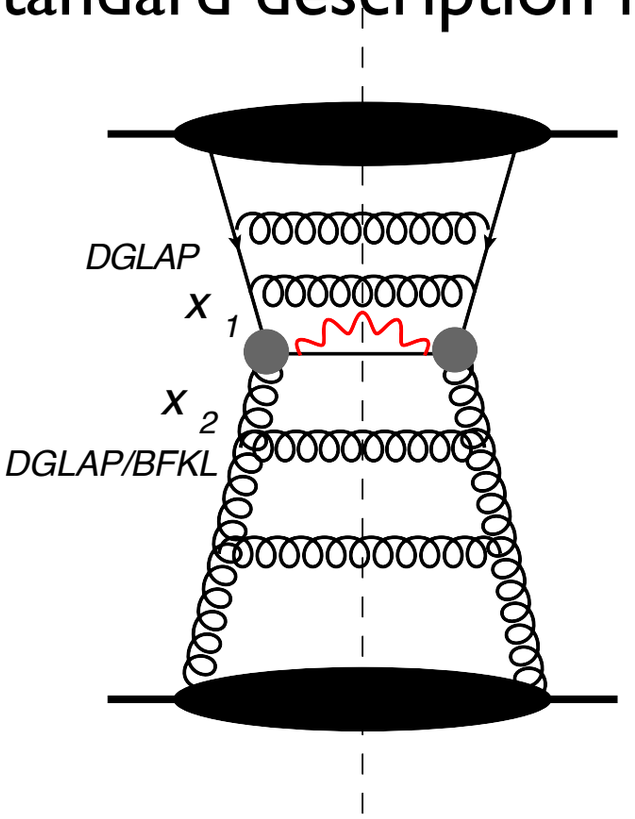
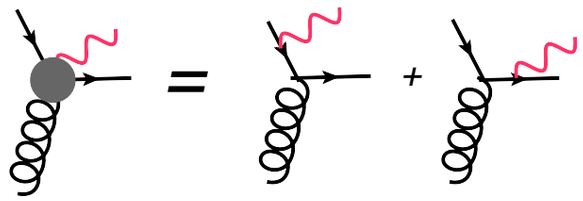
(Work in progress; started with Leszek Motyka)

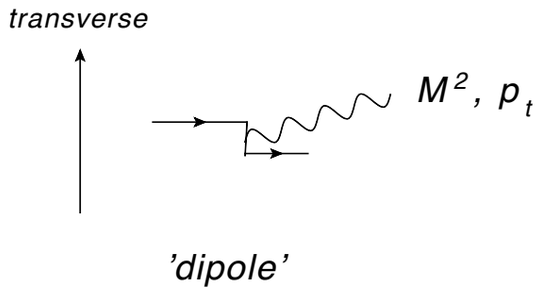
Introduction

Drell-Yan cross section in the forward region:
promising place for small-x physics at the LHC
Aim: study theoretical background, analogous to DIS.

Standard description for the inclusive Drell Yan cross section:





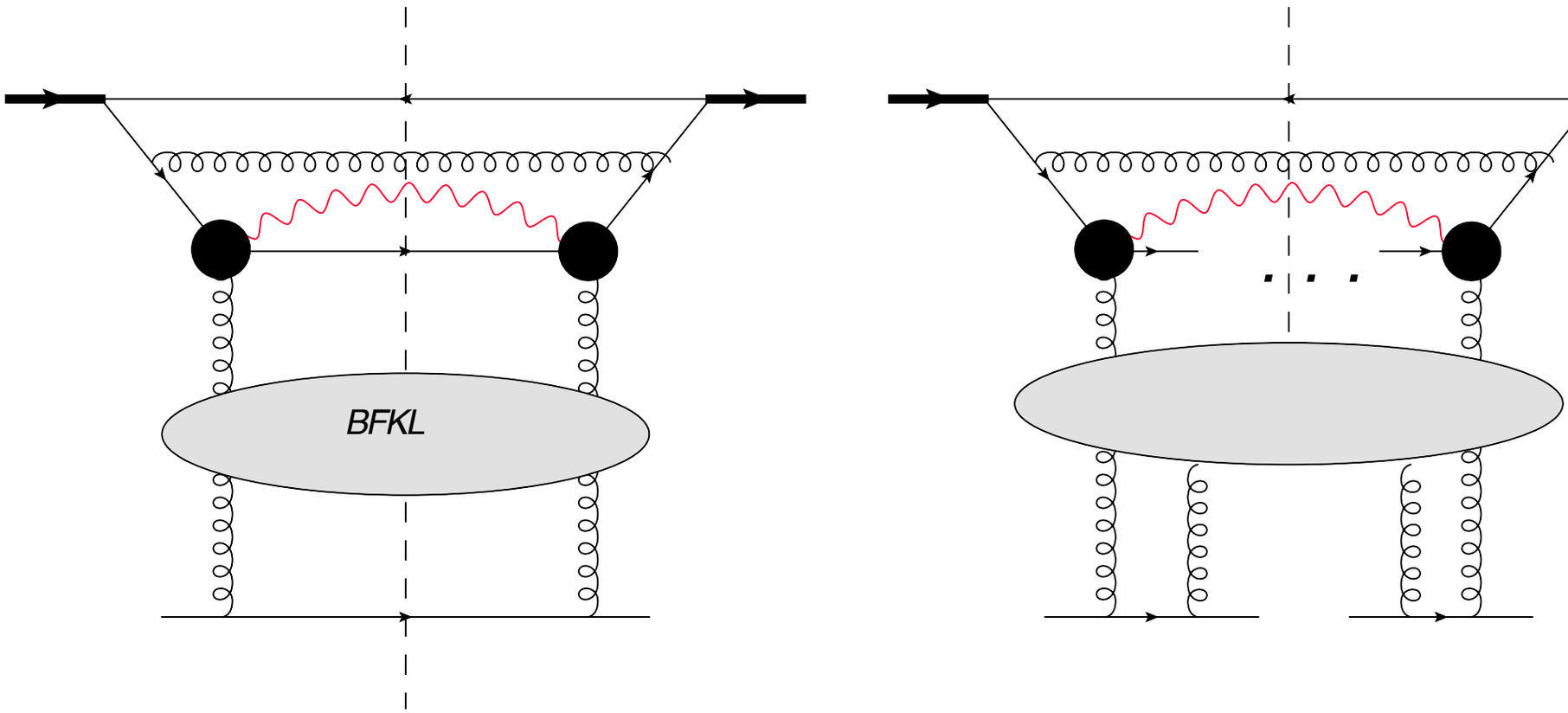


At small x: (Kopeliovich...)

upper quark looks like dipole,
replace lower gluon density
by dipole cross section

In the following: try to derive this from Feynman diagrams

Define setup:
replace the upper proton by a quark-antiquark pair, scattering on two targets

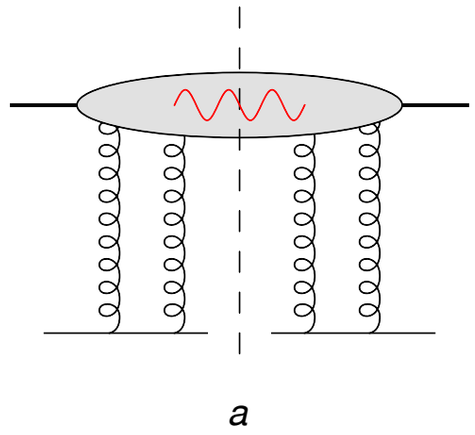


Initially :
Drell-Yan photon with finite mass, transverse momentum.
gluons see quark-pair as total system: 'impact factor'
(no gluon rung inside the quark pair)

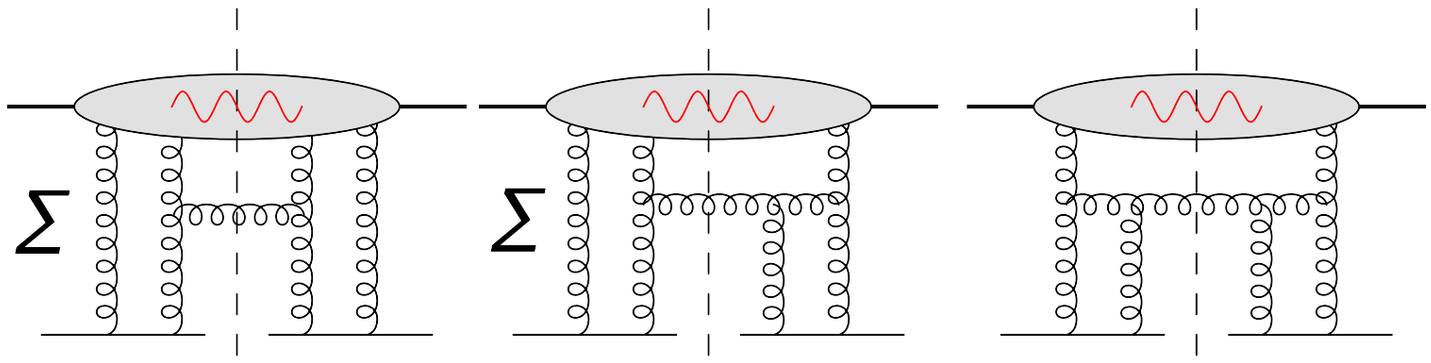
Later on: large Mass

What needs to be calculated?

Lowest order diagrams:



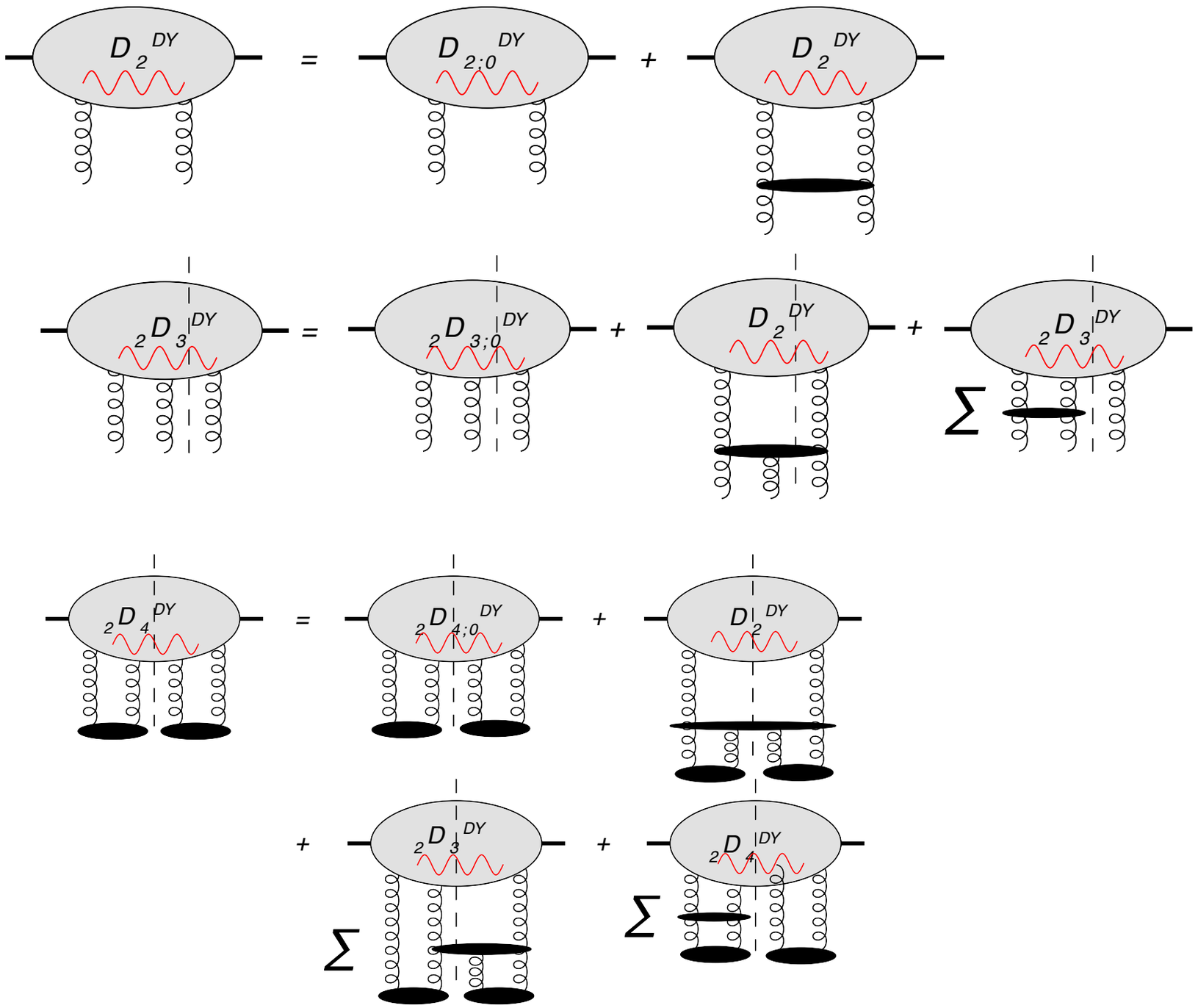
a



b *c* *d*

Need ‘impact factors’ with 2, 3, or 4 gluons

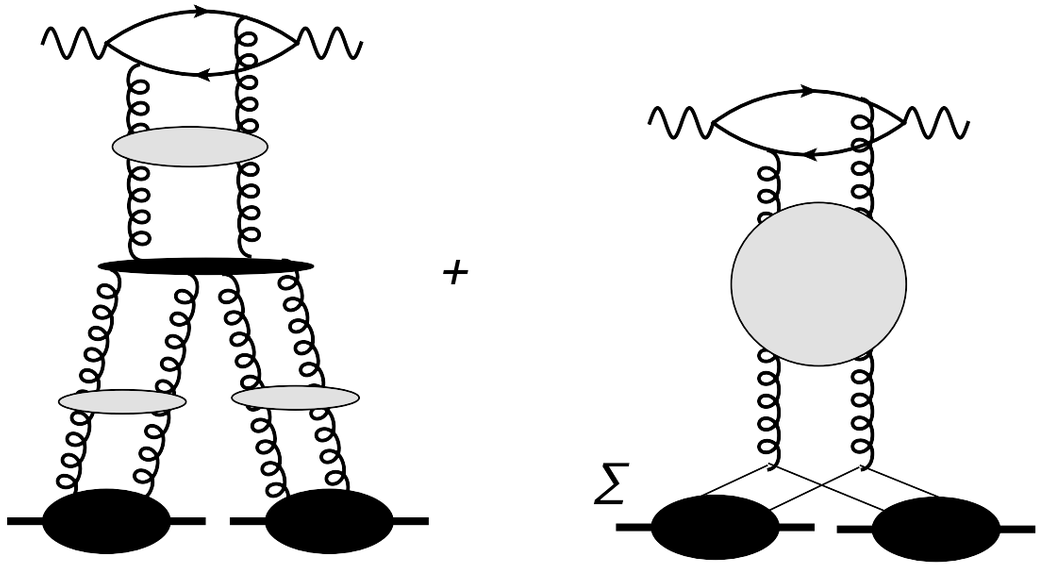
After 'dressing' these diagrams: infinite sums, use integral equations



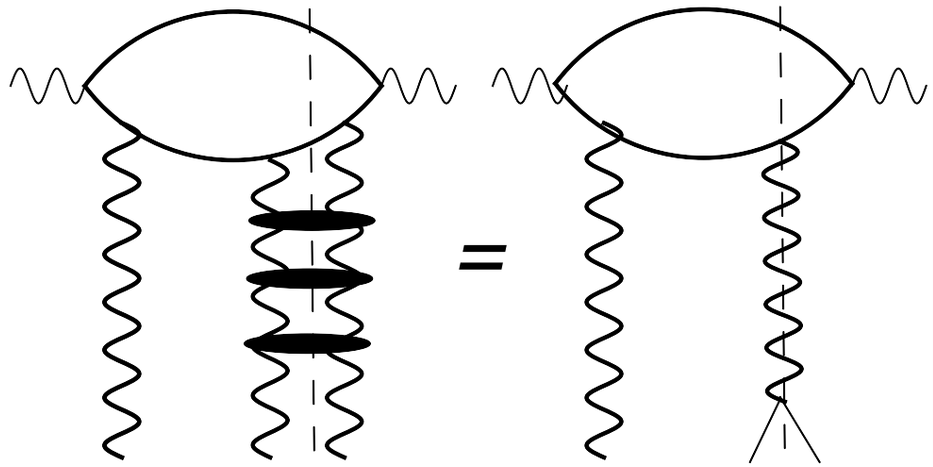
Need to be re-organized: reggeization of the gluon

Reminder of the inclusive case (DIS):

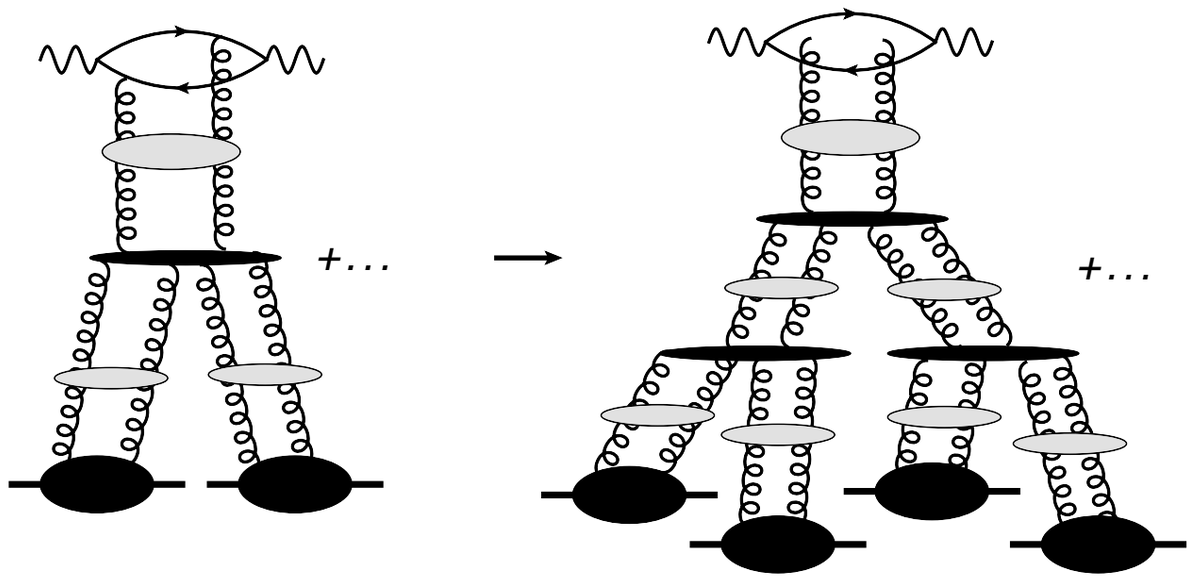
similar equations, remarkably simple solution



reason: reggeization



bootstrap: gluon reggeization

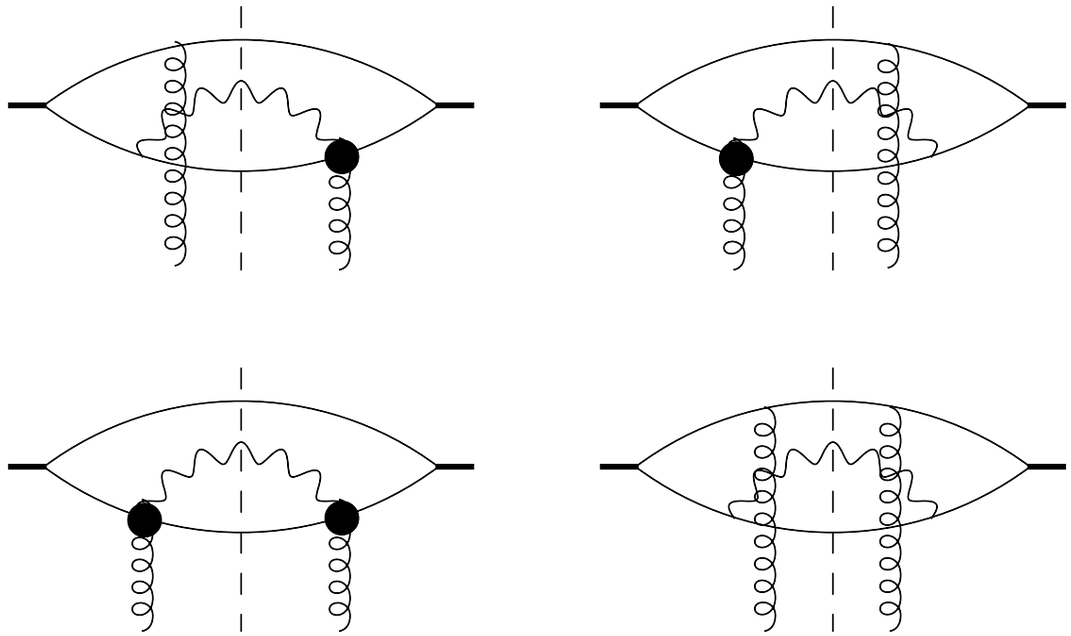


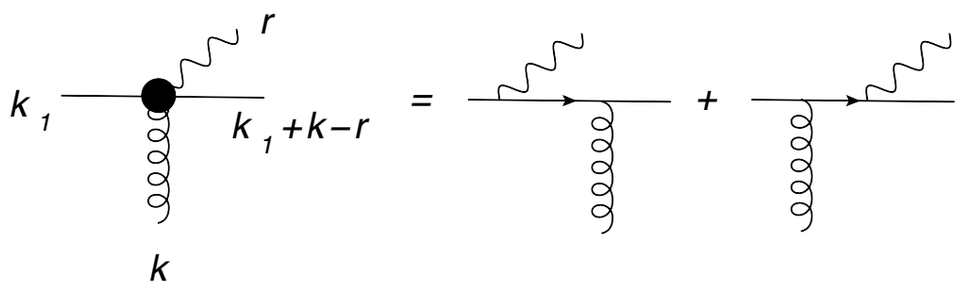
BK–equation (at large N)

Drell-Yan: works differently, three gluon state remains

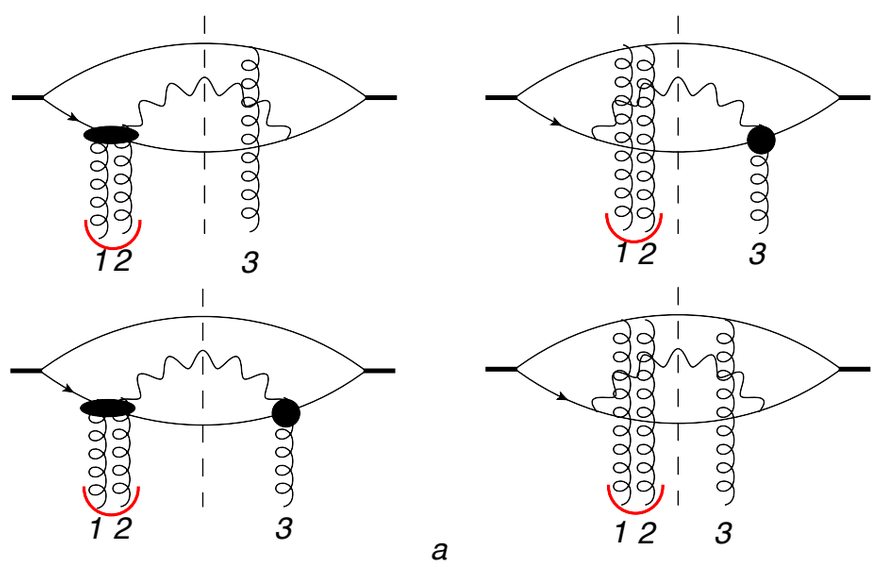
‘Impact factors’

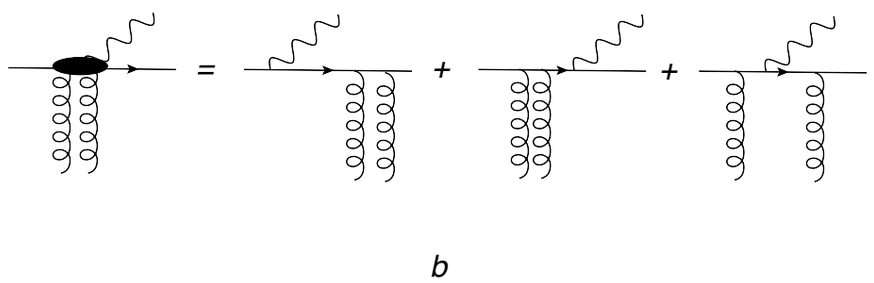
Lowest order, elementary gluons:

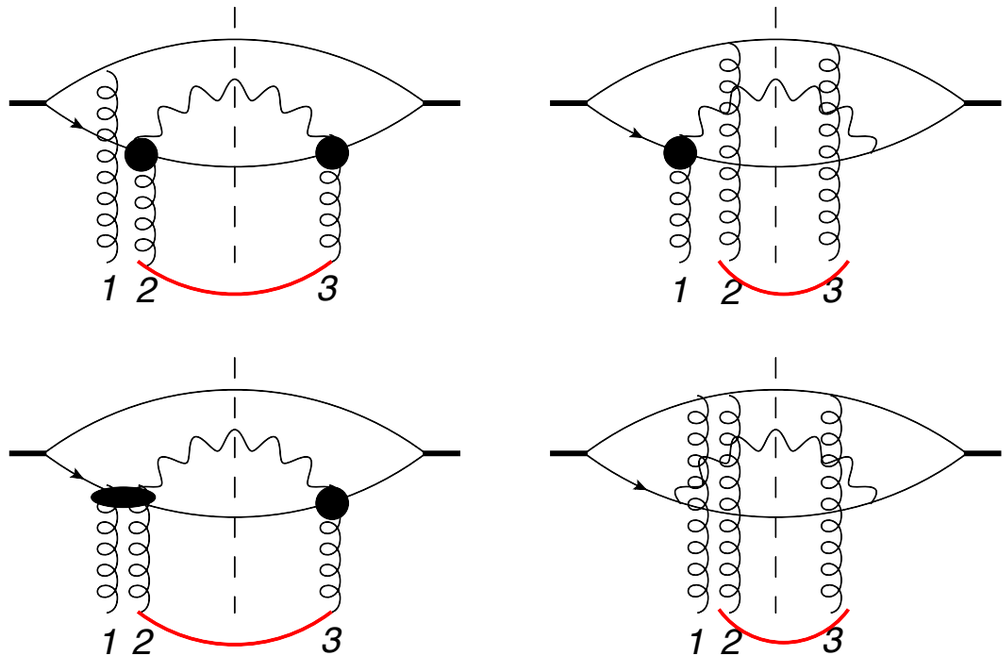




Beginning of reggeization: coupling of three gluons



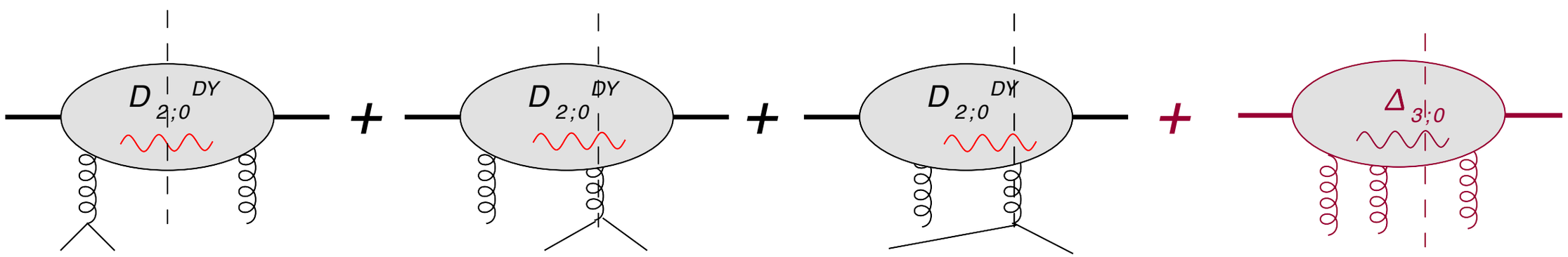




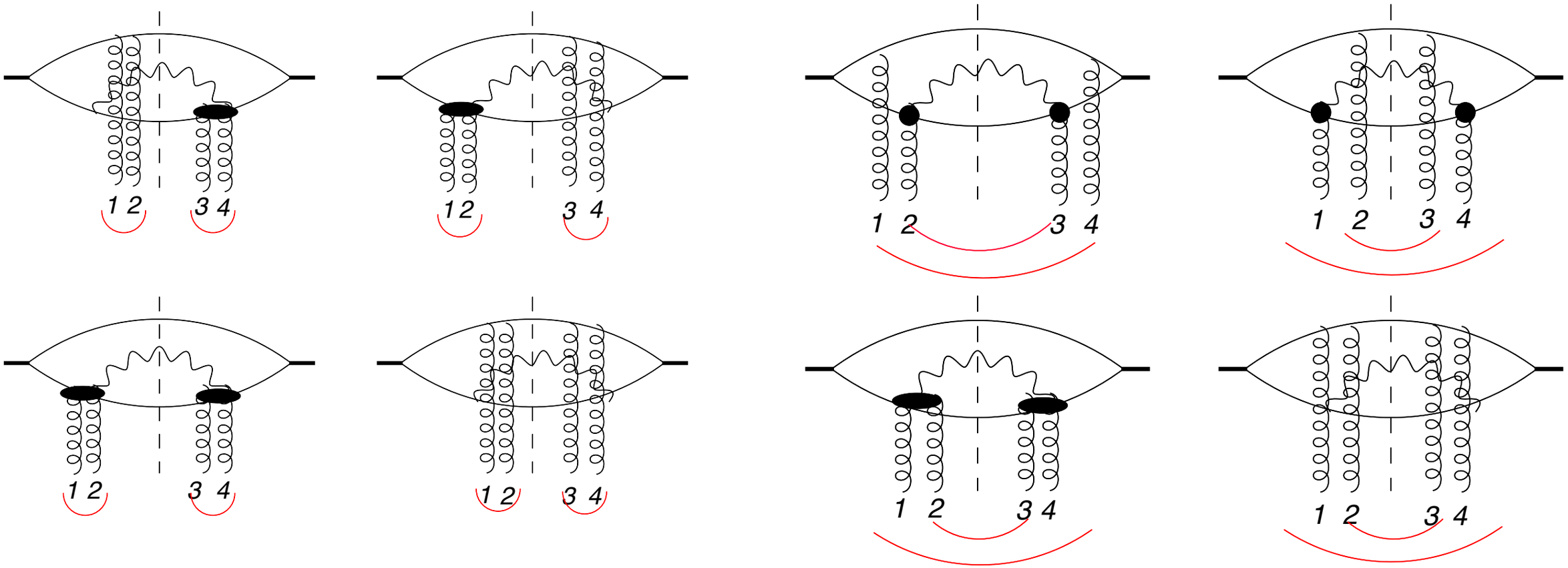
reggeization of left gluon works

reggeization of right gluon does not work

→ effective 3 gluon coupling remains

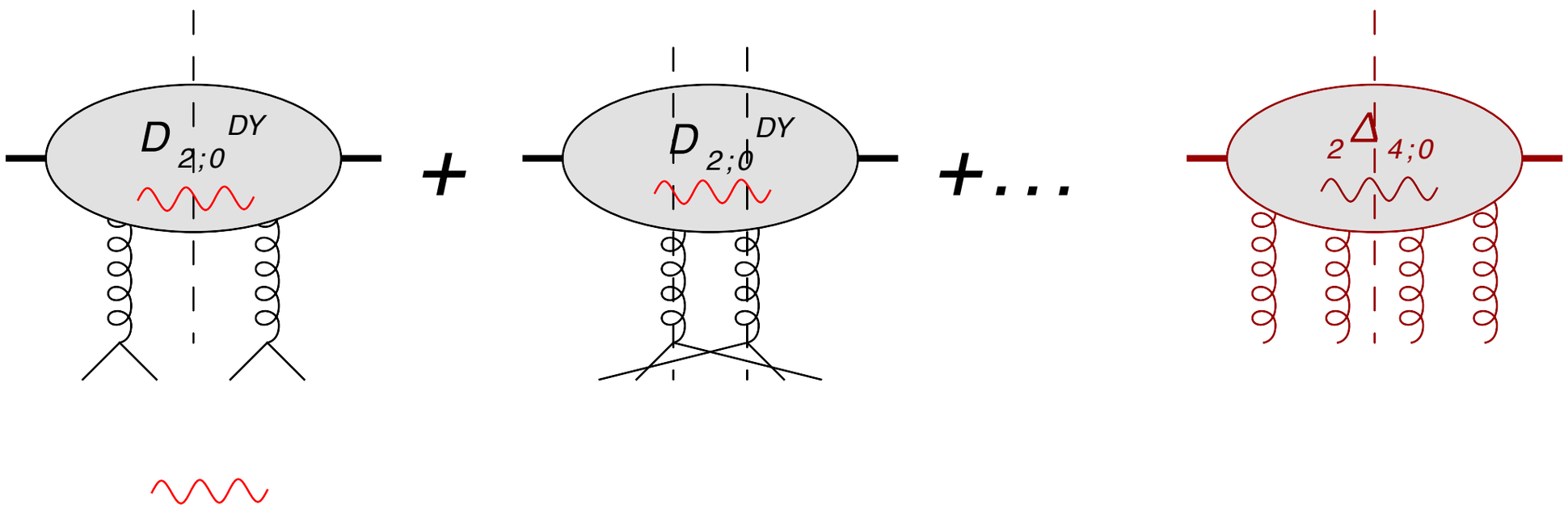


Similarly: four gluons

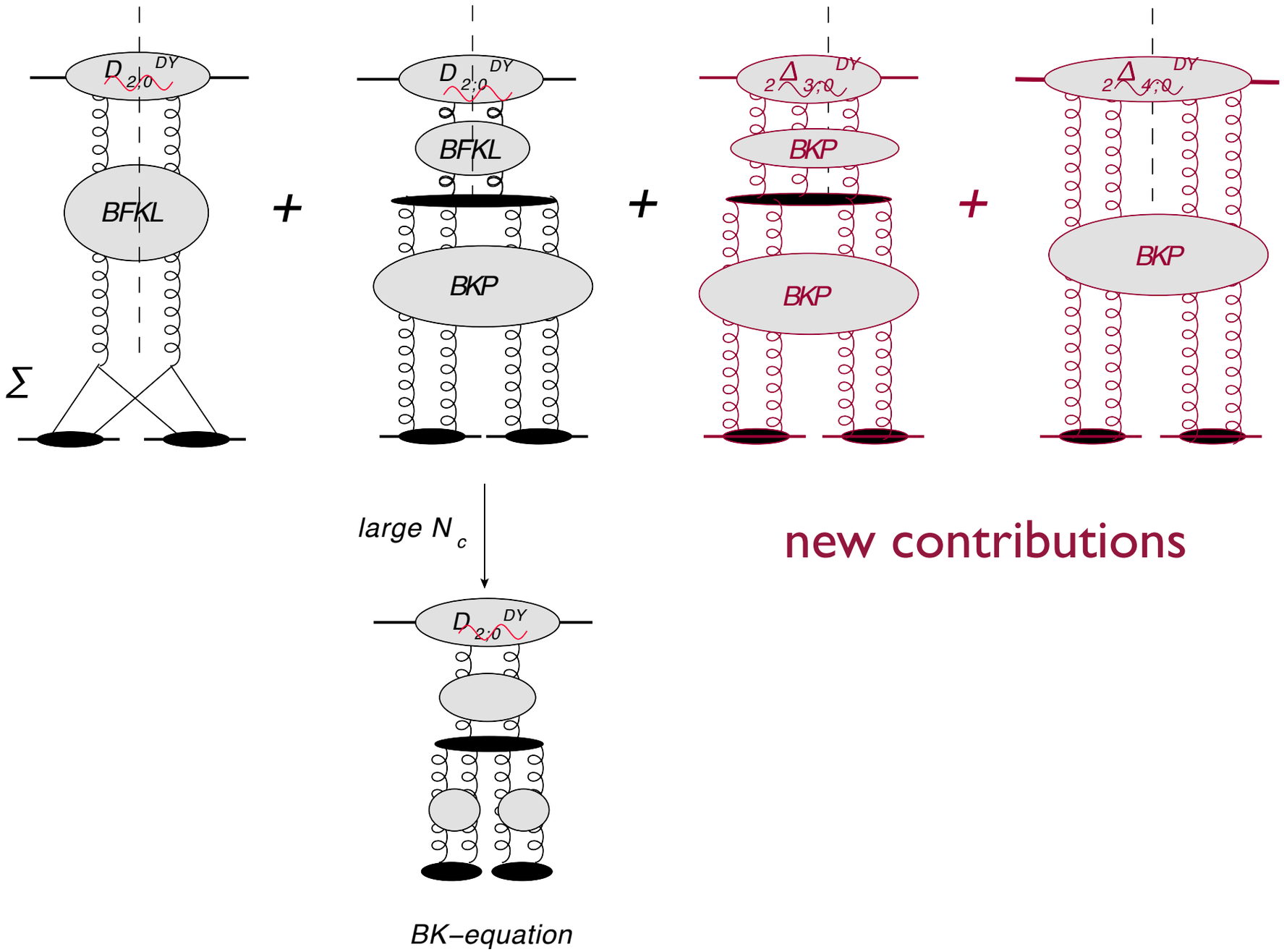


reggeization works

reggeization does not work



Evolution equations



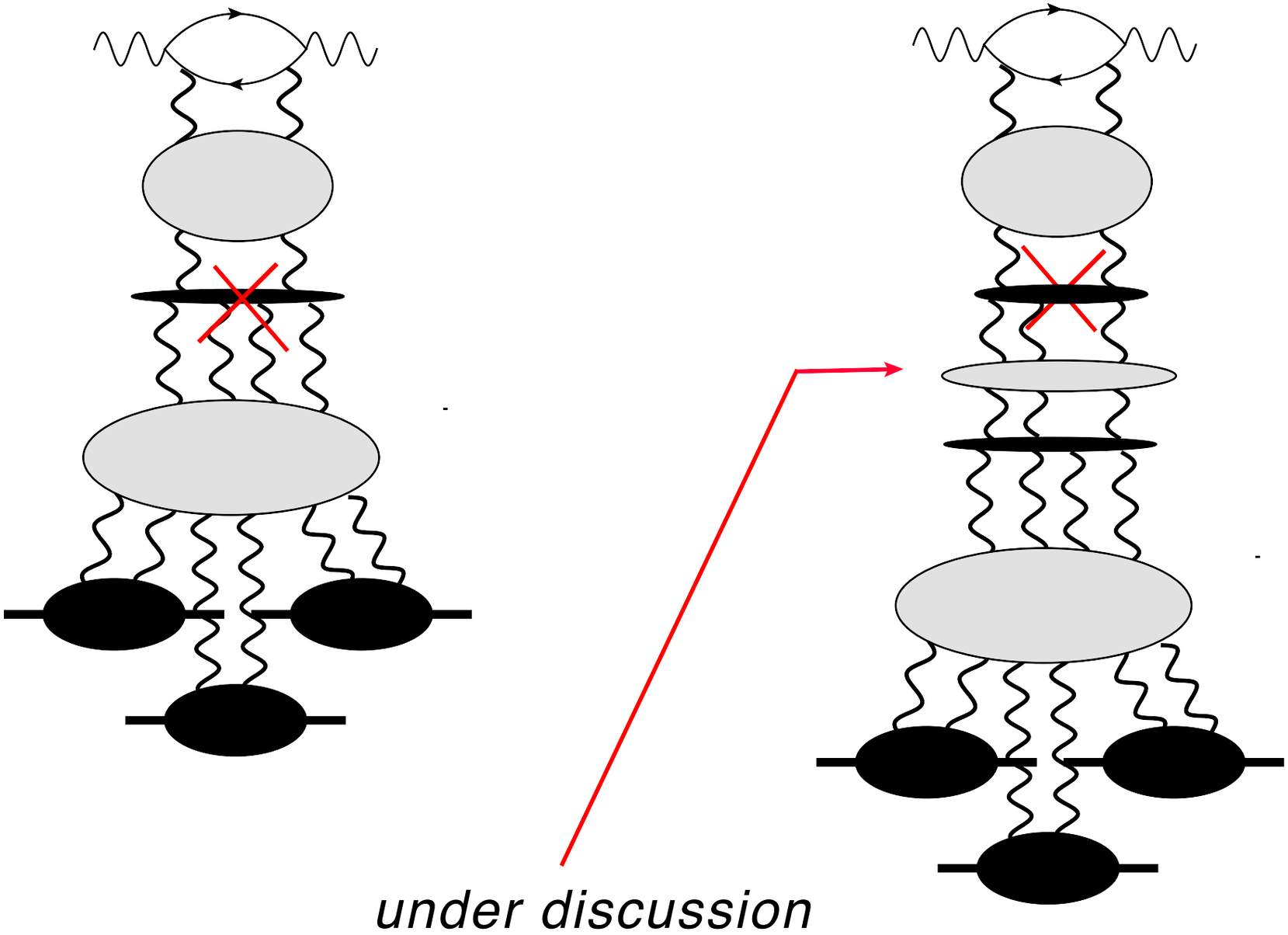
new contributions

Breakdown of factorization

Higher gluon correlators needed. Is JIMWLK? enough? (Gelis, Venogopalan)
Are 4 gluons enough?

Similar observation: in single jet inclusive cross section:

JB, Salvadore, Vacca;
Kovchegov, Tuchin, Levin, Braun



under discussion

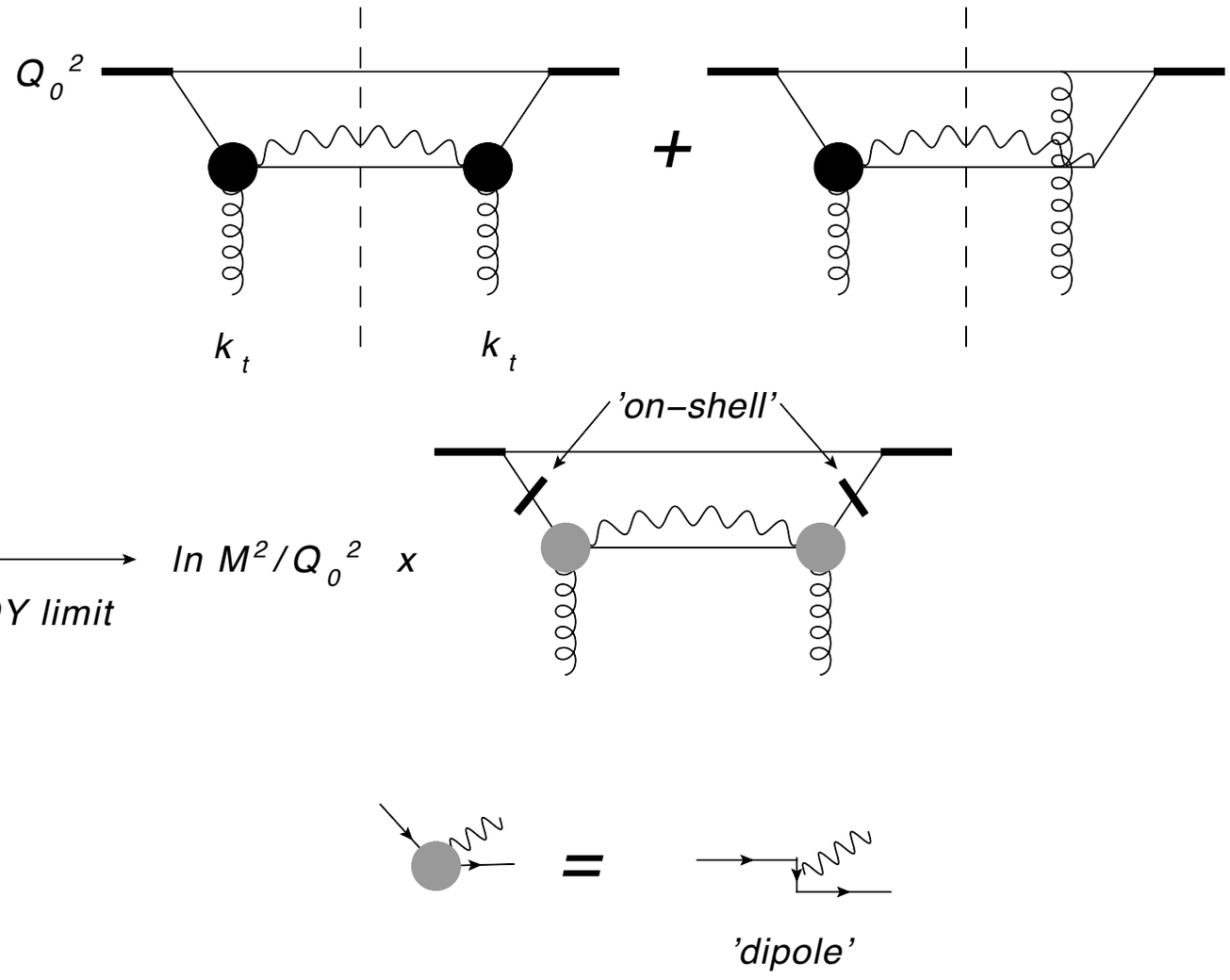
New kernel for $3 \to 4$ transition has good properties (Möbius invariance, Ward identities)

Does the 3 gluon state cancel? (Braun)

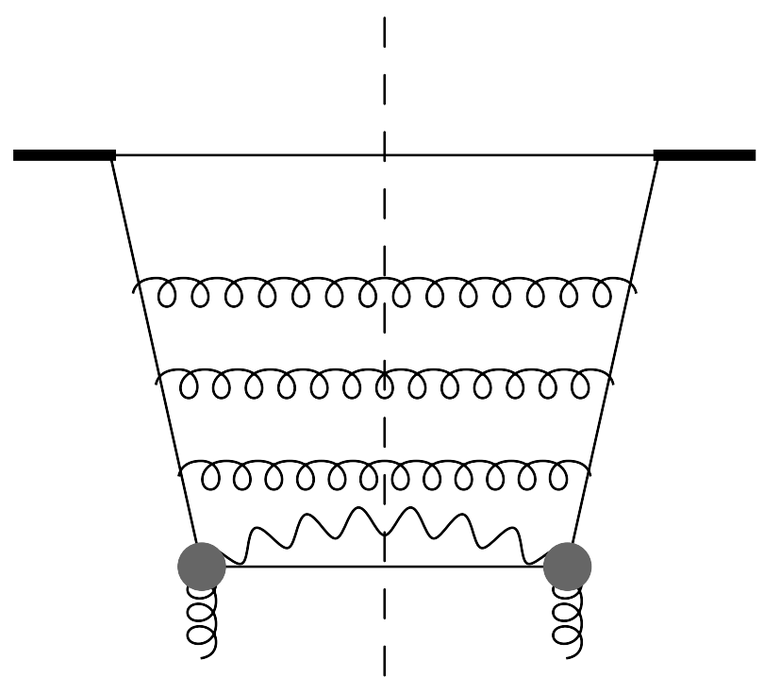
The Drell -Yan limit

So far: small-x limit of inclusive (massive) photon production

The Drell-Yan limit (large mass, large k_t): dipole picture emerges

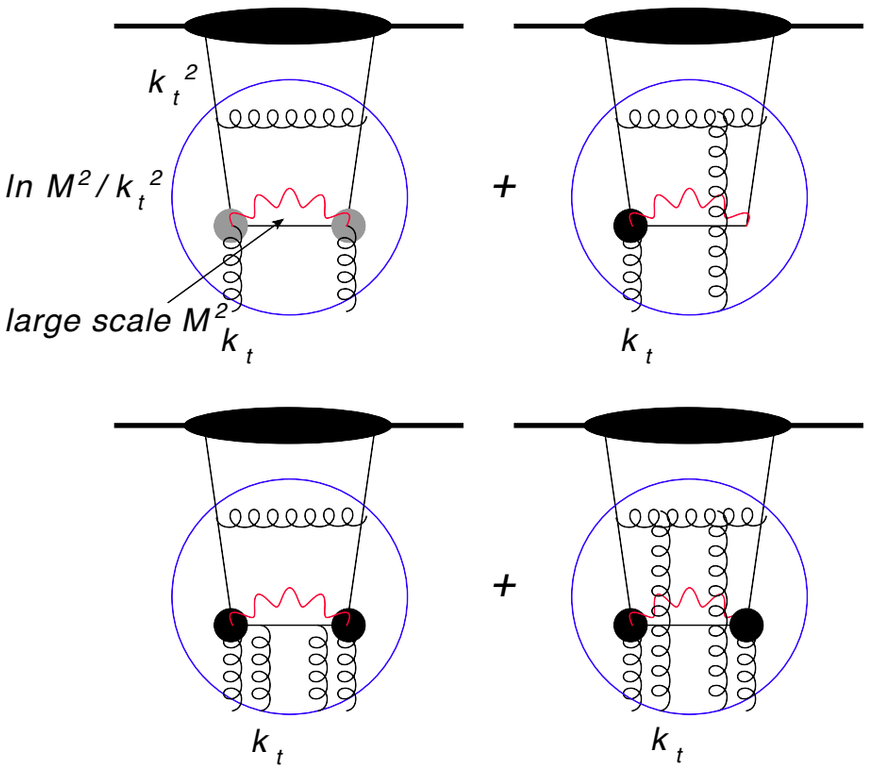


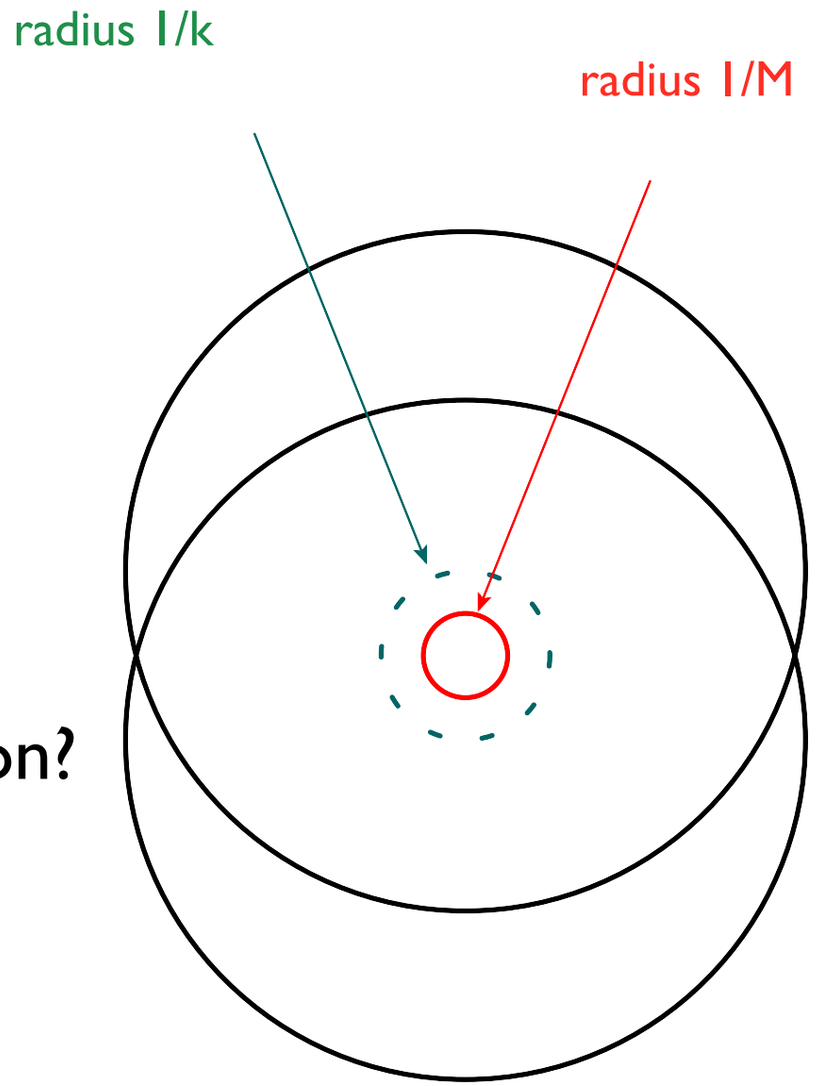
gluon sees the whole system



generalization to DGLAP

The Drell-Yan limit (large mass, smaller k_t): picture changes





If $k_t^2 \leq M^2$:

pattern of logarithms changes
interference with evolution inside the upper hadron?
softer gluon sees quark + gluon?

needs further study

Conclusions

Results:

- Drell-Yan at small-x needs higher correlators

  (see earlier work on inclusive cross sections)
- modifications of evolution equations?
- interference with DLAP evolution inside the upper hadron?

Further work needed:

- Drell Yan
- single, double inclusive cross sections
- nucleus-nucleus scattering