Multiple Interactions in ep/pp scattering: AGK Rules

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- Introduction: Multiple Interactions
- Basics in pQCD
- Results of AGK in pQCD
- Conclusions

Based upon:

JB, M.Wüsthoff, Zeitschr.Phys.C
JB, C.Ewerz, JHEP

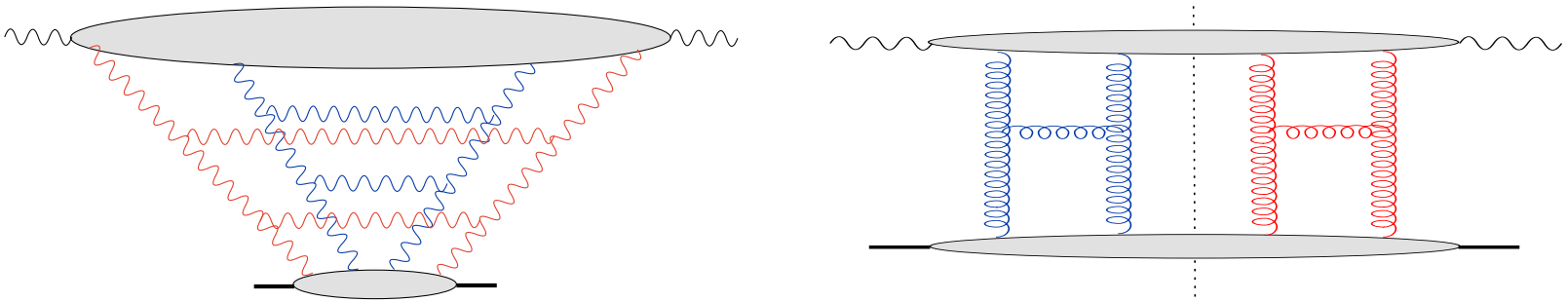
JB, M.Ryskin, Zeitschr.Phys.C
JB, M.Salvadore, G.P.Vacca, Eur.Phys.J. C
JB, M.Salvadore, G.P.Vacca, in preparation

Introduction: Multiple Interactions

Multiple interactions: interface between hard and soft physics.

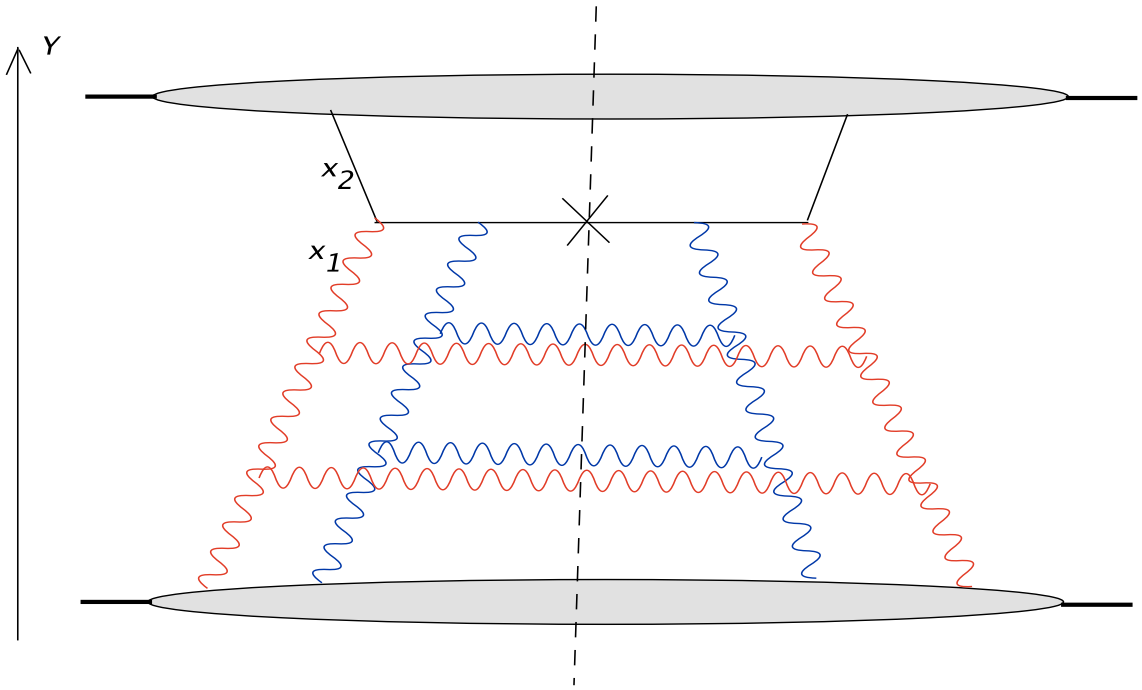
Multiple interactions are present at HERA (low Q^2, small x),
are also be important at Tevatron and at the LHC.

HERA: somewhere at low Q^2 and/or small x expect multiple interactions (saturation):



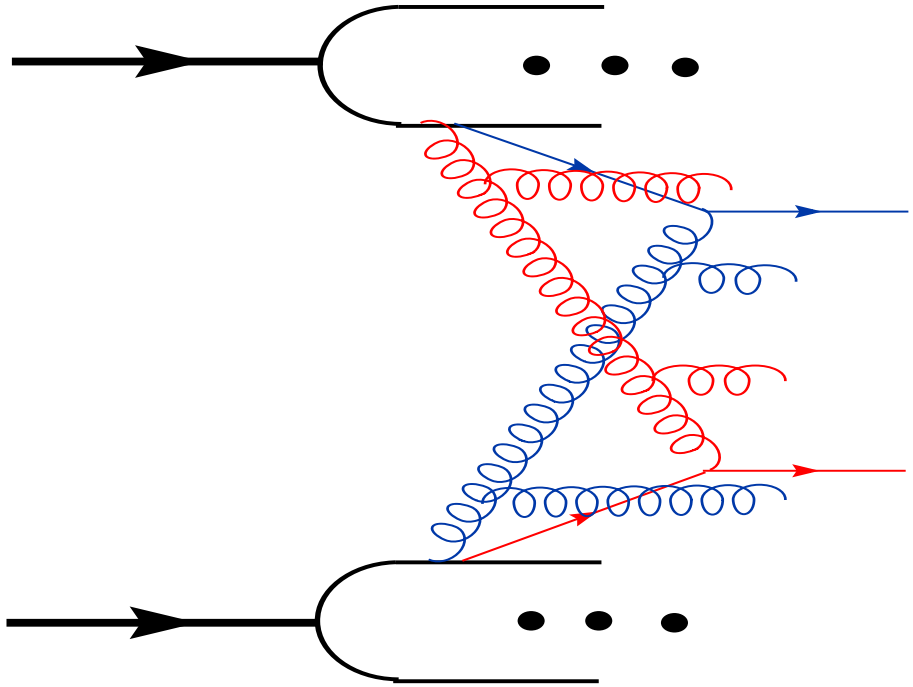
Related to higher twist, supression in $1/Q^2$ compensated by growth in $1/x$.
'Prove of existence' by observation of DIS diffraction.

LHC: jet near the beam directions ($x_1 \ll x_2$)



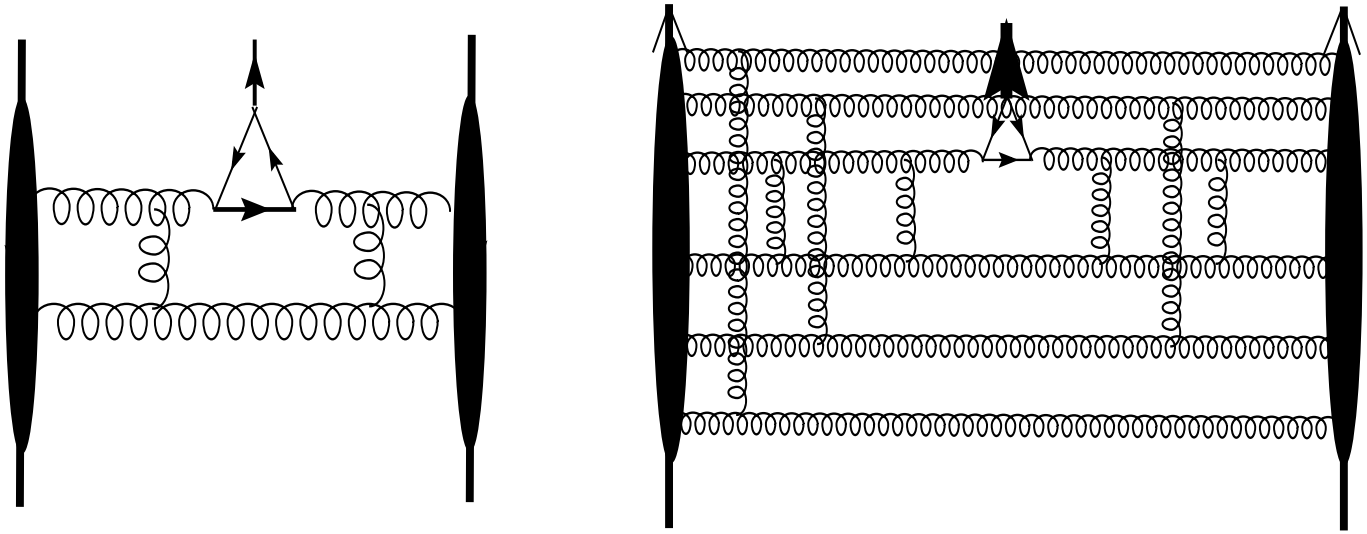
Multiple interaction across large rapidity intervals.

Multi-jet final states, QCD background to new physics:



For $n > 1$ jets: multi-chain configurations could be quite important.
Correlations.

Much discussed: the structure of semihard diffractive events.

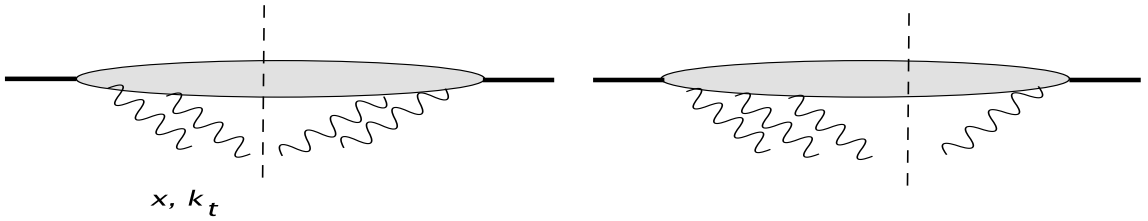


'Insert a hard scale into soft elastic scattering': how far does hardness spread out?

Can we hope to approach the 'soft rescattering' from the 'hard side',

to understand the structure of the underlying event?

Fundamental quantities: multiparton correlators



Strength of multiple interactions depends upon size of these correlators: how big are they? Theoretically not much studied (higher twist operators (BFKL), but at small x twist not a good concept).

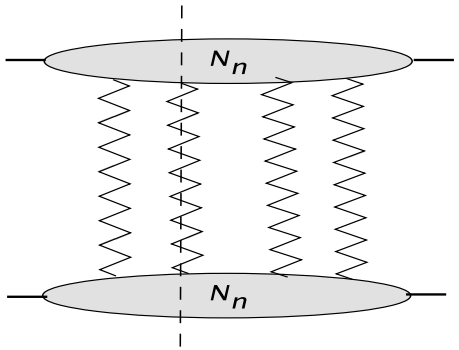
In DIS, photon side: hope to be able to calculate in pQCD (saturation models).

In pp scattering: couplings have to be modelled, look for guidance.
In the region of small x: constraints from AGK cutting rules.

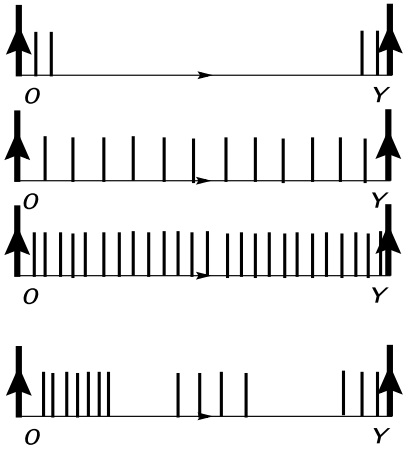
First steps, may be of help in designing Monte Carlo models:
(i) structure of multiparton correlators (AGK cutting rules),
(ii) identify couplings of multiparton chains to jet vertices, compute in pQCD.

Basics in pQCD

AGK cutting rules have been formlated in times before QCD. No color degree of freedom.
Main results: different cuts in multi-Pomeron exchange contribute to different final states.

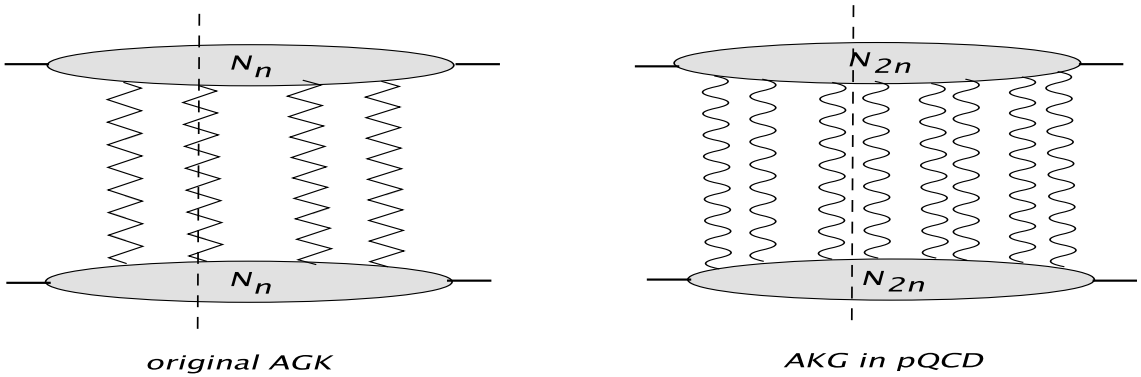


original AGK



- inclusive cross section: fluctuations, counting rules for multiplicities.
- one, two jet inclusive cross sections: cancellations of Pomeron rescatterings

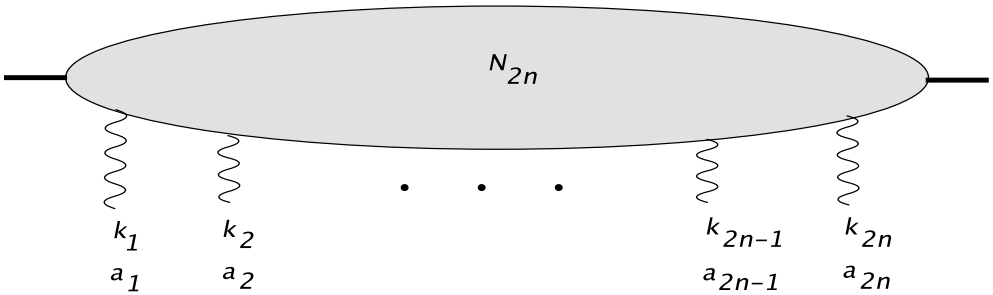
How does this work in pQCD: replace Pomeron by color singlet ladder.



Main ingredients of AGK:
1) symmetry of vertex function N_n under permutation of Pomerons
2) cut $=$ uncut

Analogous feature of pQCD:
1) symmetry of vertex function N_{2n} under permutations of gluons
(bound states are inside N_{2n}).
2) cut $=$ uncut
Has been verified in pQCD (elastic $\gamma^*\gamma^*$ scattering).

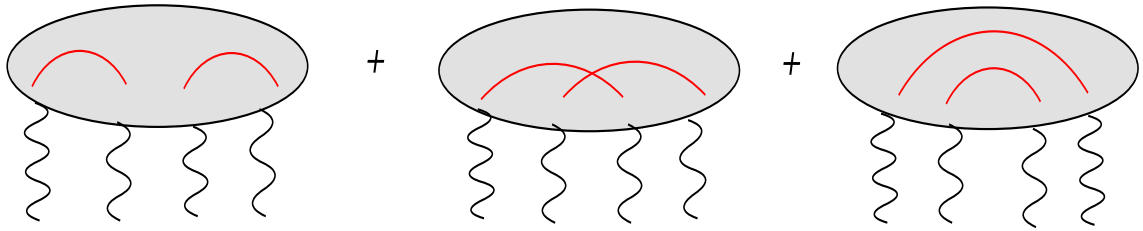
Popular example: eikonal ansatz



$$N^A_{2n}(\boldsymbol{k}_1, a_1; \ldots; \boldsymbol{k}_{2n}, a_{2n}; \omega) =$$

$$\frac{1}{\sqrt{(N_c^2-1)^n}}\left(\phi^A(\boldsymbol{k}_1, \boldsymbol{k}_2; \omega_{12})\delta a_1 a_2 \cdot \ldots \cdot \phi^A(\boldsymbol{k}_{2n-1}, \boldsymbol{k}_{2n}; \omega_{2n-1,2n})\delta a_{2n-1} a_{2n} + \sum_{Pairings}\right).$$

Symmetry requirements important in modelling multiparton correlators; color flow:

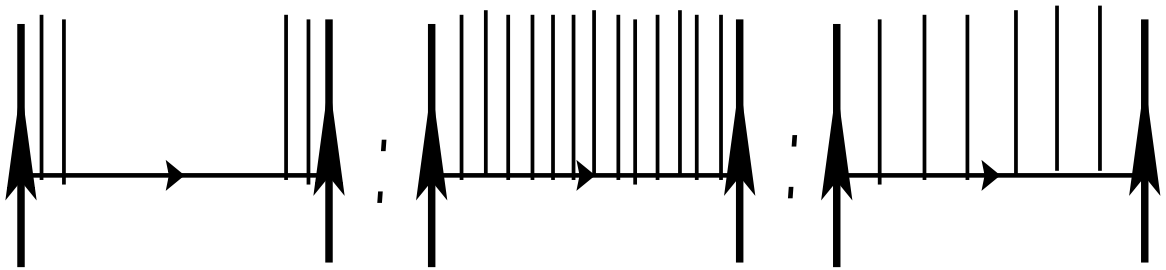


Important: sum over all cuttings: $\longrightarrow$ interference terms . Large N_c?

Results of AGK in pQCD

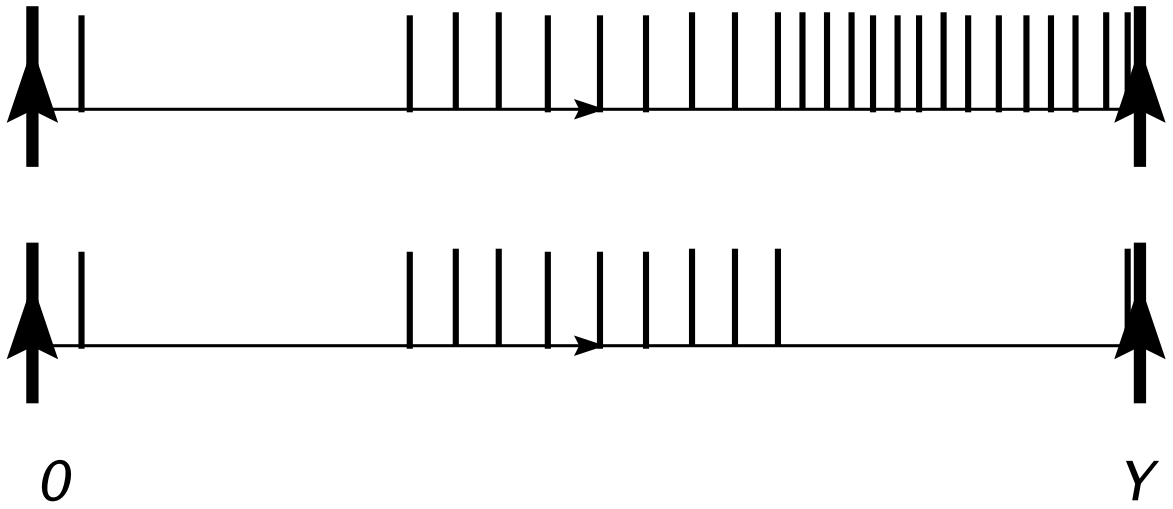
The same counting rules as in AGK paper.

a) Inclusive cross section: ratios of different multiplicities in a rapidity intervall.
Example: two-ladder exchange, single rapidity interval:



$= 1 : 2 : -4$

Generalization to several rapidity intervals (new in pQCD):



In each rapidity interval the same ratio $1 : 2 : -4$.

Generalization to multiple chains:

k cut pomerons inside n Pomerons:

$$F_k^n \propto (-1)^{n-1-k} \frac{n!}{k!(n-k)!}, \qquad k = 0, ..., n-1$$

for the probability of finding k cut Pomerons among n Pomerons.

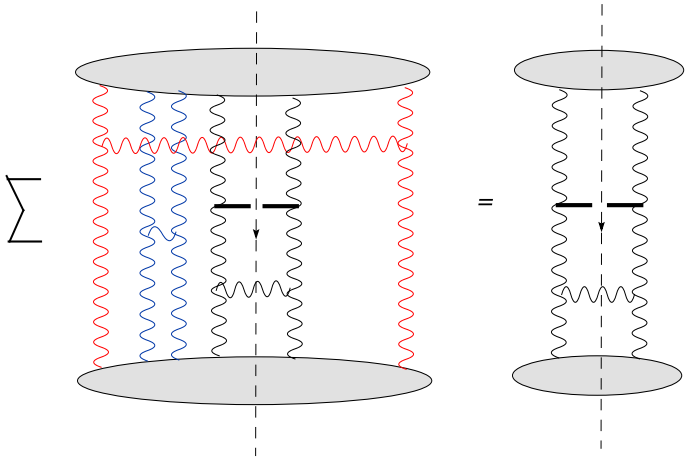
If you want to sum over n: need model, e.g. the eikonal coupling (with large N_c):

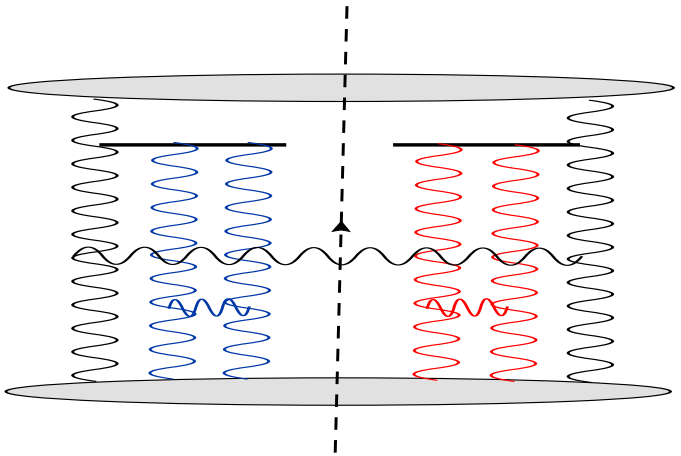
$$P(s, \vec{b}) = \frac{[\Omega(s, \vec{b})]^k}{k!} e^{-\Omega(s, \vec{b})}$$

for the probability of finding k cut BFKL Pomerons any number of exchanged Pomerons.

Consistency: 'cut Pomeron' and 'rescattering' are related!

b) Another famous AGK result: cancellations in inclusive jet cross sections

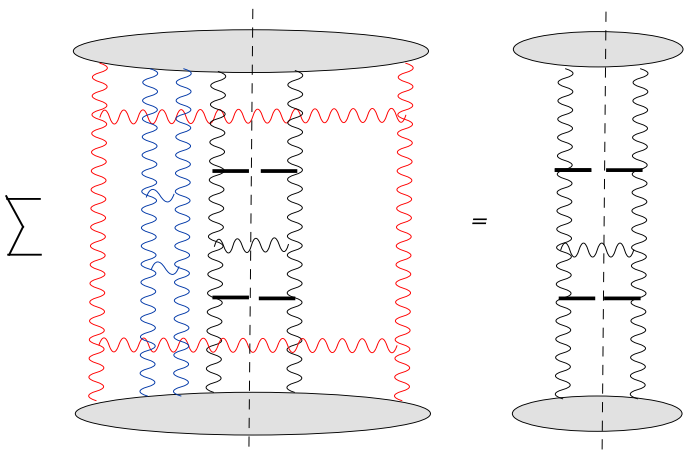


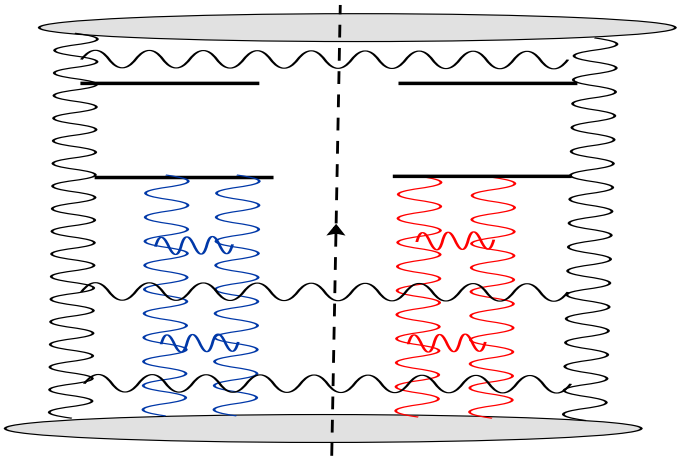


Works in pQCD. Includes soft rescattering. Agrees with QCD factorization theorems.

But: rescattering effects between the jet and one of the projectiles.
Breaks k_t factorization, requires new vertices. Dipole picture?

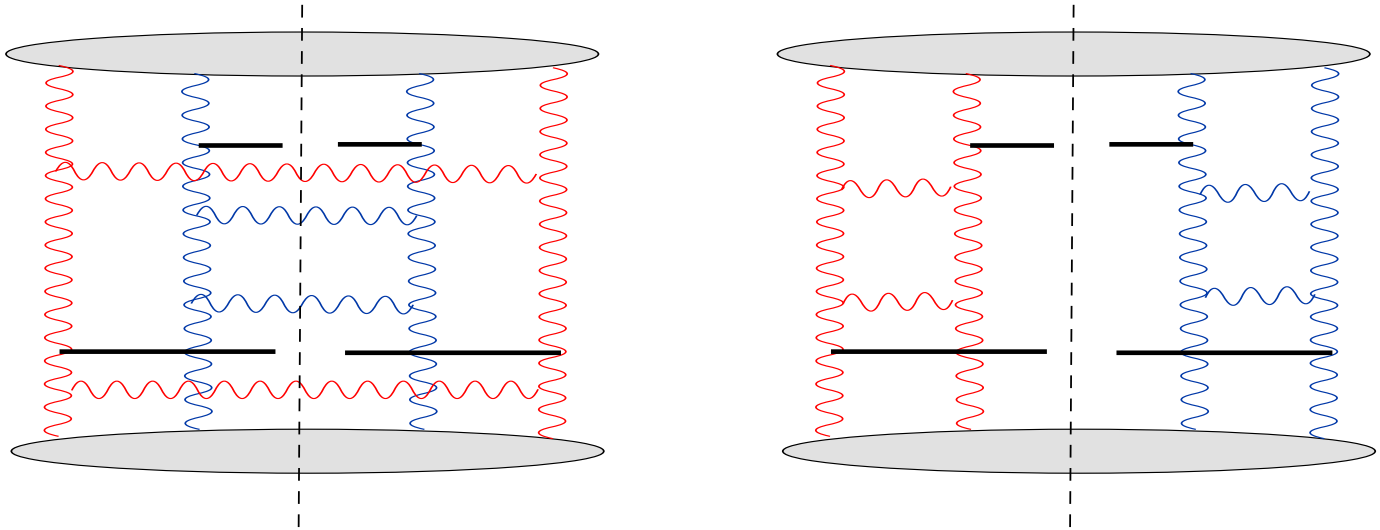
The same in double inclusive cross sections:





But there are rescattering effects between jet and projectile.

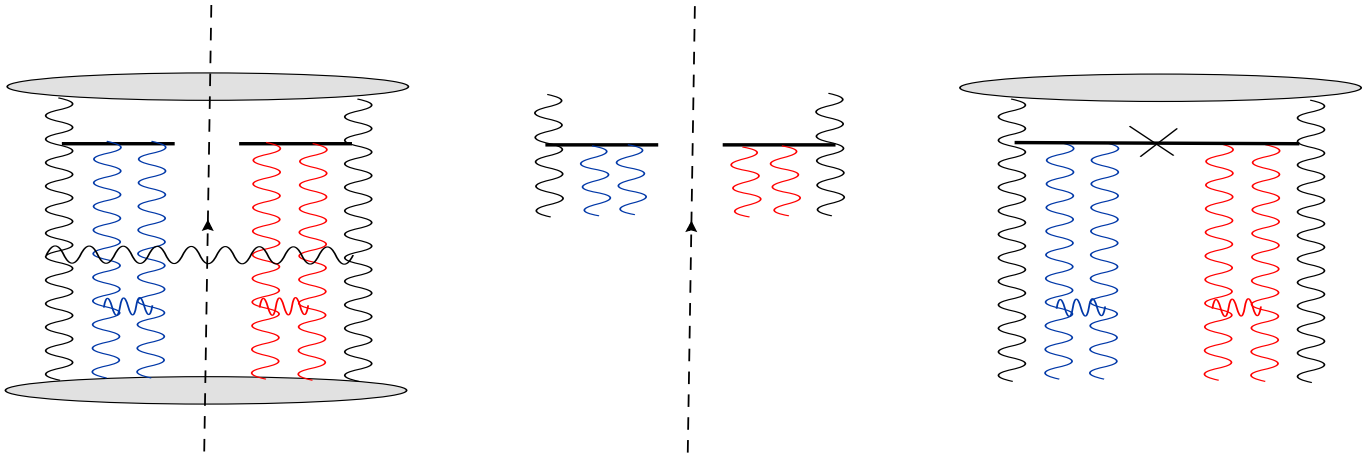
And a new contribution (Mueller-Navelet jets):



Energy dependence: double intercept, compared to single ladder cross section (Tevatron Data).

Interesting connection with hard color singlet exchange: needs to be worked out.

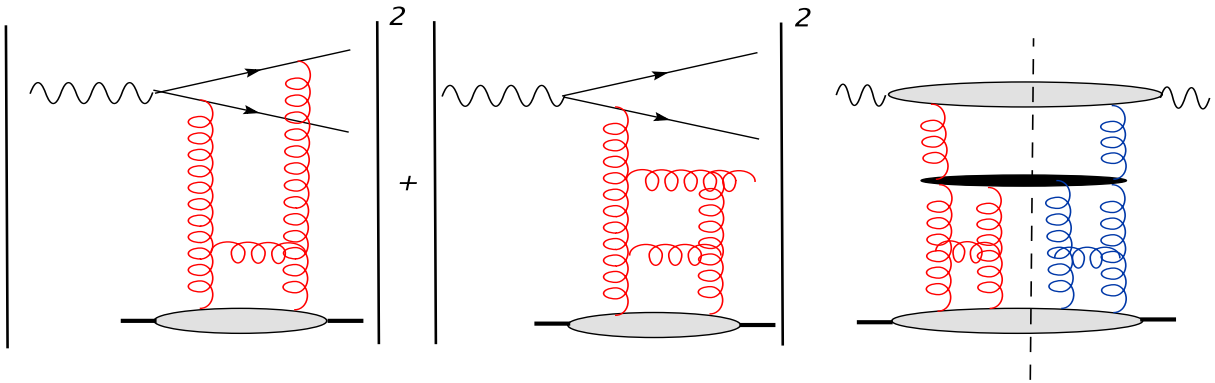
c) more complicated situations:
rescattering in one-jet inclusive production:



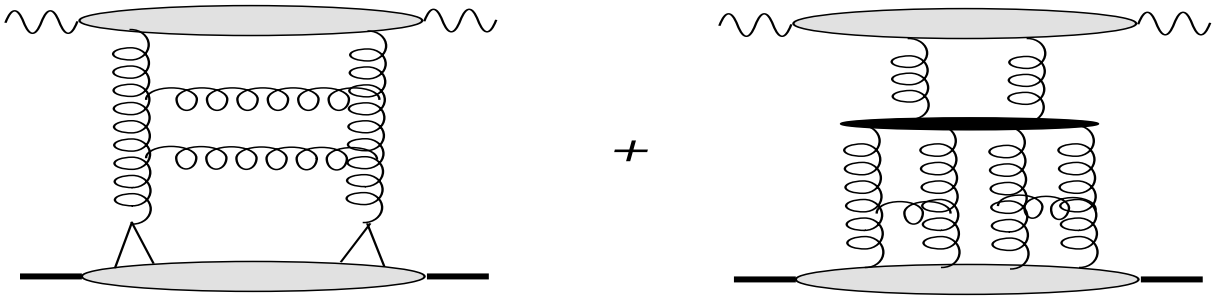
Two new features:
- new vertex to be computed
- AGK counting below the jet vertex does not hold. Under study.

Deeper reasons: reggeization of the gluon.

Another case of interest: diffraction in DIS.



Cannot directly use AGK counting to estimate the four gluon exchange in F_2:



AKG works, but two-gluon exchange needs separate treatment.

Outlook

Discussed a few aspects of multiple gluon chains in QCD:

- AGK cutting rules in pQCD provide guidance in analyzing multiple interactions and in designing models
- numerical studies are being done (Lund, R.Field)
- more complicated multi-chain structures to be studied

- bootstrap is fundamental property in QCD