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Deep Inelastic Structure Functions and DIS Diffraction:

Two Frames - Two Pictures

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Question: Have we seen Saturation?

Analysis of F_2 may not be enough
Would be very good to have F_L.
Use data on DIS Diffraction

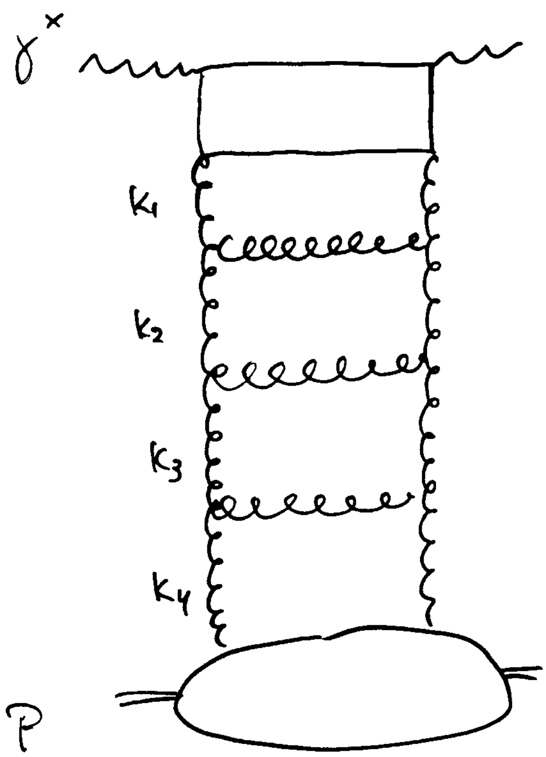
Find a language which applies to both $\sigma_{tot}^{\gamma^* p} = \frac{4\pi\alpha^2}{Q^2} F_2$ and DIS Diffraction: Dipole picture.

This talk:
Compare DGLAP Analysis and Dipole Picture:
Formulations are equivalent
(proven only in LO, task for theorists)

But: Formulations are connected with different physical pictures
based upon different Lorentz frames.

As a result:
different questions and different approximations
→ sometimes confusing, seems contradictory

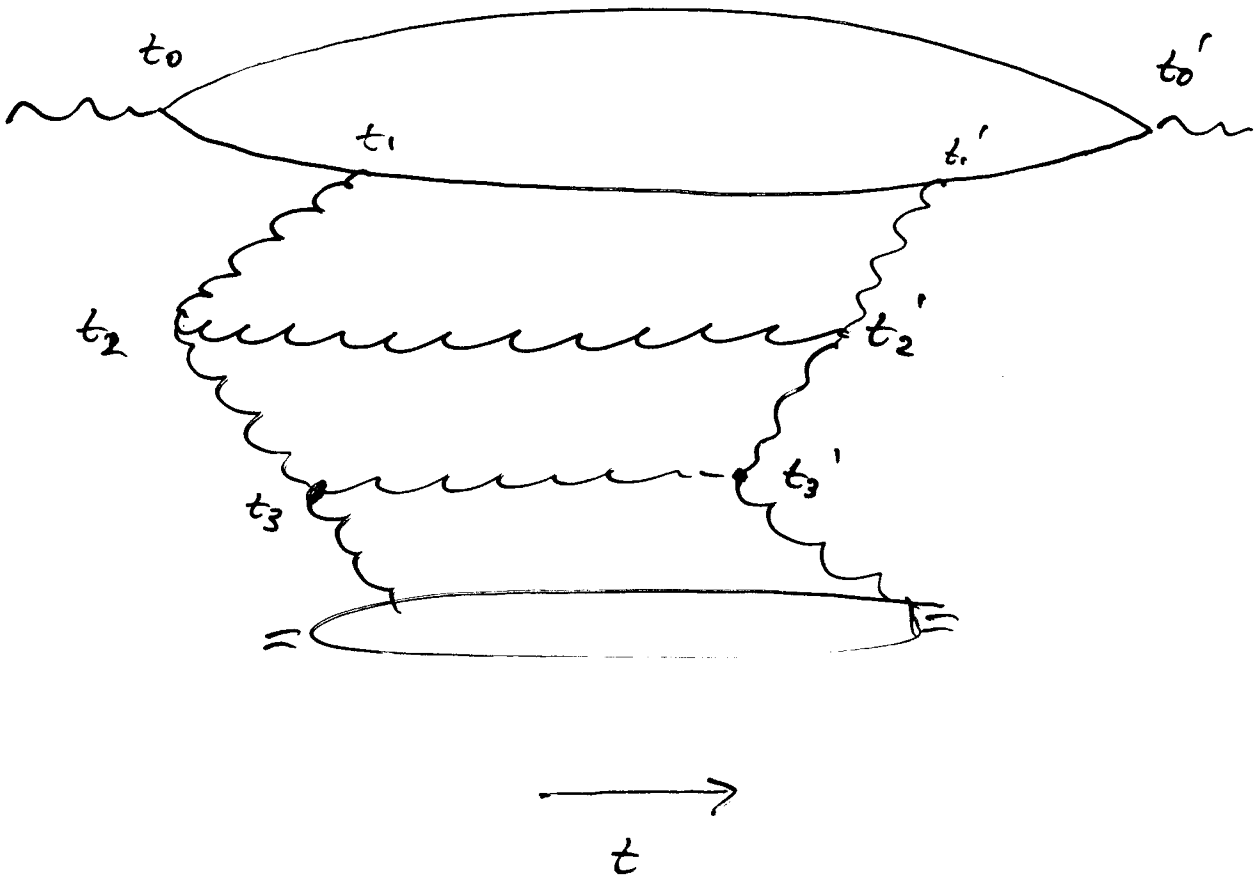
Start from standard QCD **perturbation theory** in momentum space:
QCD evolution (DGLAP) corresponds to ladder graphs.

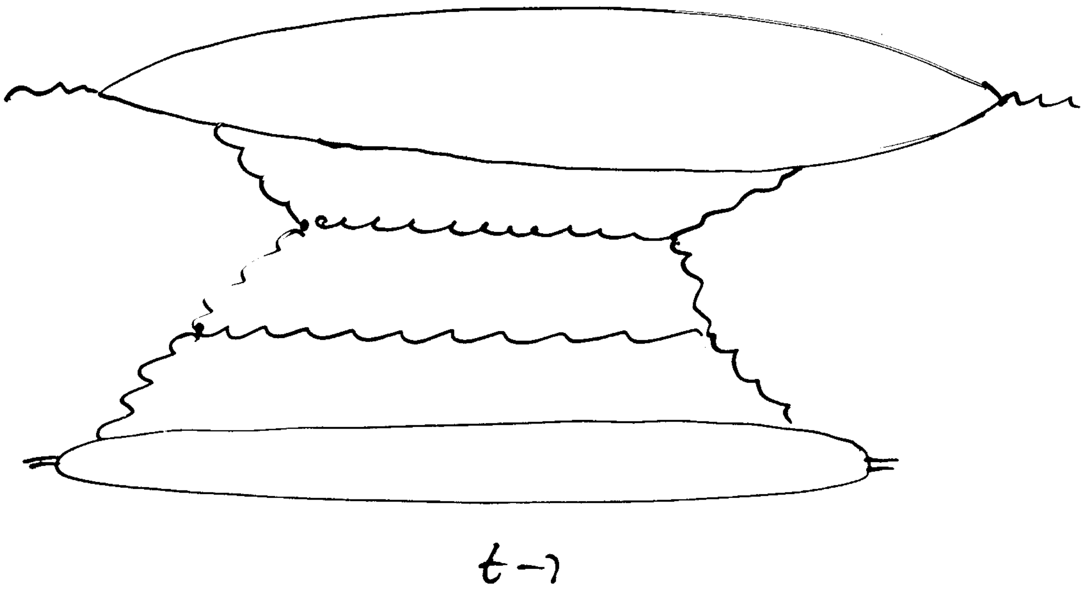


Choose a Lorentz frame, and translate to time-ordered (old-fashioned) perturbation theory:
for large energies (small x)
particular time orderings dominate
(depend upon frame).

Two popular examples:
Infinite Momentum Frame (Bjorken Frame) and Proton Rest Frame

Examples of time-orderings:





Bjorken frame

For the Structure Function F_2: $t_1' > t_2' > \cdots > t_n'$

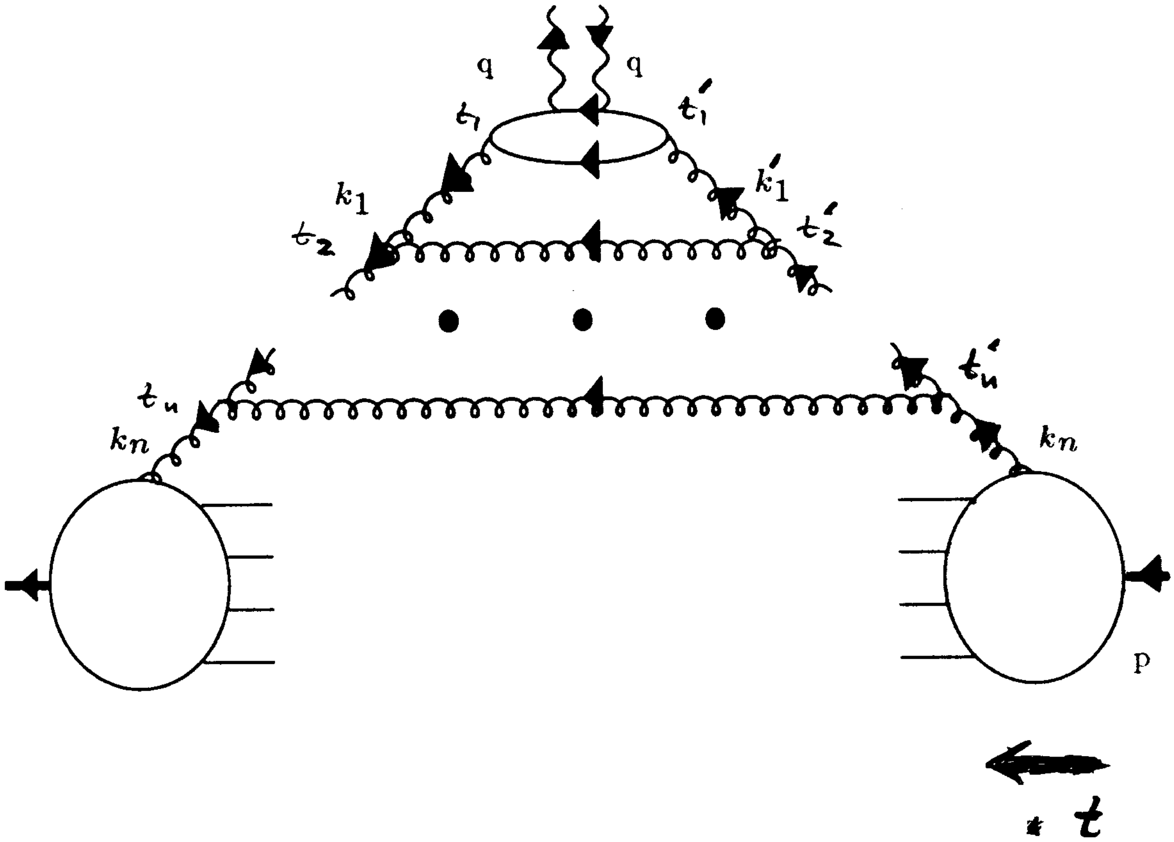


Figure 1: Evolution in z and t of the $\gamma^* p$ scattering process in the deep inelastic frame (Bjorken-system)

$$p^\mu = \left(\sqrt{p^2 + m_p^2}, 0, 0, -p\right), \quad p \ \ very \ \ large$$
$$q^\mu = \left(Q^2/2xp, \vec{q}_t, 0\right)$$

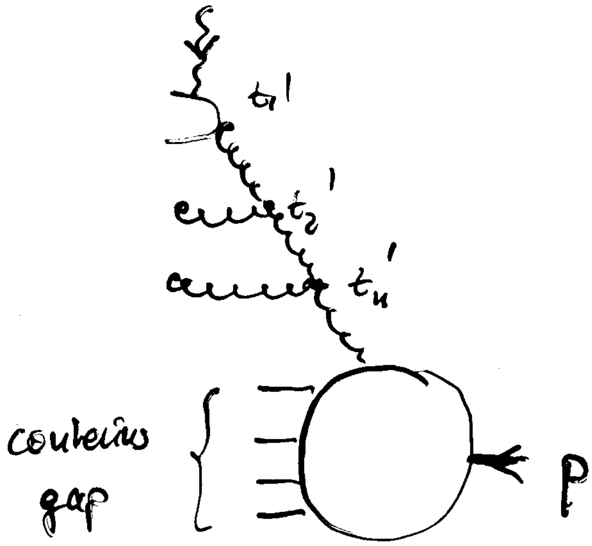
Needs:
x-distribution at low momentum scale (input to DGLAP):
"probability density of finding partons with scale Q_0^2"

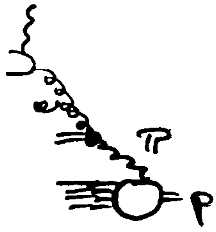
No information on:
what is inside the low momentum remnant?

Only leading twist.

Higher twist: more complicated picture (two cascades etc.)

Diffractive parton densities (→ **John's talk**):



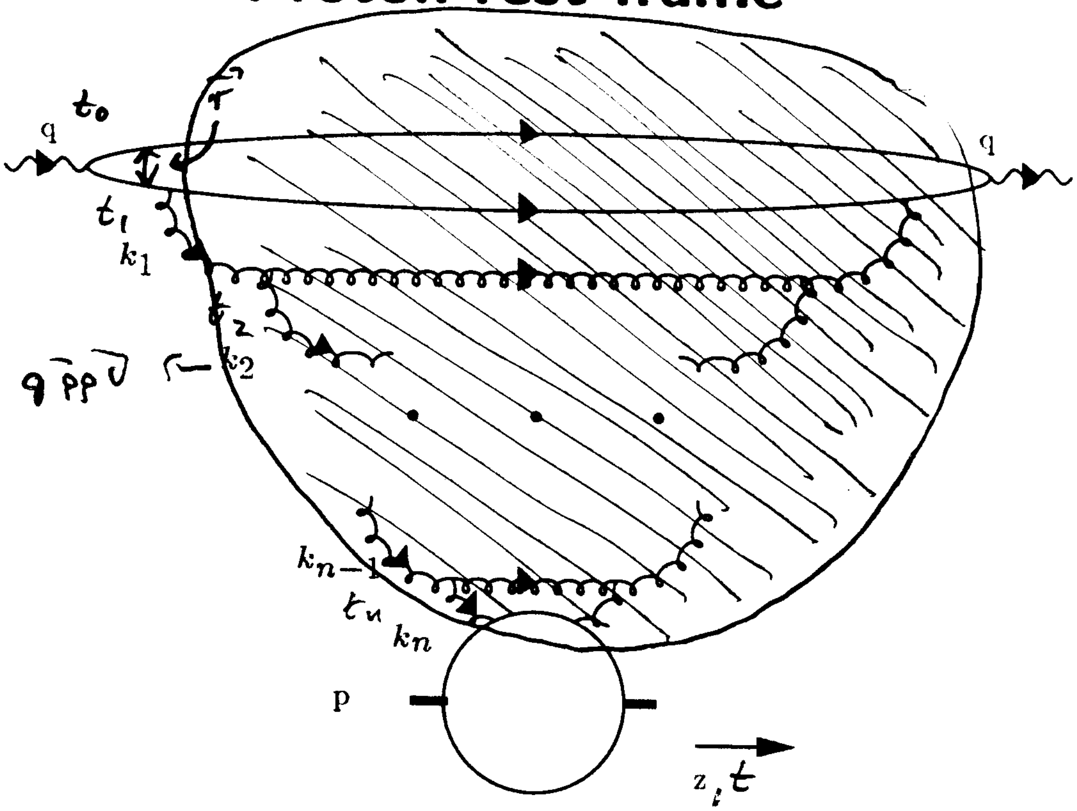


Restriction on remnant: must contain a rapidity gap. ("Pomeron Structure Function")
Needs:
z-distribution at low momentum scale (input to diffractive DGLAP):
"probability density of finding partons inside the Pomeron with scale Q_0^2":

No information on:
what is the dynamics of the rapidity gap (e.g. hard or soft Pomeron)?
Only leading twist

$t_0 < t_1 < t_2 < \dots < t_n$

Proton rest frame



Space time evolution of the elastic $\gamma^* p$ scattering process in the proton rest frame

$$p^\mu = (m_p, 0, 0, 0)$$

$$q^\mu = \left(Q^2/2xm_p, 0, 0, \sqrt{Q^2 + (Q^2/2xm_p)^2} \right) .$$

$$\tau = 1/mx$$

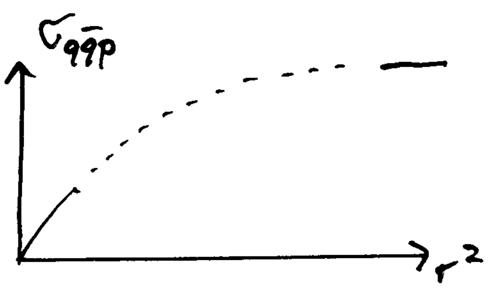
Dipole formula:

$$\sigma_{t,l}^{\gamma^* p}(x, Q^2) = \int d^2\vec{r} \int dz\, \psi(Q^2, z, \vec{r})^* \, \sigma_{q\bar{q}p}(x, \vec{r}) \psi(Q^2, z, \vec{r})$$

Connection with DGLAP (in LO): at small transverse distances

$$\sigma_{q\bar{q}p}(x, \vec{r}) = \frac{\pi^2 \vec{r}^2}{3} \alpha_s(\bar{Q}^2) x g(x, \bar{Q}^2)$$

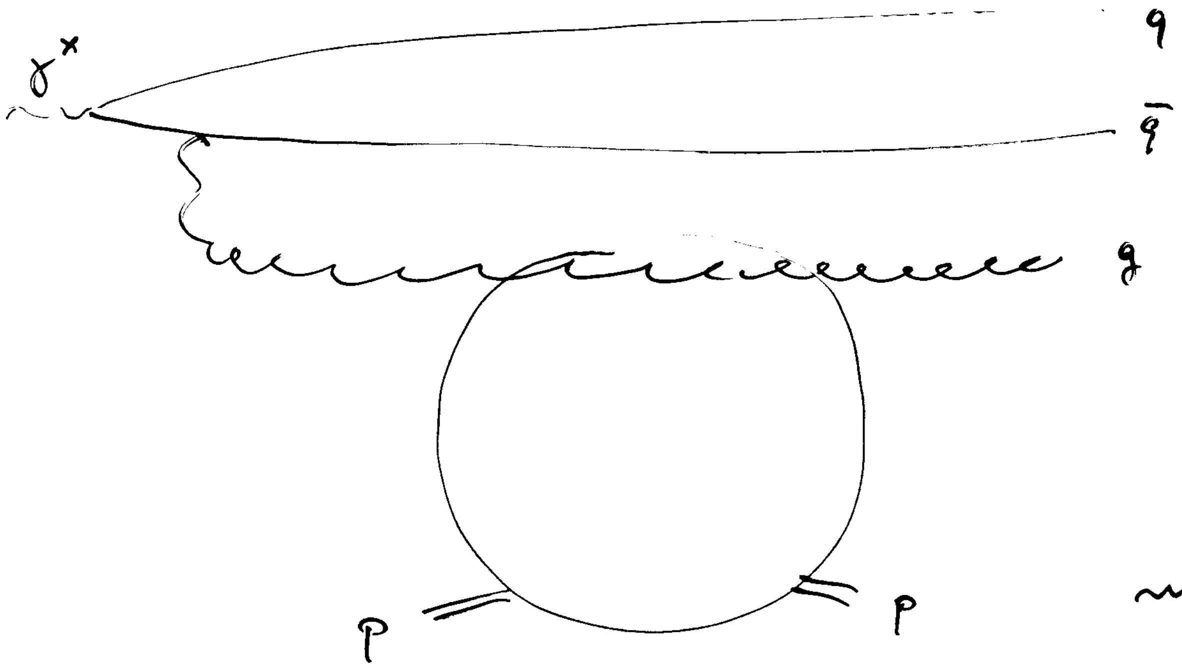
Natural in this framework: extend to larger $\vec{r}^2$: construct dipole models (with some physical picture behind), designed
to interpolate $\sigma_{t,l}^{\gamma^* p}(W^2)$ in the low-Q^2 region (Golec-Biernat, Wüsthoff; Forshaw, Kerley, Shaw; Frankfurt,McDermott, Strikman).
Contains higher twist.

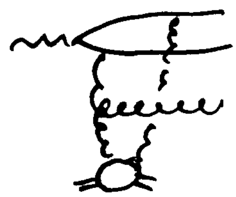


But: comparison with $\sigma_{t,l}^{\gamma^* p}(x, Q^2)$ alone does not test in detail the $\vec{r}$-dependence $\to$ diffraction.

We need a theory for this transition:
saturation, high parton density.... confinement

The same for DIS diffraction, e.g. $\gamma^* + p \to q\bar{q}g + p$





exclusive final state;
model for gp; tempting to use the same dipole cross section models as for $q\bar{q}g$;
equivalence with (inclusive) diffractive parton densities:
which final state configurations go into the initial conditions for DGLAP?
which configurations belong to higher twist?

Conclusions

Two different pictures (in different frames) of the same cross sections:
equivalence and no conflict, but:
we are tempted to ask different questions and making different approximations.

For experimentalists:
measure $\sigma_{q\bar{q}\,p}(x,\vec{r})$ (inclusive diffractive cross section, diffractive vector production for different vector particles, diffractive jets, diffraction for nonzero t)

For theorists:
investigate the equivalence of both formulations beyond leading order (k_t-factorization scheme);
study models, theory for $\sigma_{q\bar{q}\,p}(x,\vec{r})$;
study models, theory for $\sigma_{q\bar{q}\,p}(x,\vec{r},\vec{b})$