Probing the QCD Pomeron in Electron-Positron Collisions

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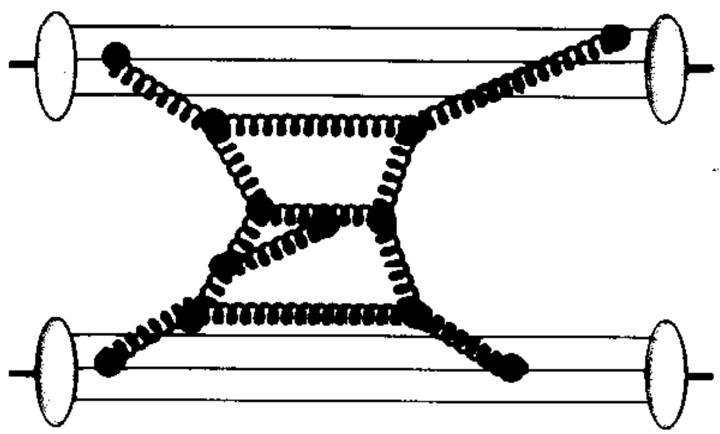
QCD theory of the pomeron

The pomeron the name for is whatever is responsible for

- hadron-hadron elastic scattering at large s and fixed t;
- the hadron-hadron total cross section at large s.

QCD suggests the physical picture below.

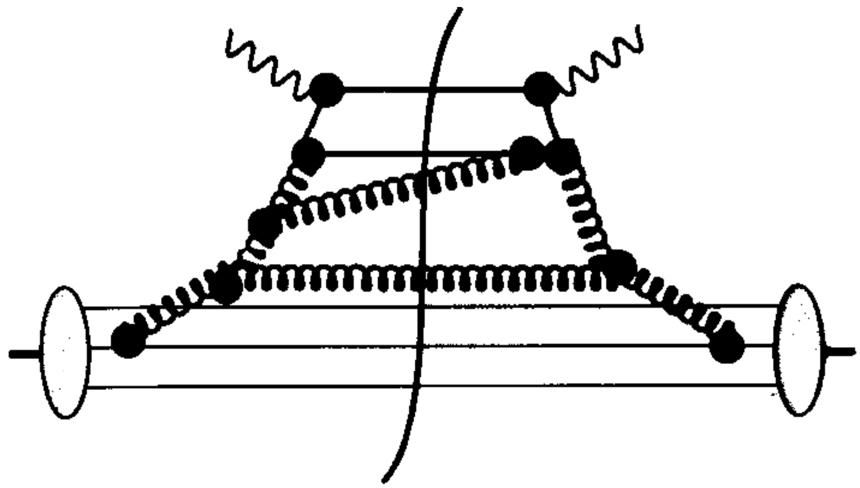


This is normally only a qualitative picture because α_s is big.

But if the hadrons are small, then (with some caveats) the transverse distances are all small and the running α_s is small.
Then the BFKL summation of the leading logs of s for each power of α_s provides at least the beginning of a quantitative theory.

Does the BFKL summation explain small x DIS?

At $x \ll 1$ pomeron physics applies.



• One end of the pomeron couples to a short distance probe.

• But one end couples to the big fat proton.

$\Rightarrow$Only part of the process is perturbatively calculable.

The perturbatively calculable part.

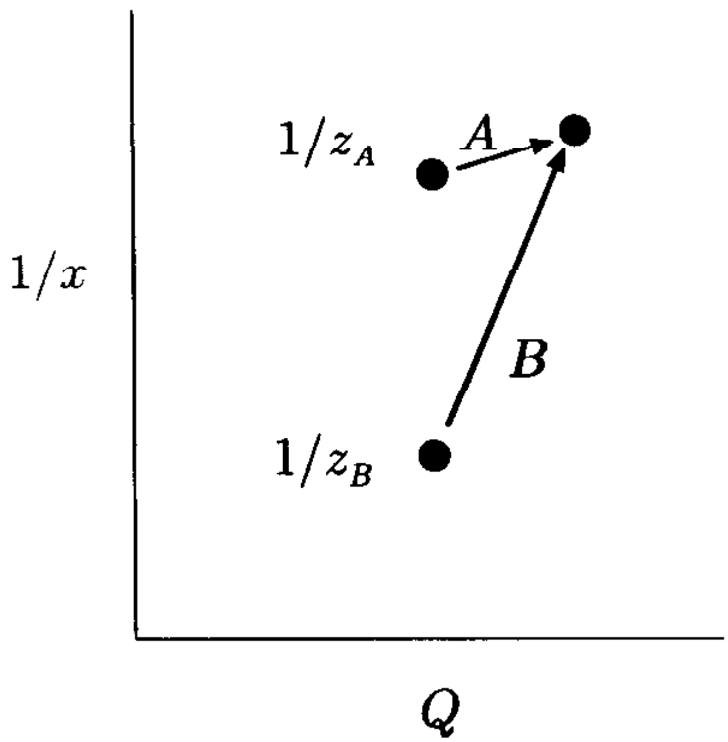
Consider evolution of the parton distributions for $x \ll 1$,

$$\frac{\partial}{\partial \ln Q^2}\, f_{a/p}(x, Q^2) = \sum_b \int_x^1 \frac{dz}{z}\, P_{a/b}(x/z, Q^2)\, f_{b/p}(z, Q^2)$$

In $P_{a/b}(x/z, Q^2)$, sum the contributions $\alpha_s^N \ln(x/z)^N$.

S. Catani and F. Hautmann; R.K. Ellis, B. Webber, and F. Hautmann.

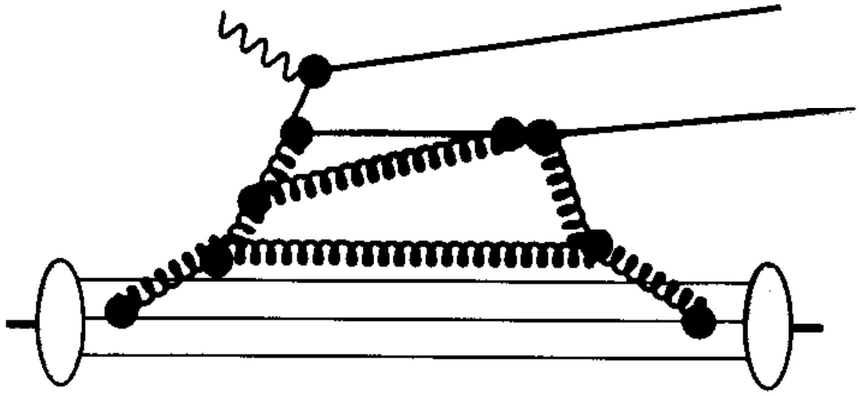
- This makes $P_{a/b}(x/z, Q^2)$ more accurate for $x/z \ll 1$.
- We do no worse for path A and better for path B.



- $z_A f_{b/p}(z_A, Q^2) \gg z_B f_{b/p}(z_B, Q^2)$: need A only.
- $z_A f_{b/p}(z_A, Q^2) \sim z_B f_{b/p}(z_B, Q^2)$: need A & B .

Unfortunately for theorists, nature seems to favor A.

Does BFKL summation explain diffractive DIS?



Diffractive DIS is a direct short distance probe of the partonic structure of the pomeron.
Theorists can say something about the general structure:

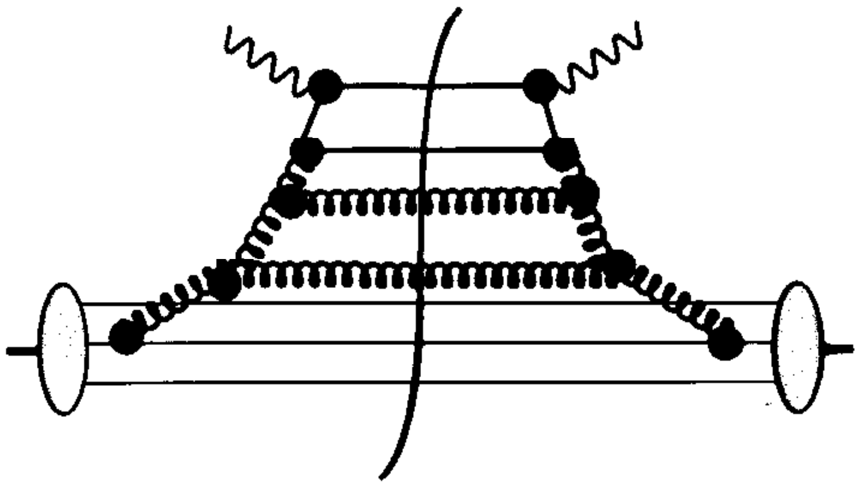
- use perturbative analysis;
- use Regge phenomenology.

But still ... one end of the pomeron is connected to a big fat proton.

⇒a completely perturbative leading log summation does not apply.

One HERA experiment where

the perturbative summation is relevant

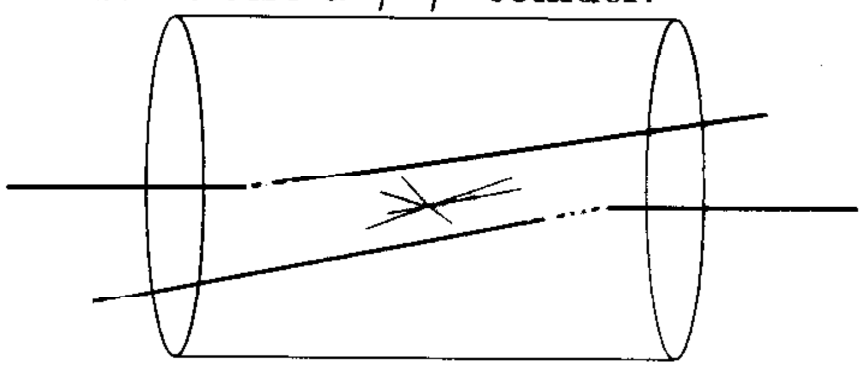


Deeply inelastic scattering at $x \ll 1$;

Measure a jet at $x_J \sim 1$ ($k_T^2 \sim Q^2$).

The pomeron controls σ_T at large s.
For perturbative calculations to apply, need small hadrons.
Theorists like bound states of heavy quarks.
But $\Upsilon\Upsilon$ colliding beams are not practical.

An off-shell photon γ^* with virtuality Q^2
is essentially a hadron with size $1/Q$.
An e^+e^- collider is also a $\gamma^*\gamma^*$ collider.



Q_A^2, Q_B^2, and s are determined by the momenta of the scattered leptons.
For the simplest case of $Q_A^2 = Q_B^2 = Q^2$, we need
- $\alpha_s(Q^2) \ll 1$.
- $s \gg Q^2$.

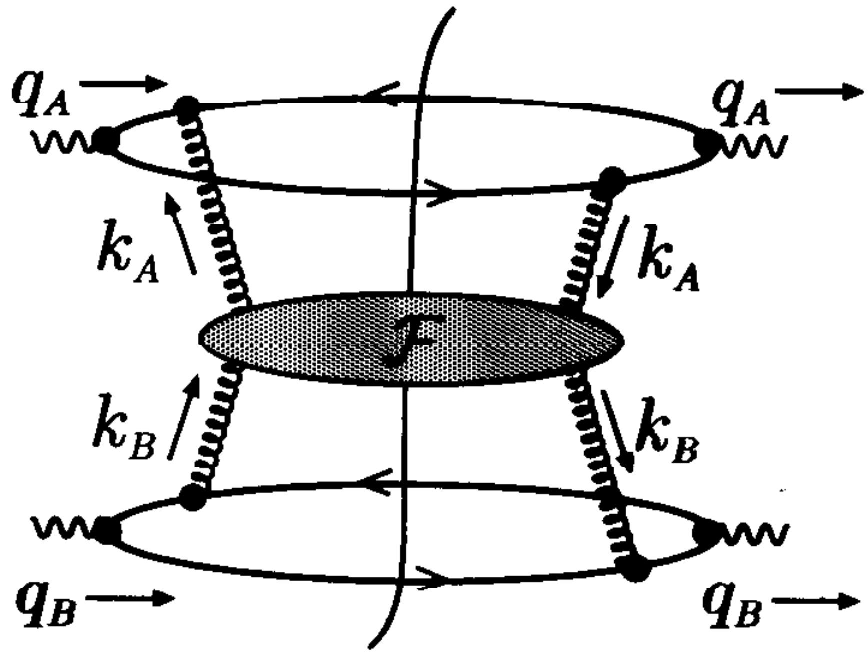
See

Brodsky, Hautmann, & Soper, Phys. Rev. Letters.

Bartels, De Roeck, & Lotter, Physics. Letters.

Brodsky, Hautmann, & Soper, detailed work in preparation.

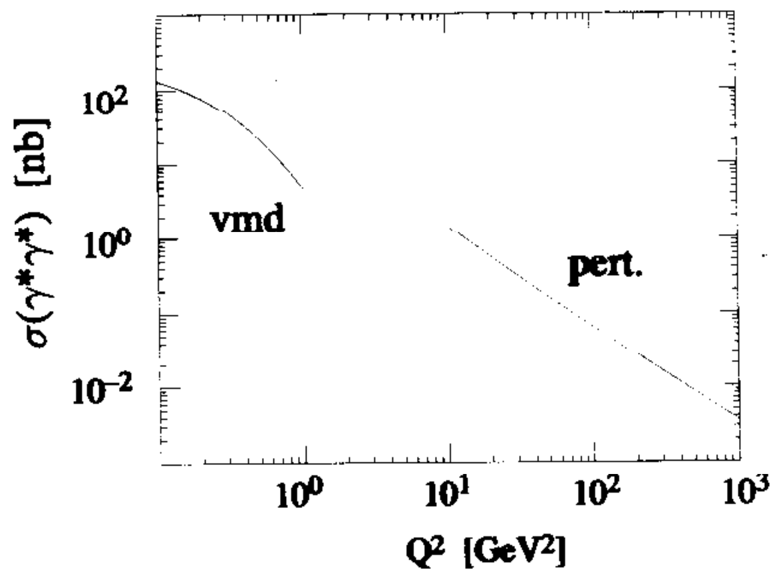
Theorist's picture of the process



Insert BFKL summation into $\mathcal{F}$.

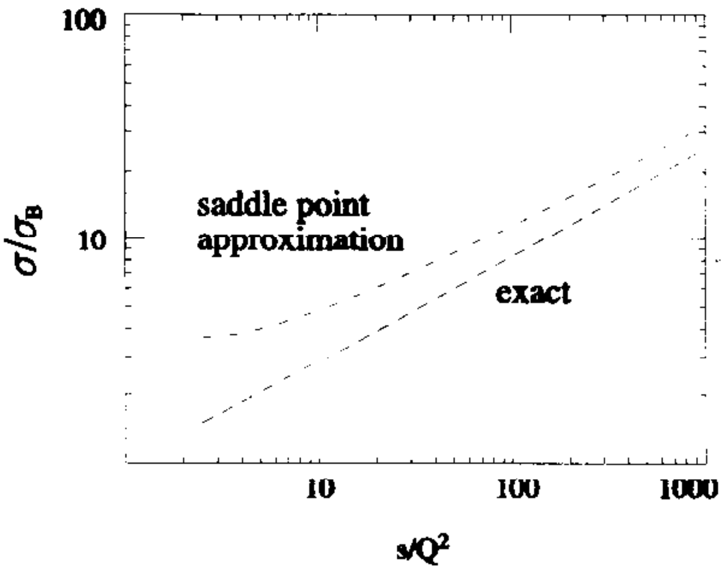
The cross section falls with virtuality

- at small Q^2, one sees the soft pomeron.
- at larger Q^2, it should become the perturbative pomeron.



The cross section rises with energy

The Born cross section is independent of s.
The $\alpha_s^N \ln^N s$ summation creates a rise



Can one do it?

Beware. With only a leading log theory, σ_T is uncertain.

- The predicted cross section is a little marginal at LEP200.

Take cuts

$$Q_A^2 > 10\ \text{GeV}^2,\ Q_B^2 > 10\ \text{GeV}^2,$$
$$s(\gamma^*\gamma^*) > 100\, Q_A Q_B$$

Then

$\sigma \approx 1$ pb.

For $L = 500\ \text{pb}^{-1}$, this is 500 events.

- There should be plenty of events at a next linear collider with $\sqrt{s} \sim 500$ GeV.

Take the same cuts.

Then

$\sigma \approx 4$ pb.

For $L = 50\ \text{fb}^{-1}$, this is 2×10^5 events.