The behaviour of single scale hard small x processes in QCD near the black disk limit

B. Blok

(based on
B. Blok and L. Frankfurt
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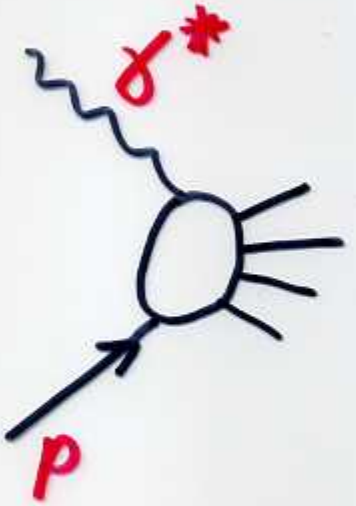
I Challenges of small x physics



$q^2 = -Q^2$

$\nu = 2pq$

$x = \frac{Q^2}{2pq}$

moderate x:

$\alpha_s \ll 1$, $\frac{\alpha_s}{\pi} \ln \frac{Q^2}{\Lambda^2_{QCD}} \sim 1$

$F_2(x, Q^2) = \sum f_i \left(x, \alpha_s \ln \frac{Q^2}{\Lambda^2}\right) \alpha_s^i$

for each f_i - QCD evolution equation.

For small x - new parameter

$\ln \frac{x_0}{x}$ - large $\Rightarrow$ DGLAP ?

One of the striking predictions of DGLAP (LO+NLO)

$$F_{2p}, \times G_p \sim x^{-n(Q^2)}$$

$n \sim 0.2$ for $Q^2 \sim 10\ GeV^2$
(consistent with HERA data)

Another approach - BFKL

$\alpha_s \ll 1$, $\alpha_s \ln \frac{x_0}{x} \sim 1$

$F_2, xG \sim x^{-M}$

$M = 4 \log 2 \frac{\alpha_s(10^2) N_c}{\pi} (1 - \ldots\ldots)$

(G. Salam)

However, LO+NLO BFKL
and LO+NLO DGLAP
give the same results
for $x < 10^{-7} \div 10^{-8}$
(G. Salam, M. Ciafaloni, D. Colferai
A. Staśto 1999, 2002)
Thus in the kinematics up to
small x pQCD calculations

However: problem with unitarity.

$$\sigma^{DGLAP}_{\gamma^*_T}(\text{inclusive}) \sim \frac{1}{x^{\sim 1/(10^2)}} \frac{1}{Q^2}$$

violates Froissart bound

or, in impact parameter space representation

$$A(\text{dipole} + T \to \text{dipole} + T) =$$

$$= 2s \int d^2b\, e^{i q_t b} f(b, s, Q^2)$$

$|f(b^2, s, Q^2)| \leq 1$ must be,

But reaches

$f \sim 1$ for $Q^2 \sim 10\ GeV^2$

already at $x \sim 10^{-2} - 10^{-5}$

(LHC kinematics)

$$\sigma_{tot} = 2\pi b_{max}^2$$

$$b_{max} \sim \frac{1}{m} \ln s/s_0$$

(Froissart bound)

How to achieve such behaviour in perturbative QCD?

The observation —

- α_s series are only asymptotical and defined up to $O(\exp(-\frac{1}{\alpha_s}))$ terms

for sufficiently large energies the latter terms dominate, α_s expansion nonvalid - black disk limit (Froissart) behaviour