J Barlels
St. Petersburg,
April 26, 2003

Small-x Physics -

Where are we going ?

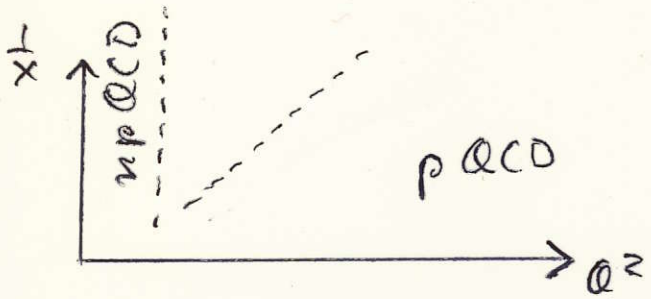
Small-x Physics:

- novel branch of QCD
- stimulated by HERA measurements
- roots in Gatchina
- created lots of theoretical activities

Introduction

What defines small-x physics:

in DIS



- new kinematic limit: large Q^2 and large $1/x$

  pQCD offers DGLAP and BFKL (CCFM)

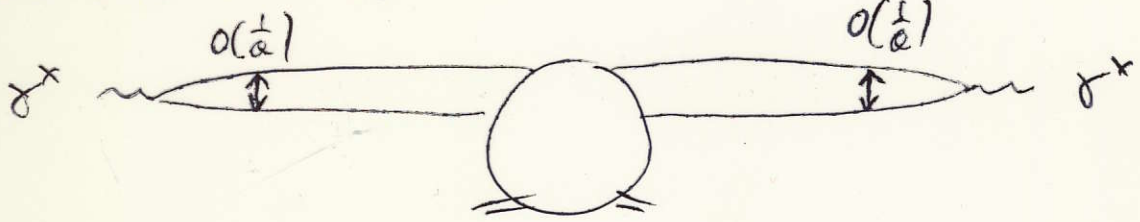
- close to nonperturbative region:

  Regge limit in hadron-hadron scattering

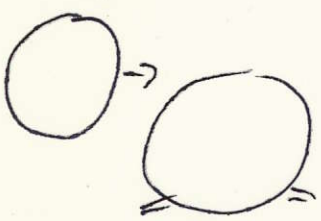
A more physical definition:

- a new type of high energy scattering process

small-size or large-size:



compared to 'old type' hadron-hadron:



- by varying the size of the $q\bar{q}$-pair: continuous transition

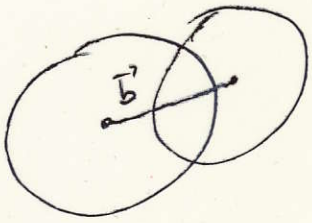
What could we learn from this transition?

- transition from short to long distances in QCD

For comparison: static potential

$$V(r) = -\frac{\alpha_s}{r} + c + \alpha' r$$

High energy scattering process: in transverse plane



Th: $\sigma_{\gamma^*\gamma^*} \sim s^{\lambda>0}$

$\langle \vec{b}^2 \rangle$ grows exponentially with energy

$T(s,\vec{b}^2) \sim \left(\frac{1}{\vec{b}^2}\right)^2$

Exp: $\sigma_{pp} \sim s^{\epsilon}$

$\langle b^2 \rangle \sim 2R_0^2 + 2\alpha_p' \ln s$

$(R \sim c \cdot \ln s)$

$T(s,b) \sim e^{-b^2/R^2}$

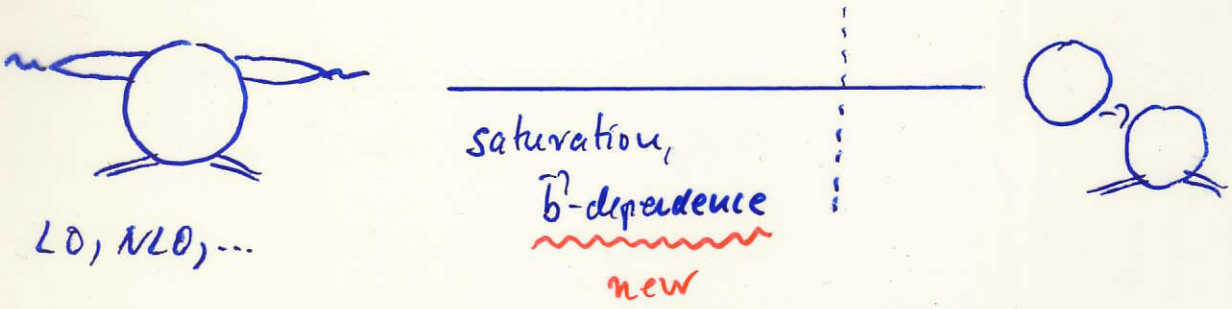
"unconfined", Coulomb force

"confined"

unitarity problem

Observation (e.g. this conference):

- move along the route from pQCD to npQCD:



In the following:

- pQCD
- saturation
- $\vec{b}$-dependence

A few theoretical highlights,
wishes for experimental measurements

Short Distance – pQCD

1) DGLAP, collinear factorization

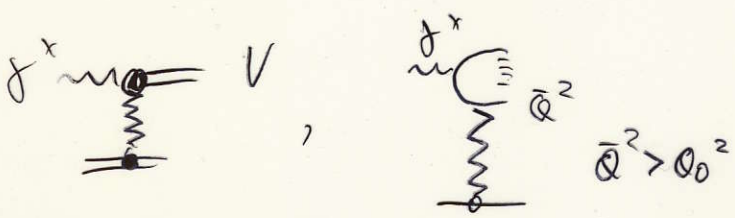
- DGLAP, NNLO — Moch
- DGLAP, resummation + improvement — Altarelli, Thorne
- Observables — Mandesini

Question:

- HERA has measured F_2 in new kinematic region
- How far down in Q^2 and/or x can we describe F_2 by **DGLAP** (leading twist)?

Warnings, doubts:

- **small or even negative gluon at low Q^2** — MRST
- systematic studies of uncertainties — Martin
- curvature of F_2 — Harlot
- Part of diffractive events $\not\subset$ leading-twist DGLAP — Ryskin



- higher-twist studies: cancellations inside $F_2 = F_2^{tw} + F_2$ — JB, Golec-Biernat, Peters

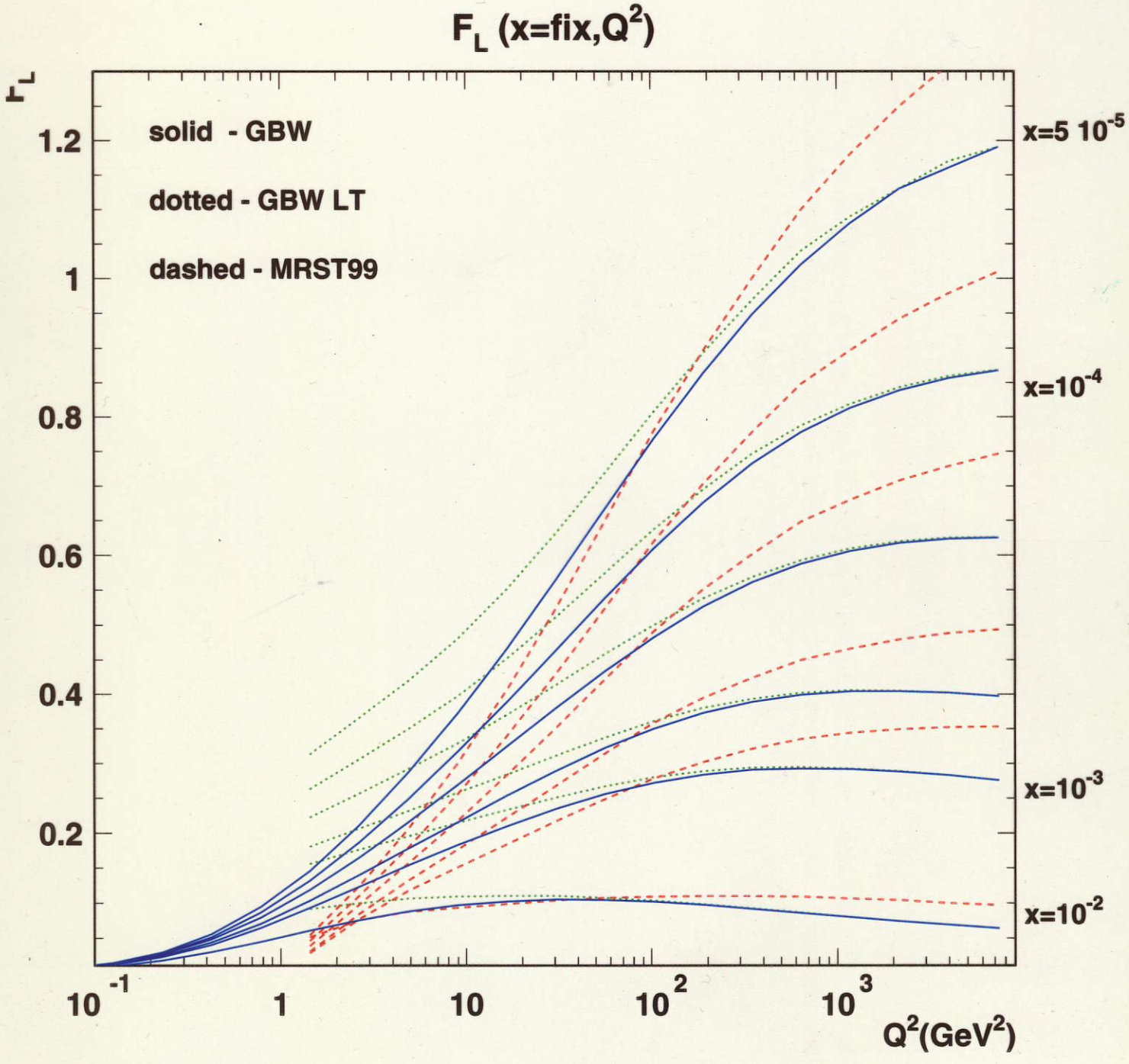
needs to be made quantitative!

Need for F_L:

- interesting per se
- potentially very useful for testing validity of leading-twist DGLAP — Theorie
- theoretical argument: F_L could have large twist-4 correction → Fig.

→ Please measure F_L !

Golec-Biernat



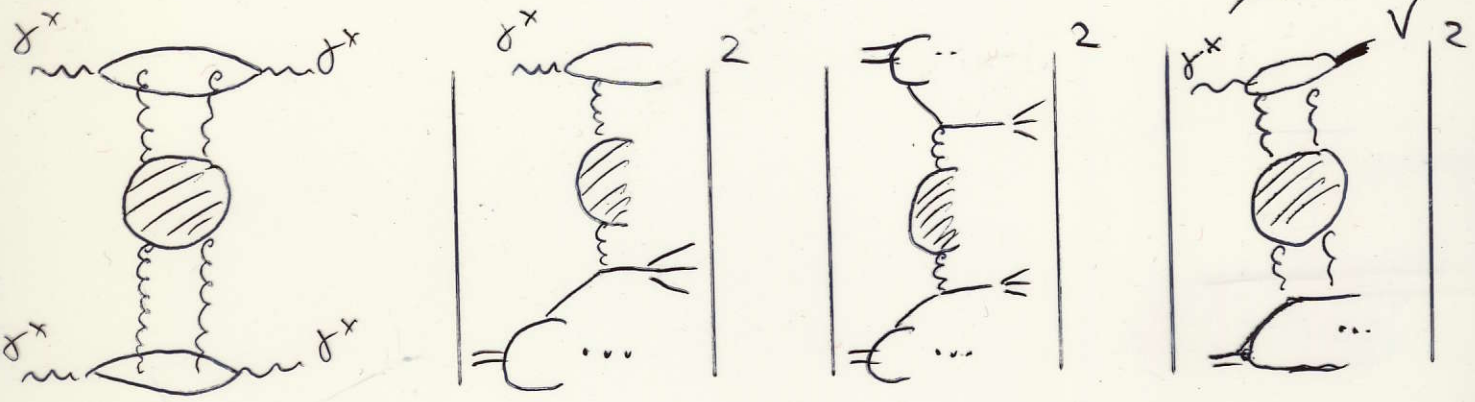
2) BFKL - calculations:

- NLO calculations on the way but not complete

The kernel:

- analytic NLO calculations done for $t=0$ — Fadin, Lipatov; Ciafaloni, Camici
- RG-improvements — Ciafaloni, Salam, Colferai
- numerical **algorithms** — Ciafaloni, Colferai, Stasto; Sabio-Vera

Couplings to external particles:



$\sigma_{\gamma^*\gamma^*}$ | forward jets | Mueller-Navelet | large-t vector production

Three ingredients:

- photon impact factor ($t=0$)
- jet vertex
- $\gamma^* \to V$ impact factor (for $t \neq 0$)

Photon impact factor:

- analytic part ✓ — JB, Gieseke, Qiao Kyrieleis, Colferai
- numerical part on the way — Fadin, Kotsky Colferai, Ciafaloni

Jet vertex:

- analytic part ✓ — JB, Colferai, Vacca
- numerical part to be done

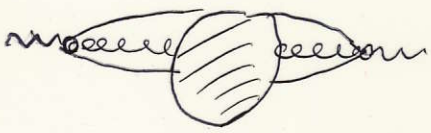
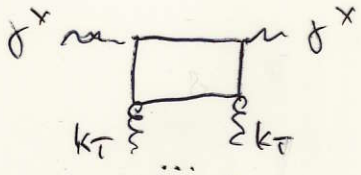
Kernel for $t \neq 0$:

- color octet ✓ — Fadin, Papa, ..
- color singlet: partially done — Fadin, Papa, ..

$\gamma^* \to V$ for $t \neq 0$:

?

Questions to be answered in MO:

- dipole picture —  Wilson loop? $C_{q\bar{q}}$ diagonal?
- k_T-factorization — 

- unintegrated gluon density — 

Other BFKL issues:

- bootstrap equations in NLO: foundament of BFKL

BFKL

Braun, Vacca

Fadin, Papa, Fiore

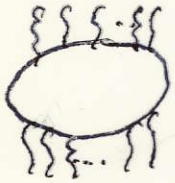
$$T - T^+ = i T T^+$$

set of nonlinear equations

rigorous derivation of BFKL

- spectrum of multigluon states

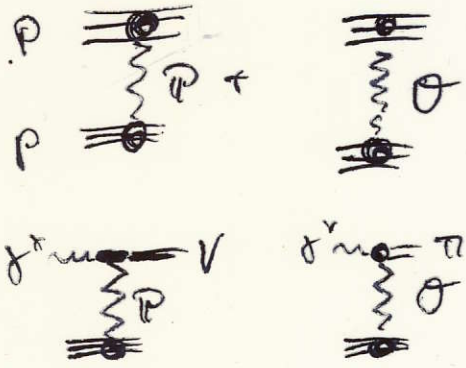
Lipatov



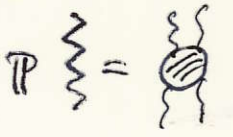
- odderon (odd partner of Pomeron)

....

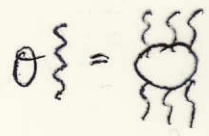
Braun



pQCD:



BFKL



"QCD-Odderon"

→ Phenomenology