Durham, Dec 6/7
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Future of HERA
&
Diffraction

Frame of this talk:

HERA I : rise at small x
diffraction

HERA II : complete and improve
results of HERA I
measure F_L

006 : ? ?

HERA III : eN ?
polarized protons ?

Needs to be done:

a) the physics case (already workshops of HERA, RHIC)

b) improve communication to outside world

c) gain support of experimentalists!
Detector building ...

The Message of HERA I

JB, H. Kowalski
EPJC

- measurement of proton structure function in new kinematic regime: rise at small x (and low Q^2)
- diffraction is important part of DIS cross section

These two message are not uncorrelated:

compare $\gamma^* p$ and $\overset{(-)}{p} p$

Ad 1): hadron-hadron scattering at high energies, small angles

- σ_{tot}, $\frac{d\sigma_{el}}{dt}$, $\frac{d\sigma_{diff}}{dt}$ have universal features: independent of h.

- can be encoded in 3 parameters (Regge-Theory)

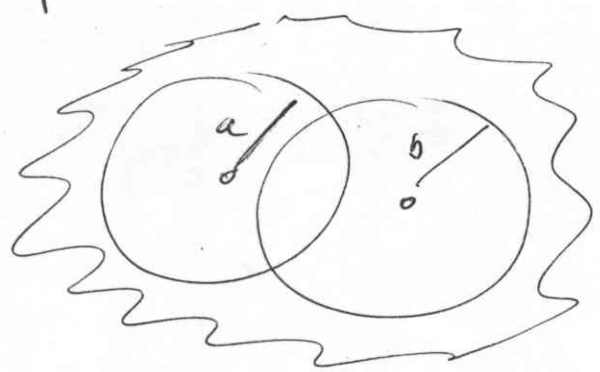
$$\alpha_{I\!P}(0) = 1.08 \ : \quad \sigma_{tot} \sim s^{\alpha_{I\!P}(0)-1}$$

$$\alpha'_{I\!P} = 0.25\ GeV^{-2} \ : \quad \frac{d\sigma}{dt} \sim s^{2(\alpha_{I\!P}(0)-1)} e^{Bt},$$

$$B = 2\left[B_{0,a} + B_{0,b} + \alpha'_{I\!P} \ln s/s_0\right]$$

$$g_{I\!P I\!P I\!P} = 1\ GeV^{-1}:$$

- these parameters represent (nonpert.) properties of QCD transverse plane:



- interpretation: see below

Ad 2): $\gamma^* p$ - scattering at high energies, small angles: diameter of $\gamma^* \sim O(\frac{1}{Q})$

- previous universal features are different

- new values for the parameters

$$\alpha_{I\!P}(0) \to \lambda(Q^2) > \alpha_{I\!P}(0)$$

$$\alpha_{I\!P}'(0) \to \alpha'_{eff} < \alpha'_{I\!P}$$

$$g_{I\!P I\!P I\!P} \to \; ? \quad \text{(not measured)}$$

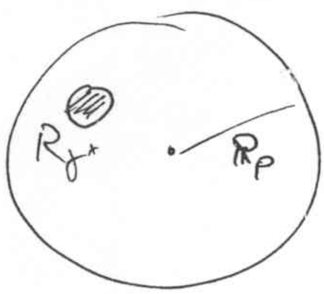
- at large Q^2 these parameters are "computable"

- $\lambda(Q^2)$: follows from DGLAP ($xg \sim e^{\sqrt{\beta_0 \ln t/t_0 \ln 1/x}}$)

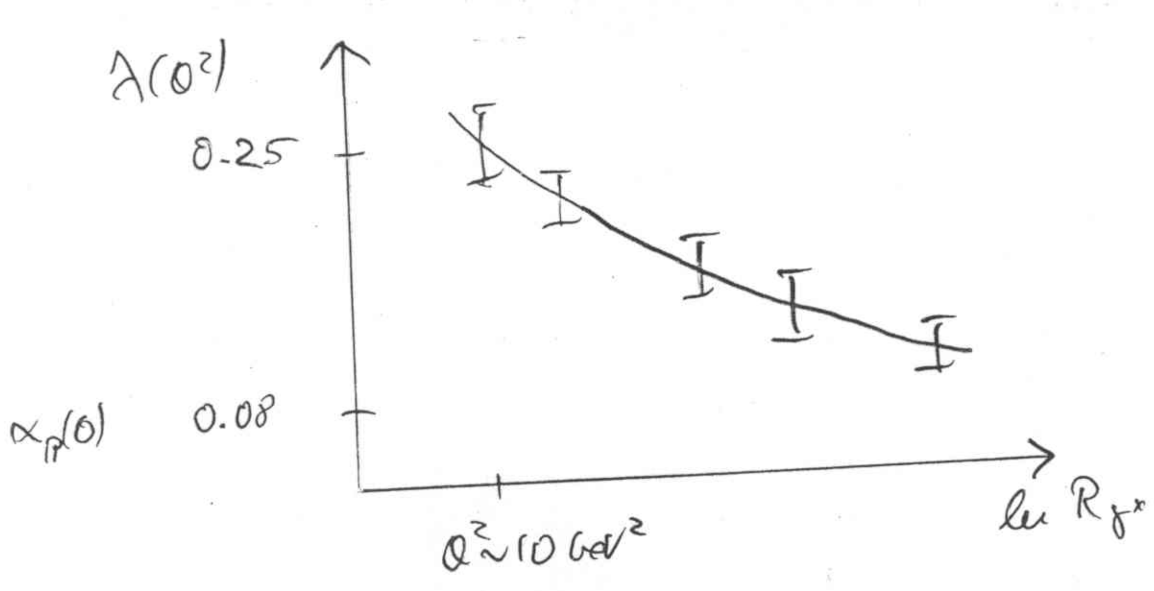
- α'_{eff} small ($\to 0$ for $Q^2 \to \infty$)

- $g^{pert.}_{PPP}$ (larger, under investigation) (JB, Ryskin, Vacca)

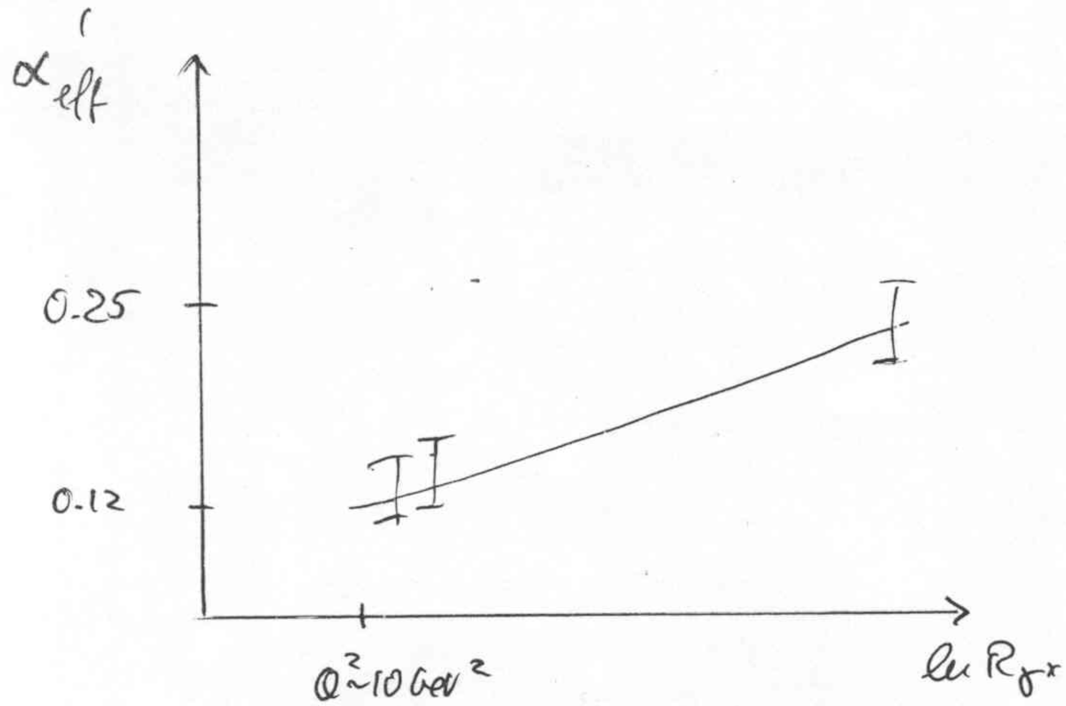
transverse plane:



Put together: as function of R_{γ^*}:



well-measured



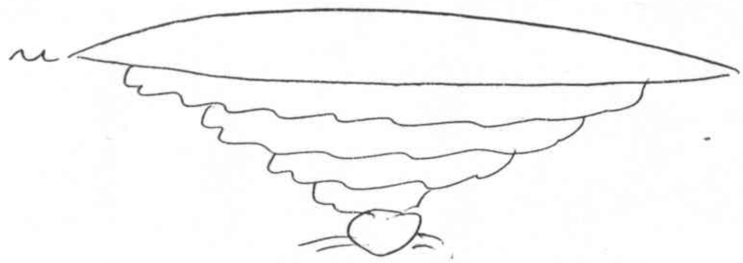
(only few points so far)

Very advantageous situation:

- physical parameter which can be measured in the whole interval
- at small distances: 'computable'
- at large distances: we have effective theory (Regge theory!)
- challenge for theorists: understand the transition
- historical precedent (black body radiation)

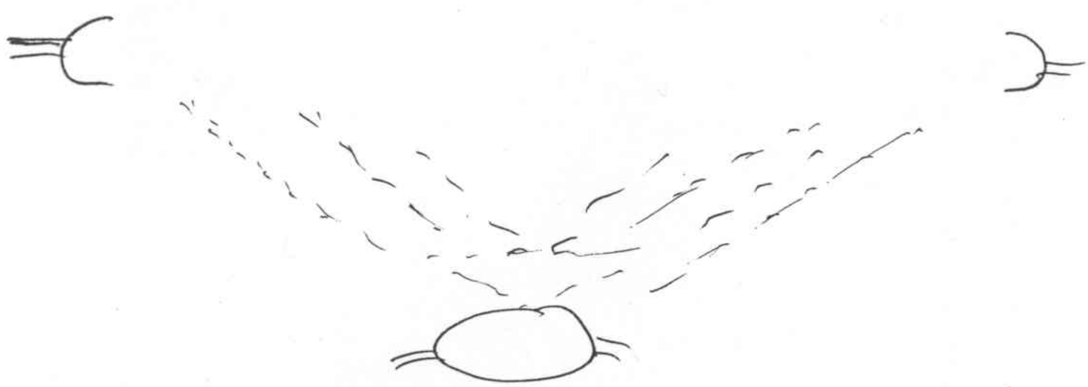
Physical picture which interpolates:

- small distances: QCD in proton rest frame



→ radiation of gluons, $q\bar{q}$-pairs

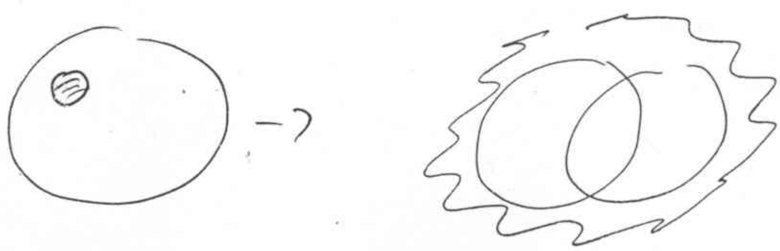
- large distances R_{γ^*}: wee partons of Gribov, Feynman



→ radiation of wee partons

Provides intuition on

- intercept: large $\lambda(\phi^4)$ → $\alpha_{I\!P}(0) \approx 0$
- slope



Gribov diffusion

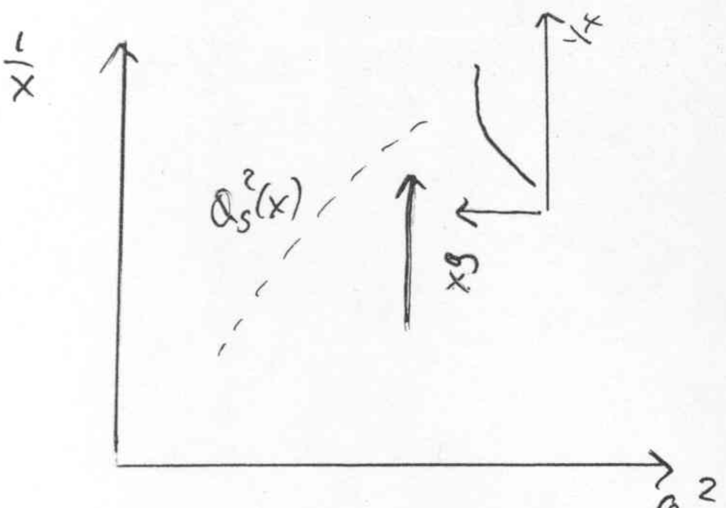
How does this transition happen in detail? 7

Gribov, Levin, Ryskin
Mueller
...

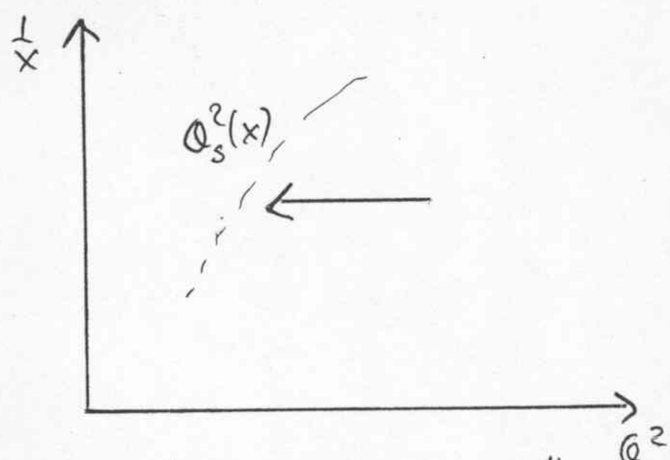
? saturation ?

What is saturation: Kinematic region where

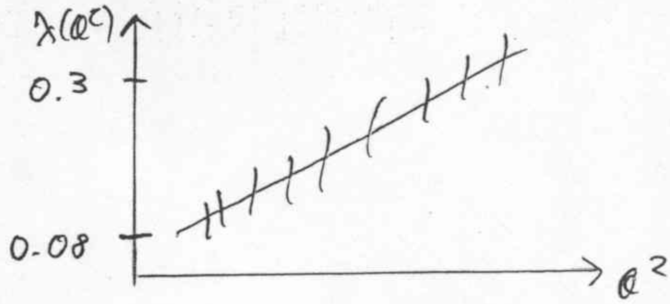
- α_s is small, but cross section is large
- strong field, nonlinear dynamics



"xg becomes flat"



"Saturation model"
Golec-Biernat, Wüsthoff
...



"computable up to saturation scale $Q_s^2(x)$"

- Need to find common definition,
- agree on signal of saturation

But: even if saturation has been established

- there are pions, multiperipheral physics!
- need to consider t-dependence!

Summary HERA I:

- new approach to diffraction

$$\gamma^* p \longleftrightarrow pp$$

- fits into confinement - picture

small distances ↔ long distances

- raises new question: transition

? saturation as new state of QCD ?

-

What is left for ep at HERA energies:

- more t-dependence in diffraction

- F_L

- more statistics in high Q^2, large x region

- limit of applicability of DGLAP

→ shopping list for HERA II

What could be the physics case for HERA III ?

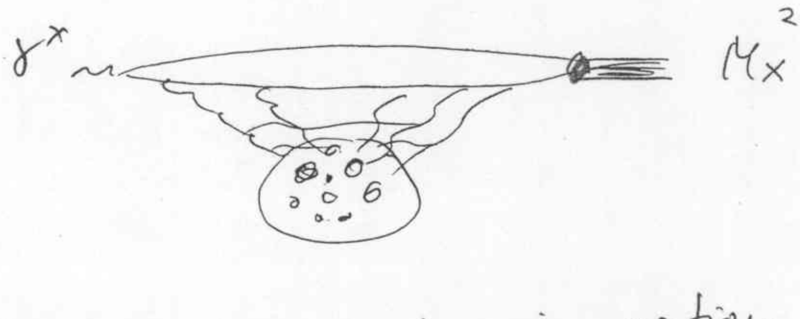
Needs questions that cannot be answered by ep at HERA energies (HERA I or HERA II) :

- eN : nuclear option
- $ep\uparrow$ (polarized) : spin option

See literature (proceedings of workshops etc.)

Particular role of diffractive final states (e.g. $\gamma^* N \to VN$)

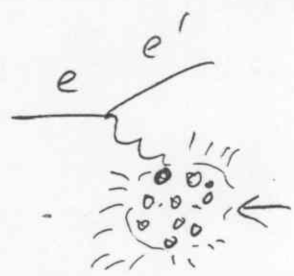
- diffraction provides additional insight, more that $\sigma_{tot}(eN)$, $\sigma_{tot}(ep\uparrow)$:
  - variation of transverse size of final state
  - t-dependence ($\to$ impact parameter dependence)



Both for nuclear and spin option

The nuclear option:

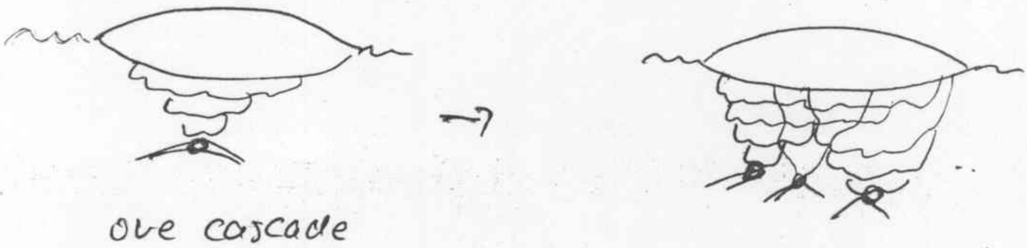
$$eN \to e'X$$



New questions:

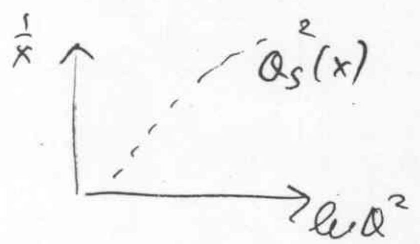
parton content of nucleus

- bound state of nucleons
- important for heavy ion physics, quark gluon plasma
- at small x : state of high gluon density $\to$ saturation



one cascade

sees multicascades



$$Q_s^2 = \frac{A^{1/3}}{x^\delta} \qquad \delta = 0.3$$

$A = 64$: x goes up by factor 100 !

- very interesting for previous discussion

→ serves 2 communities

- particle physicists
- nuclear physicists (medium energy)

The Spin option:

Clear physics goal:

- polarized structure functions, especially at small x
- important for nucleon spin, $\int_0^1 dx\, g_1(x)$
- pert. QCD: striking predictions for small-x behavior — JB, Ryskin
- diffraction: more insight than $\gamma^* p \to X$

But remember:

polarized pp-scattering very complicated

$\to$ no easy comparison between $\gamma^* p\uparrow \leftrightarrow p\uparrow p\uparrow$

Summary:

HERA I: identify physics issue

diffraction — confinement, novel approach

HERA II: shopping list

t-dependence, F_L; validity of DGLAP

HERA III: eN as new step

new questions, new community

helps to answer questions raised by HERA