CGC at LHC

.

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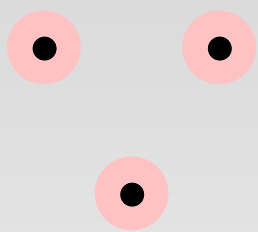
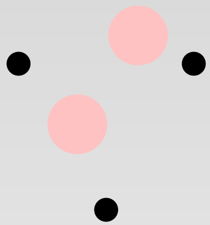
Two scales of hadronic structure

Gluons do not propagate far from the source.
Light-cone snapshot of the proton:





B.K., A.Schäfer, A.Tarasov(1999):
the valence quarks carry small size gluon clouds, $r_0 = 0.3$ fm.

Shuryak & Zakhed (2004):
gluonic spots of small size, $r_0 = 0.3$ fm are floating in the proton.

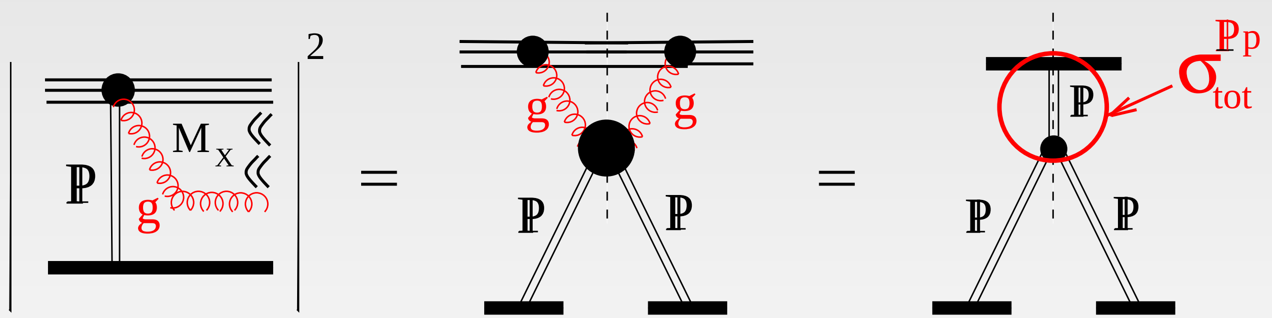
Do we have evidence for the two-scale structure in data?

Evidences for two scales

- Gluon radiation must be suppressed by an order of magnitude (Color Transparency).

In soft inelastic collisions gluons are indistinguishable.

Diffraction offers a unique way to single out gluon radiation. Only radiation of a vector particle can provide the large mass tail, $d\sigma_{sd}/dM^2 \propto 1/M^2$.



One expects $\sigma_{tot}^{\mathbb{P}p} \sim$ 50 mb.

However, data lead to $\sigma_{tot}^{\mathbb{P}p}$ ∼2 mb !!!

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Evidences for two scales

- One should expect a slow Gribov diffusion, i.e small $\alpha'_{\mathbb{P}}$.

$$\alpha'_{\mathbb{P}} = \frac{1}{2}\frac{dB_{el}}{d\ln(s/s_0)} = \frac{\alpha_s}{3\pi}\, r_0^2 = 0.1\,\mathrm{GeV}^{-2}\,.$$

This prediction is well confirmed by ZEUS measurement in photoproduction of J/Ψ:

$$\alpha'_{\mathbb{P}} = 0.115 \pm 0.018\,\mathrm{GeV}^{-2}$$

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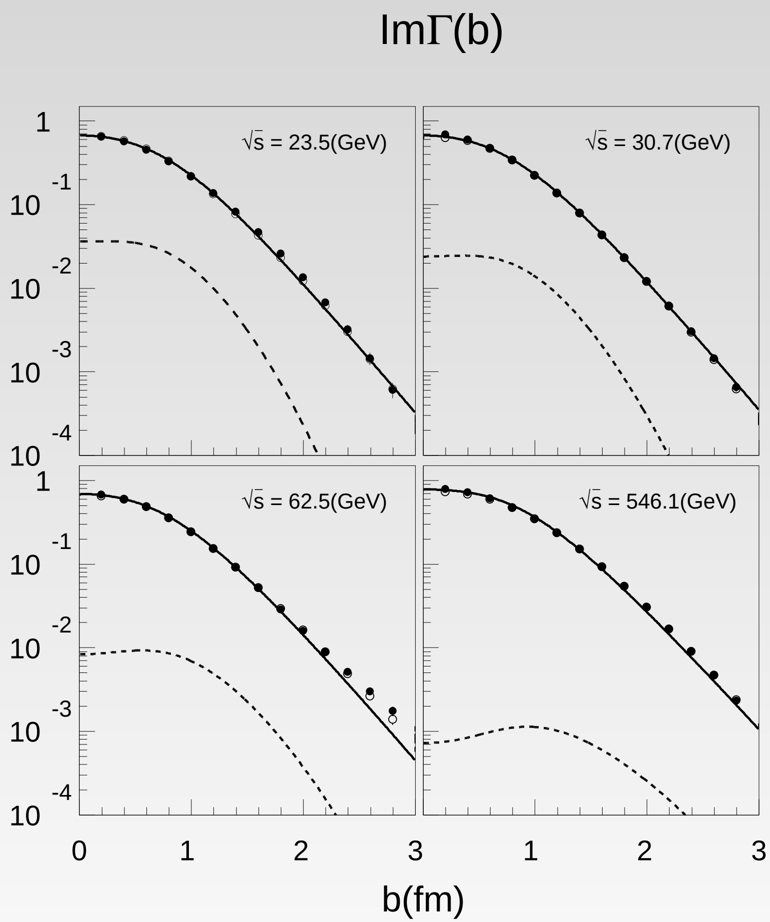
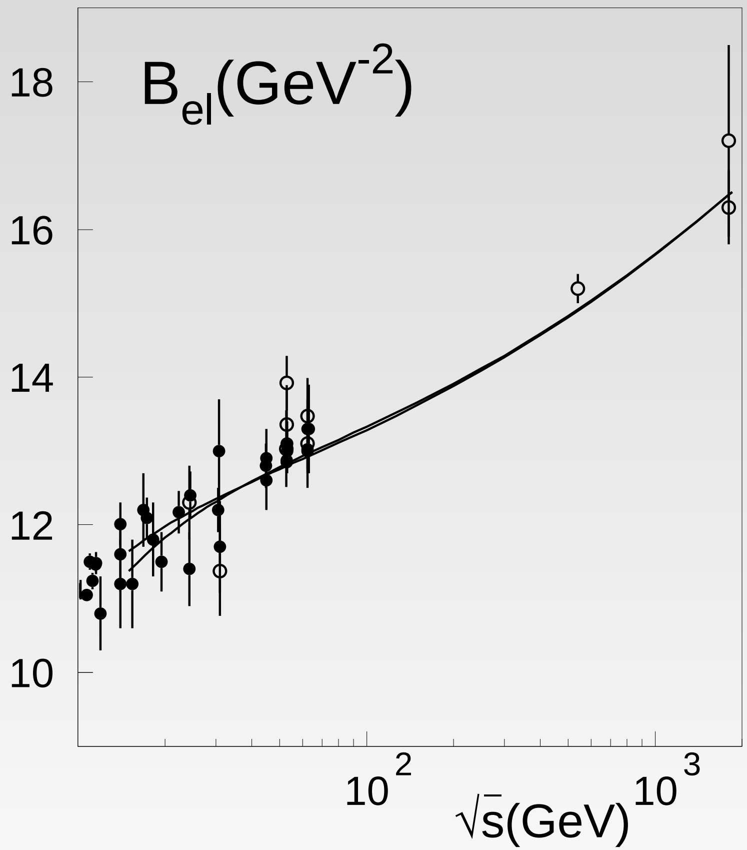
Unitarity saturation in pp collisions

Why data for pp elastic scattering show a much larger value of $\alpha'_{I\!P}$? - Unitarity saturation.





$$\alpha'_{I\!P} \approx 0.1\,\mathrm{GeV}^{-2}\ \text{, but}\ \ \alpha'_{eff} \approx 0.25\,\mathrm{GeV}^{-2}$$

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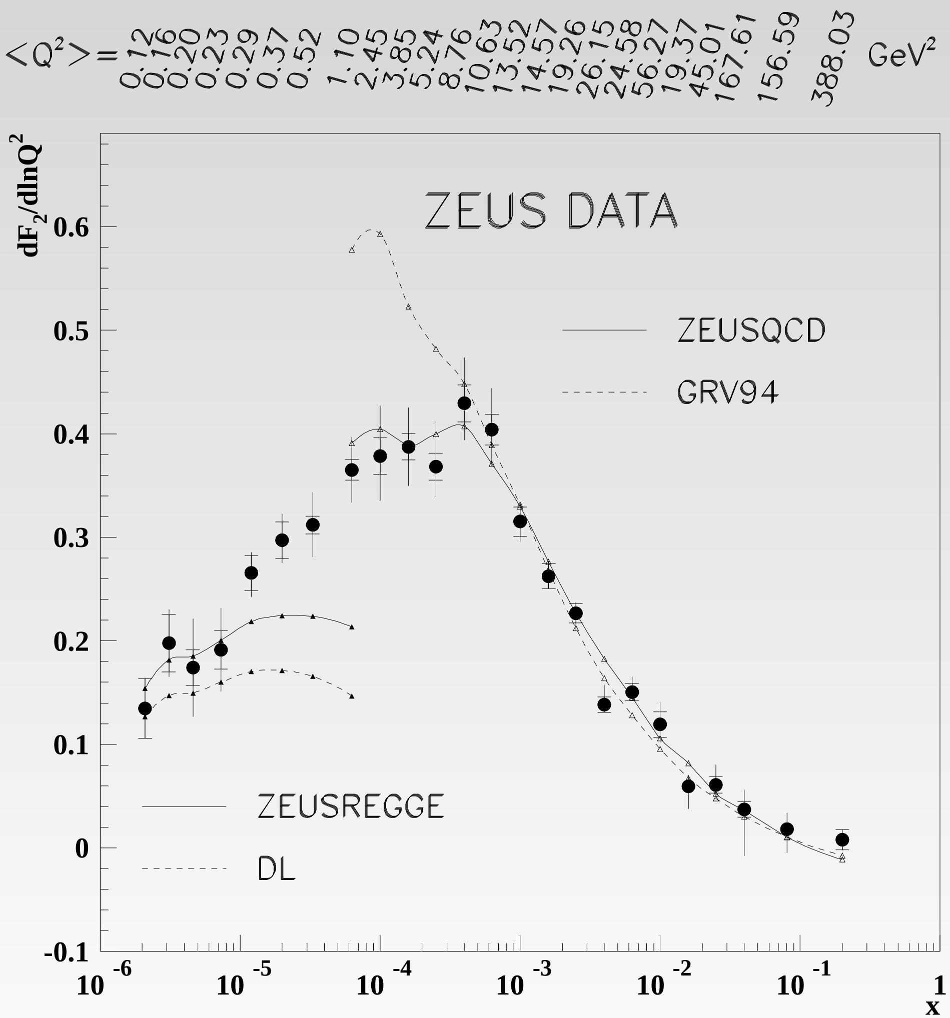
Evidences for two scales

- As far as gluons are located within small spots, it is difficult to resolve them at low scale, $Q^2 < 4/r_0^2$, while no changes happen at higher Q^2. This is confirmed by data from ZEUS.

ZEUS 1995



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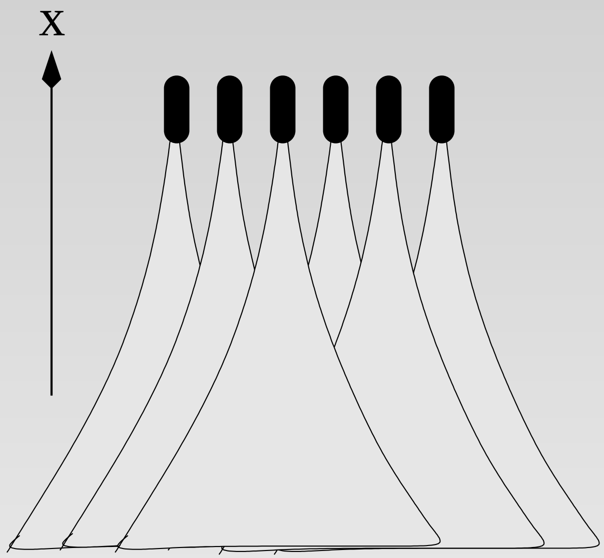
Shadowing



A Lorentz-boosted nucleus looks like a pancake, as well as the bound nucleons. So the nucleons are still well separated. However, parton at small $x < (m_N R_A)^{-1}$ are less contracted and overlap in the longitudinal directions. Then they can fuse reducing parton density at small x. This is how shadowing looks like in the infinite momentum frame [O.Kancheli (1973)].

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Shadowing

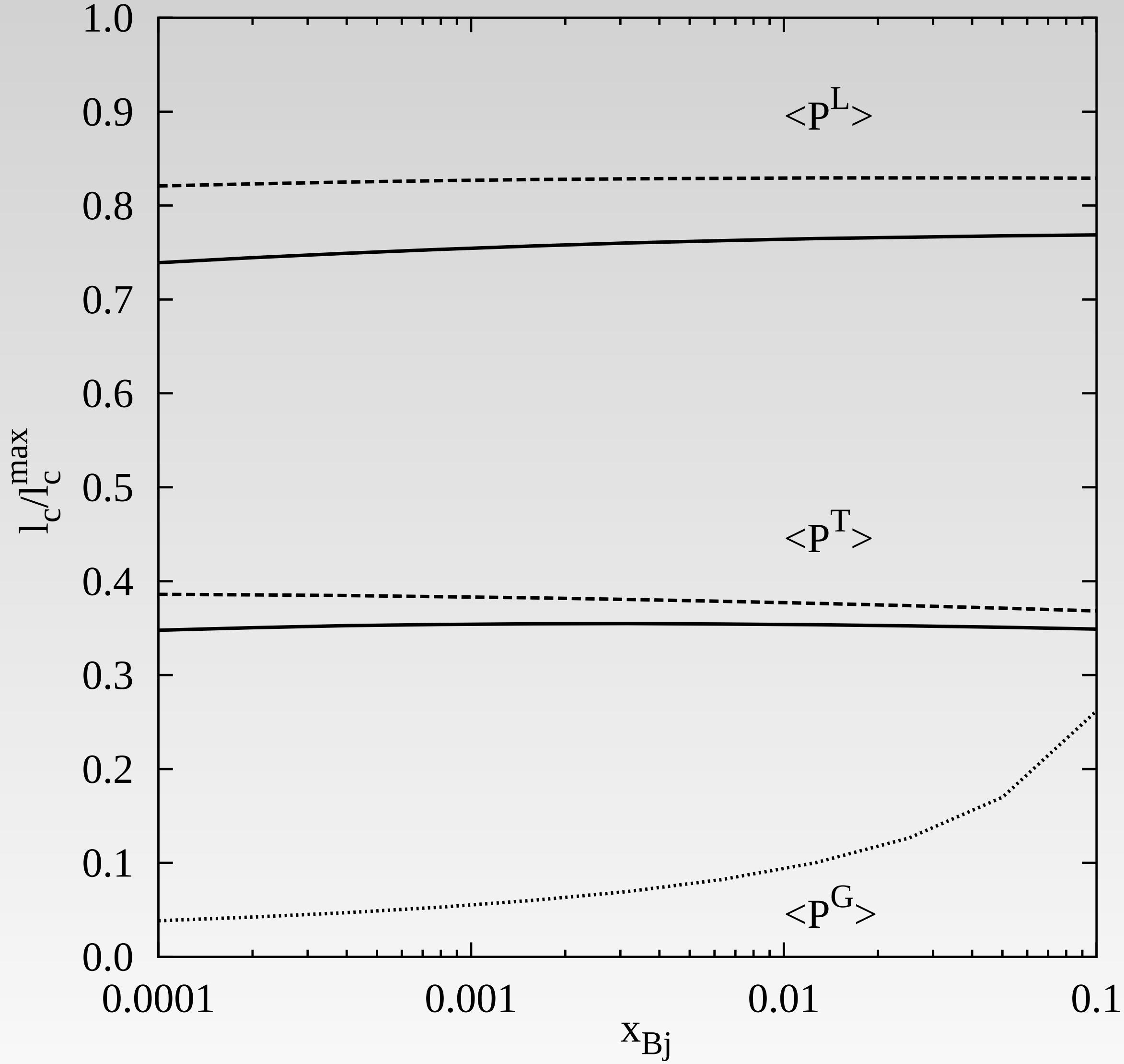
Smallness of gluonic spots makes fluctuations rather heavy.

The parameter controlling coherence is the fluctuation lifetime (coherence time),

$$t_c = P\, t_{max} = \frac{P}{x\, m_N}$$

The factor P is order of magnitude smaller for gluons than for quarks.

B.K., J.Raufeisen, A.Tarasov (2000)



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Weak gluon shadowing

Even if small-x gluons overlap in the longitudinal direction, they can miss each other in impact parameters, if they are located within small spots. Indeed, for a heavy nucleus (lead) the mean number of gluonic spots overlapping with a given one is,

$$\langle n\rangle = \frac{3\pi}{4}\, r_0^2\, \langle T_A\rangle = \pi\, r_0^2\, \rho_A\, R_A = 0.3$$

Thus, the gluonic spots hardly overlap in transverse plane. Although their size rises with $1/x$, but very slowly, as $\ln(1/x)$, while the longitudinal overlap onsets linearly in $1/x$.

Such a small overlap is another another reason for a weak gluon shadowing. It makes gluon saturation quite questionable.

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Weak gluon shadowing

Predictions for LHC

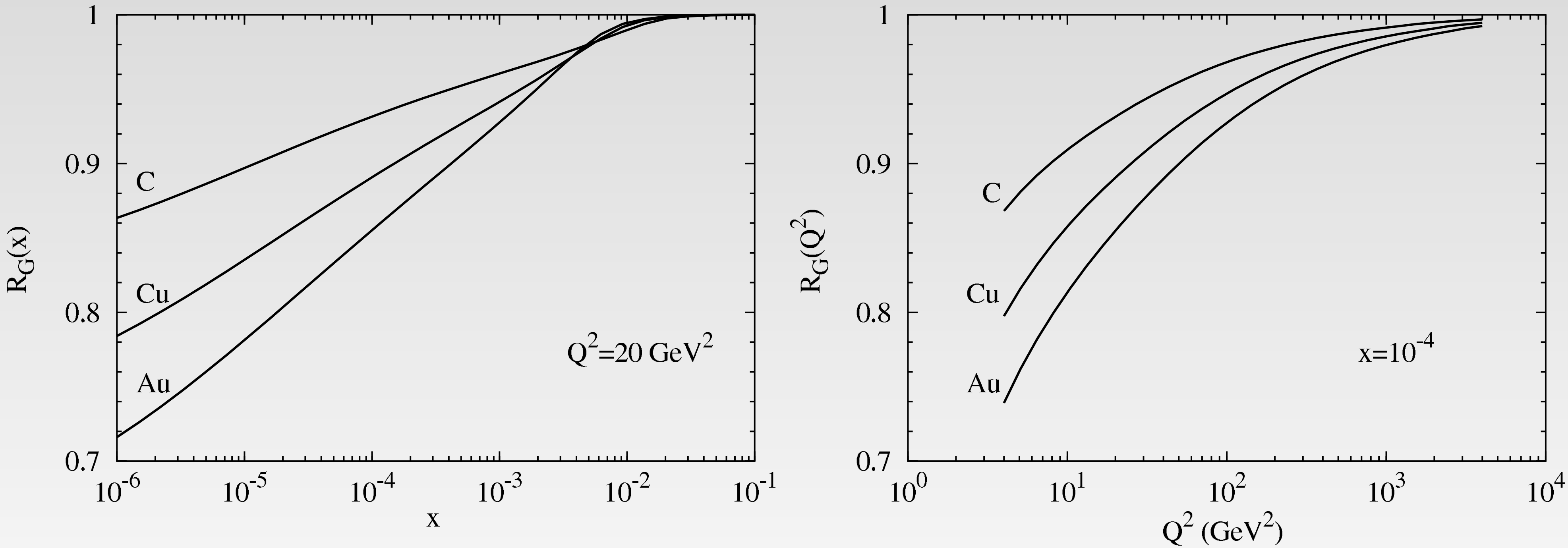

Figure 6: *The x- and Q^2-dependence of gluon shadowing for carbon, copper and gold. The x-dependence is shown for $Q^2 = 20$ GeV^2, while the figure on the right is calculated for $x = 10^{-4}$.*

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Weak gluon shadowing

Centrality dependence

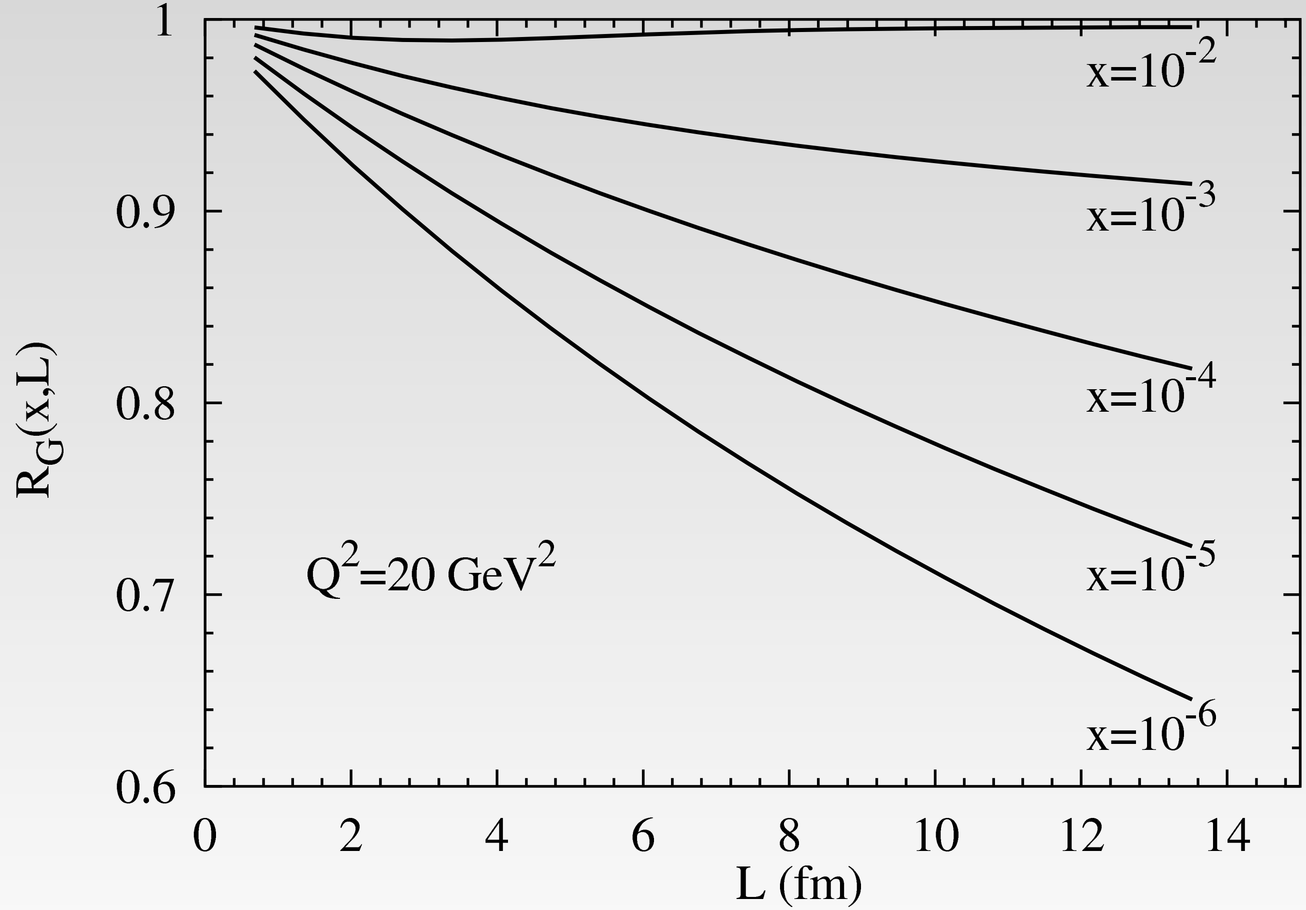

Figure 5: *Gluon shadowing vs. the length of the nuclear medium* $L = 2\sqrt{R_A^2 - b^2}$*, where* b *is the impact parameter and* R_A *the nuclear radius. All curves are for* $Q^2 = 20\ GeV^2$ *but for different values of* x*.*

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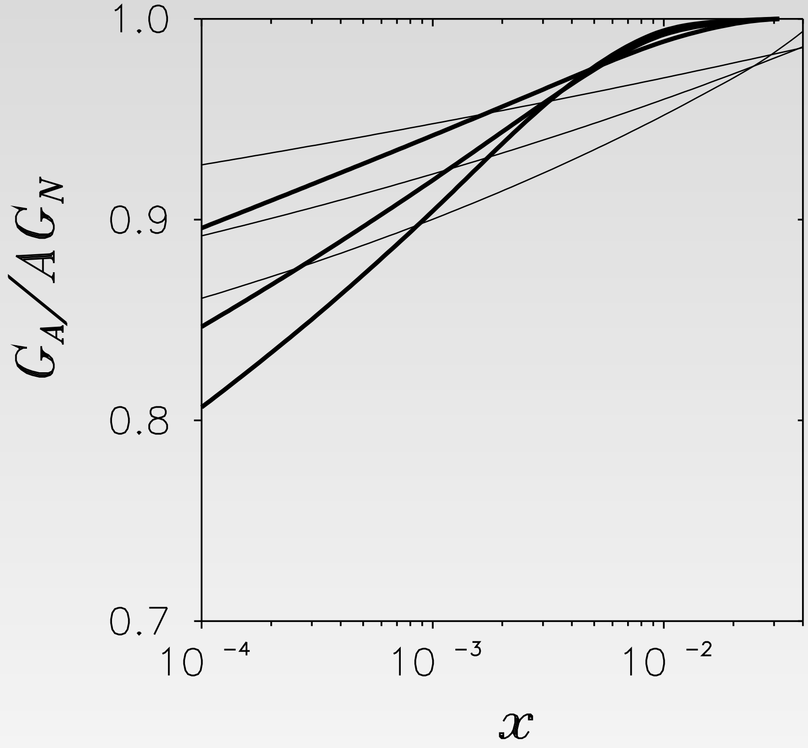
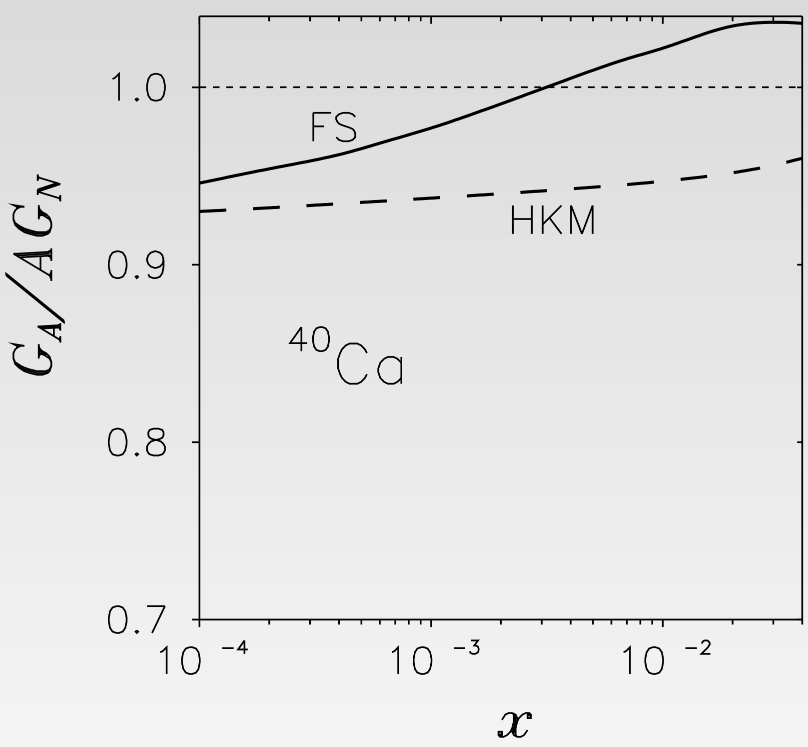
Weak gluon shadowing

Comparison with data





Predictions for C, Fe and Pb

B.K., A.Schäfer, A.Tarasov(1999)

NLO analysis

D. de Florian & R. Sassot(2004)

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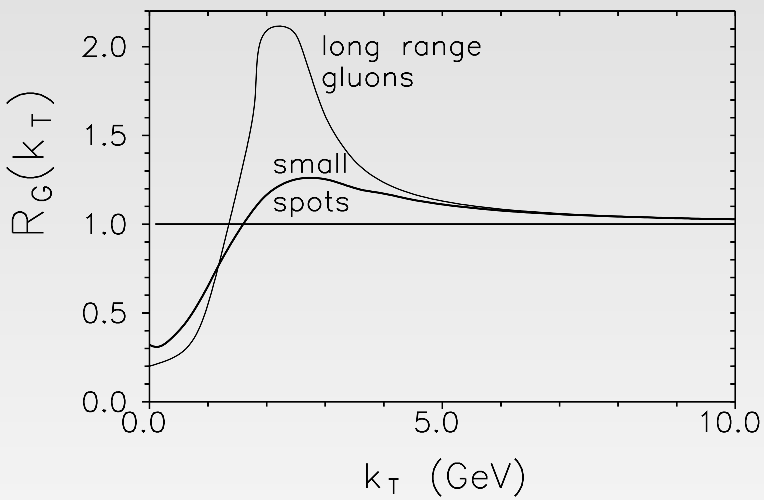
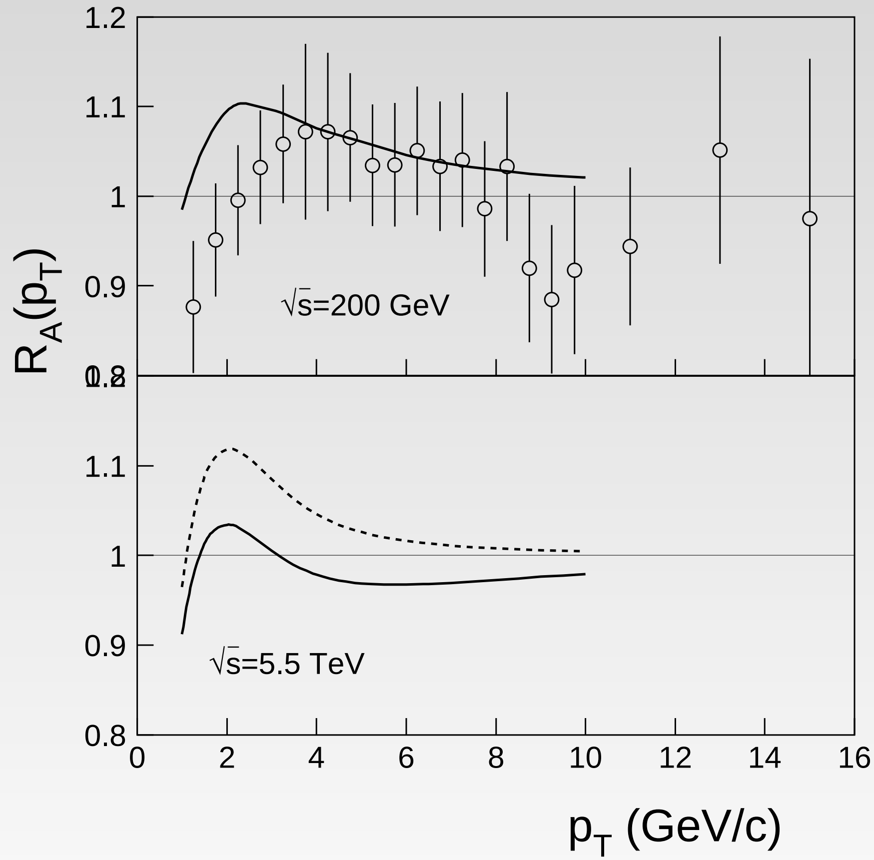
Color Glass Condensate

If gluons do not overlap in transverse plane, they do not interact, and not only gluon shadowing, but also CGC is considerably reduced.



B.K., A.Schäfer, A.Tarasov
1998

A weak Cronin effect was predicted for RHIC (confirmed) & LHC.



B.K., J.Nemchik, A.Schäfer, A.Tarasov
2002

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Summary

- There is growing theoretical and experimental support for the existence of a non-perturbative scale which is much smaller than the confinement radius $1/\Lambda_{QCD} \sim 1\,\mathrm{fm}$, and which is related to the gluonic degrees of freedom.

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Summary

- There is growing theoretical and experimental support for the existence of a non-perturbative scale which is much smaller than the confinement radius $1/\Lambda_{QCD} \sim 1\,\text{fm}$, and which is related to the gluonic degrees of freedom.

- In spite of a sufficient longitudinal overlap of gluons at small x, they hardly overlap in impact parameters. This leads to a substantial reduction of the magnitude of nuclear shadowing and CGC for gluons. This expectation is well confirmed by RHIC data for Cronin effect and by the NLO analysis of DIS data on nuclei.