Higher density QCD effects expected at THERA

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The general goal:

To find new observables for gluon saturation at THERA

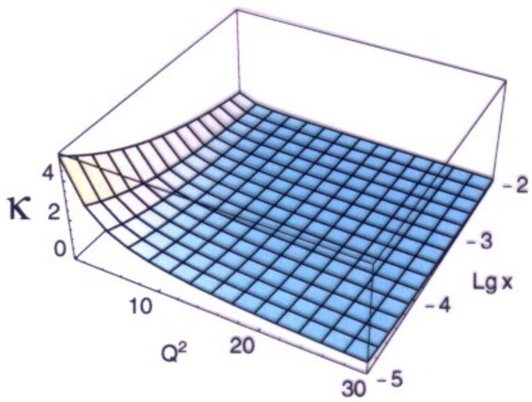
Why Saturation is expected to be important?

The packing factor κ is an averaged number of simultaneously interacting partons in the cascade

$$\kappa = \frac{3\,\pi^2\alpha_S}{2Q^2} \times \frac{x_B G(x_B, Q^2)}{\pi\,R^2}$$

When $\kappa \sim 1$ we expect that Shadowing Corrections are essential. This condition yields the saturation scale $Q_s^2(x_B)$.

The packing factor in the HERA kinematical region



Thus there are two scales in low x_B physics:

- separation scale r_{sep} at which perurbative QCD breaks down, and
- saturation scale $r_{sat} \sim 1/Q_s(x_B)$ at which shadowing corrections set in.

Balitsky (1996) and Kovchegov (1999) derived an equation which takes into account shadowing corrections:

$$\frac{da_{el}}{dy} = -\frac{2C_F\alpha_s}{\pi}\ln\left(\frac{\mathrm{r}_\perp^2}{\rho^2}\right)a_{el} + \frac{C_F\alpha_s}{\pi}\int d^2\vec{r}'_\perp\, K(\vec{r}_\perp,\vec{r'}_\perp)\left(2a_{el}-a_{el}^2\right)$$

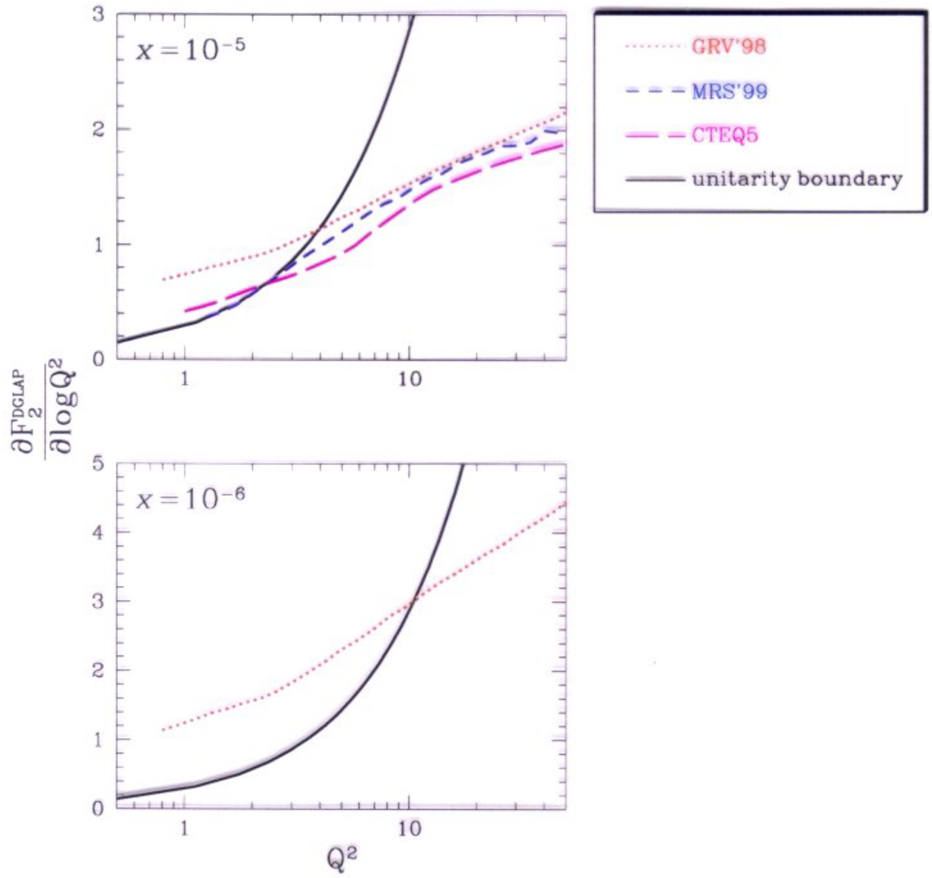
where $a_{el} = a_{el}(\vec{r}_\perp, b_\perp, y)$ is the elastic scattering amplitude of the dipole of size $r_\perp$ at energy e^y and impact parameter $b_\perp$. K is a kernel describing splitting end merging of dipoles. The non-linear term is of Glauber type and was first written by Gribov, Levin and Ryskin (1983) and Mueller and Qiu (1986).

Predictions for THERA

i. **Unitarity boundary** **There are the following boundaries for $\frac{\partial F_2}{\partial \ln Q^2}$ and $x_B G(x_B, Q^2)$ which follow from the unitarity constrain:**

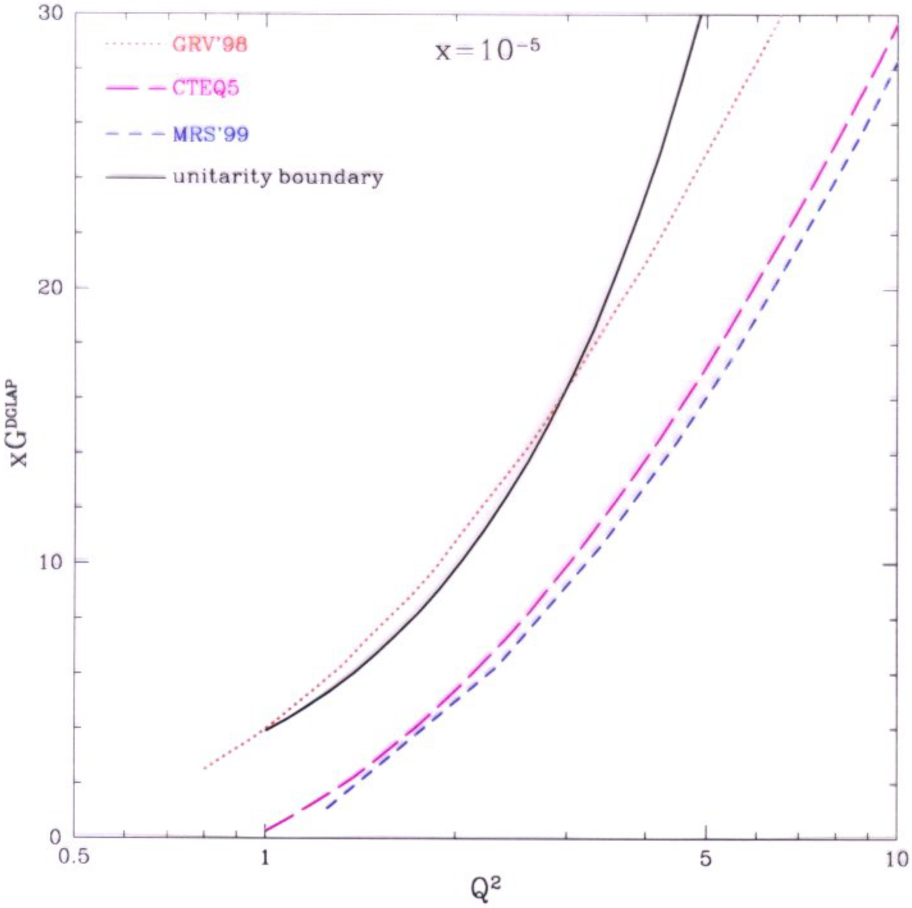
$$\frac{\partial F_2(x, Q^2)}{\partial \ln Q^2} < \frac{1}{3\,\pi^2}\, Q^2\, R^2 \; ;$$

$$\frac{\partial^2 x G(x, Q^2)}{\partial \ln Q^2 \;\partial \ln(1/x)} < \frac{2}{\pi^2}\, Q^2\, R^2 \; .$$

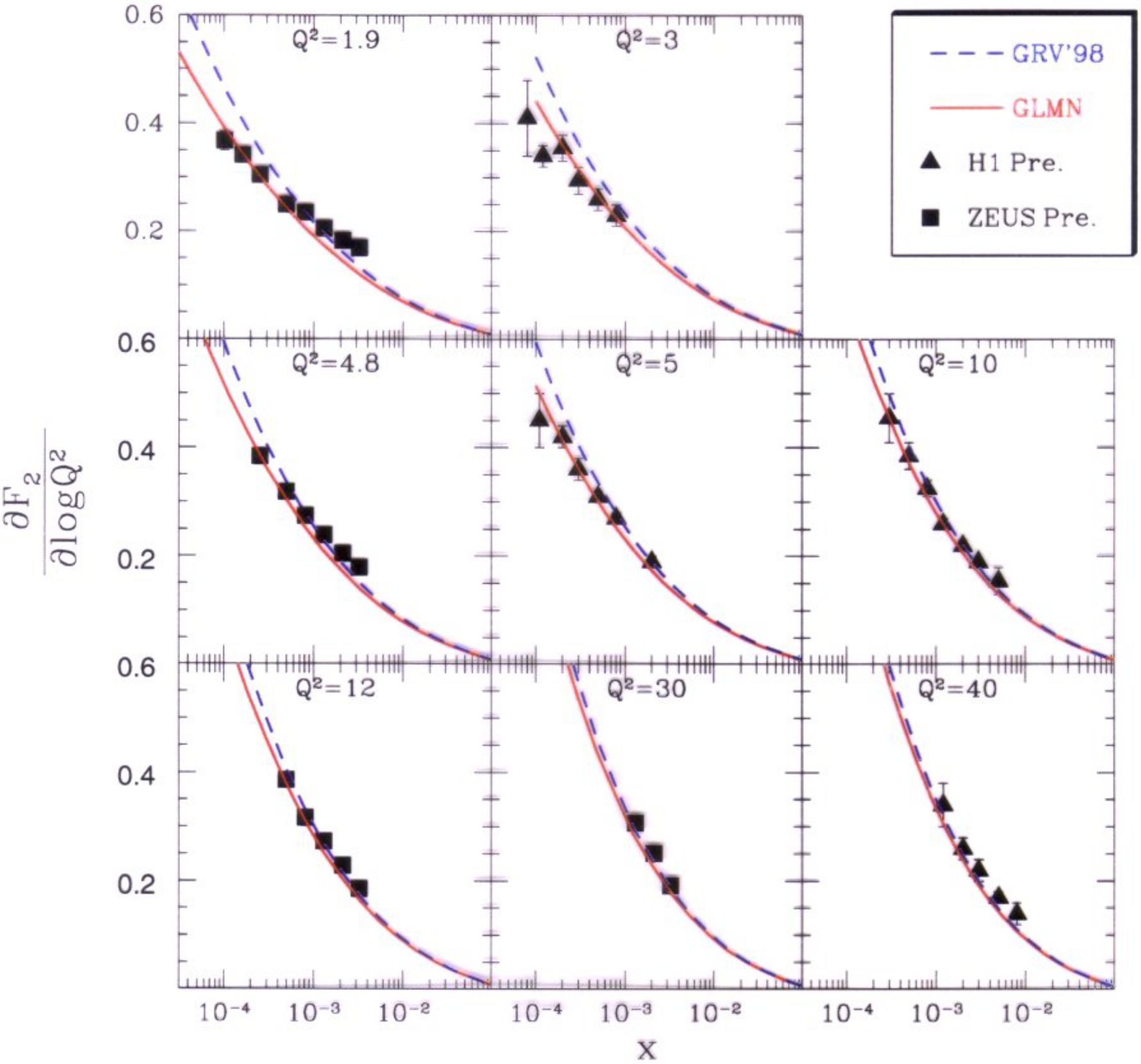


Using DGLAP at small x_B we arrive at the following constrain (valid in double logarithmic approximation):

$$xG^{DGLAP}(x, Q^2) \;<\; \frac{2}{\pi\, N_c\, \alpha_S(Q^2)}\, Q^2\, R^2 \;.$$

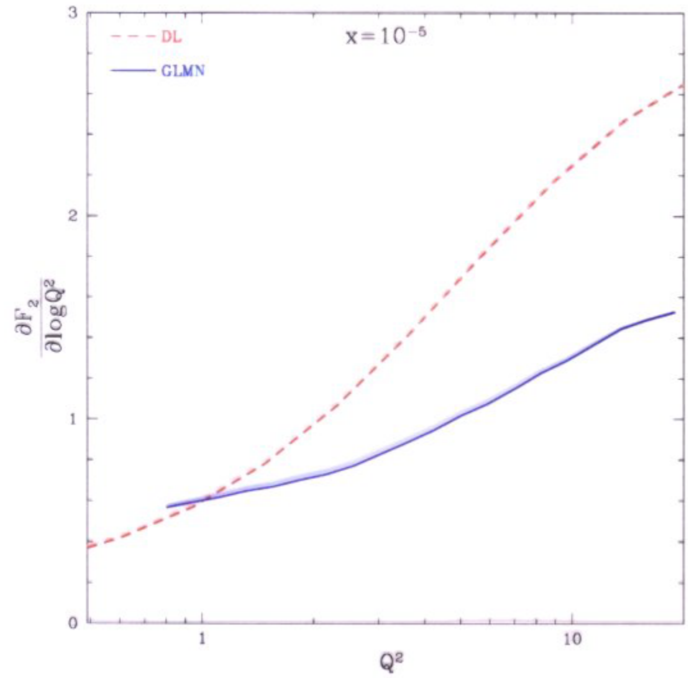


ii. F_2 slope vs HERA data.



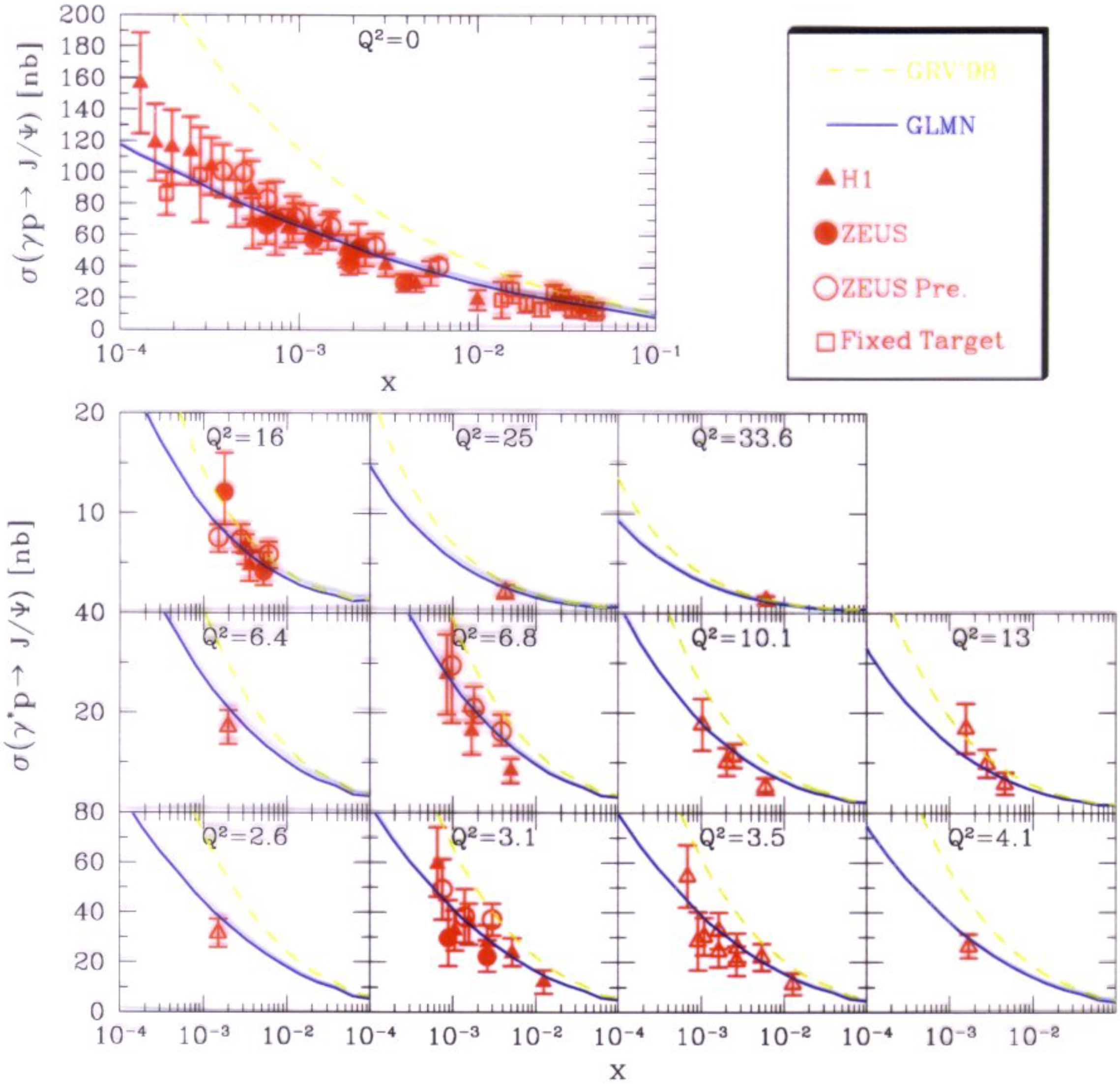
F_2-slope in GRV'98 and in our model with GRV'98 input for gluon structure function (H1 data). The picture for GRV'94 is similar. Neither parameterization of data satisfying DGLAP equation can reproduce the experimental data, while our model for inclusion of SC does this. Note, however, that the Donnachie-Landshoff model describes the data well also.

Prediction for F_2 slope



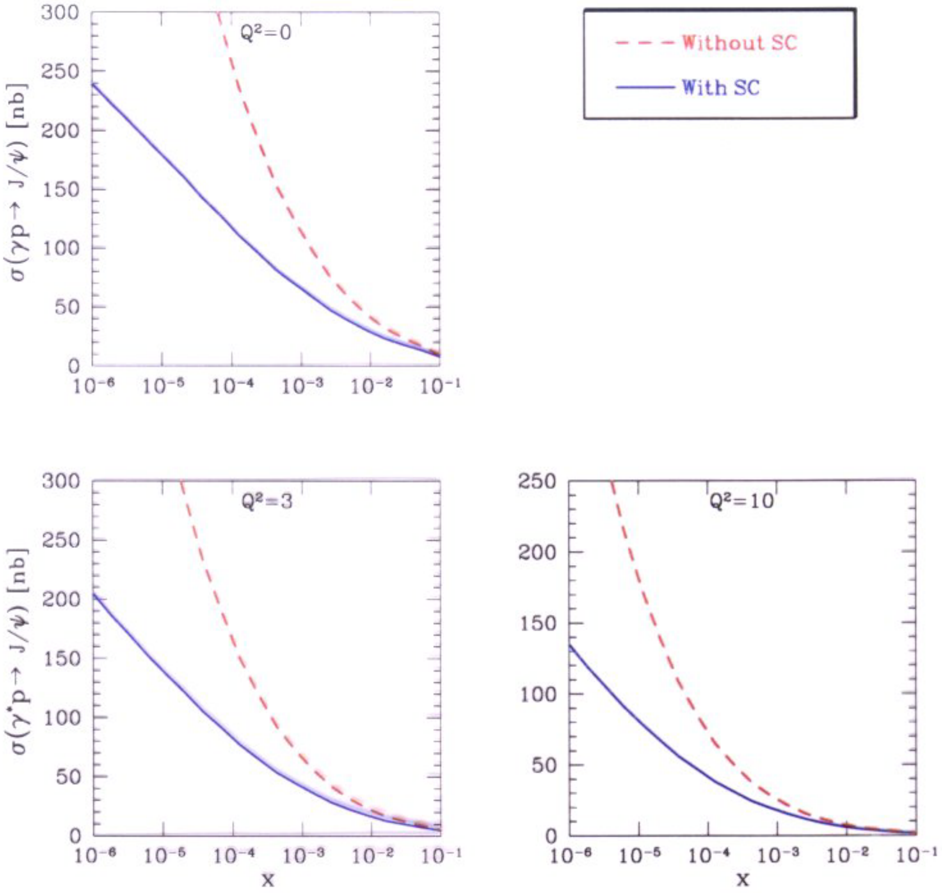
The prediction for the F_2-slope in our approach and in Donnachie-Landshoff approach

iii. Energy dependence of J/Ψ production.



The energy behaviour of the exclusive vector meson production, especially, J/Ψ-production is very discriminating with respect to SC. We believe that at the moment there is no parameterization of the DGLAP evolution equation which is able to describe simultaneously the F_2-slope and the energy dependence of the J/Ψ photo production where a huge amount of data has been accumulated.

J/Ψ production: Prediction.



The difference between our predictions and the DGLAP increases in the THERA kinematic region, which allow to conclude that we will see gluon saturation at THERA.

Conclusions

In our opinion **HERA has reached a high density QCD domain** because:

I HERA data display a large value of the gluon structure function;

II no contradictions with the asymptotic predictions of high density QCD have been observed;

III the numerical estimates of our model give a natural description of the size of the deviation from the usual DGLAP explanation.

Why we need THERA?

At THERA we investigate the kinematical region of such large energies that saturation effects become measurable:

I $\frac{\partial F_2}{\partial \ln Q^2}$ can reach the unitarity boundary;

II There is a clear differentiation between predictions for the Q^2 dependence of the F_2 slope of our model based on the existence of the saturation scale and the alternative ones which have no such scale;

III For the x_B dependence of the cross section for J/Ψ production, SC corrections give very large contribution as compared to the DGLAP approach;

IV It will be possible to extract the saturation scale from the ratios of the structure functions, in particular from F_L^D / F_T^D.