Saturation at the LHeC

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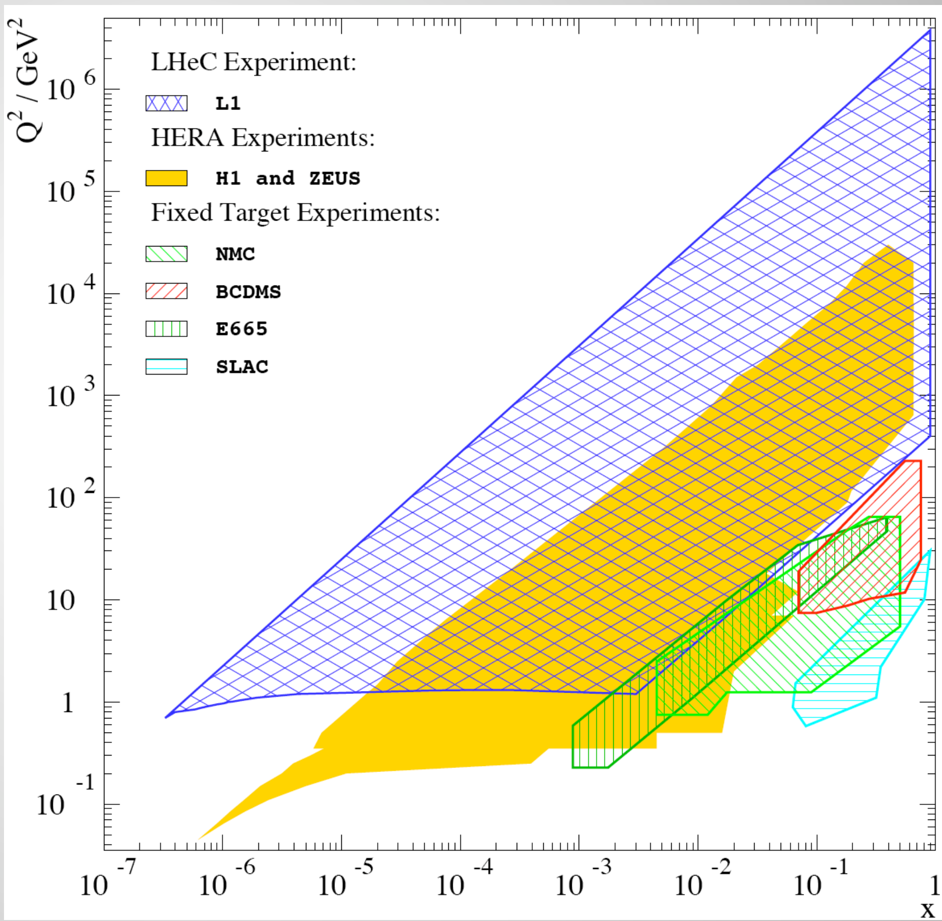
LHeC

70 GeV electrons in the LHC tunnel

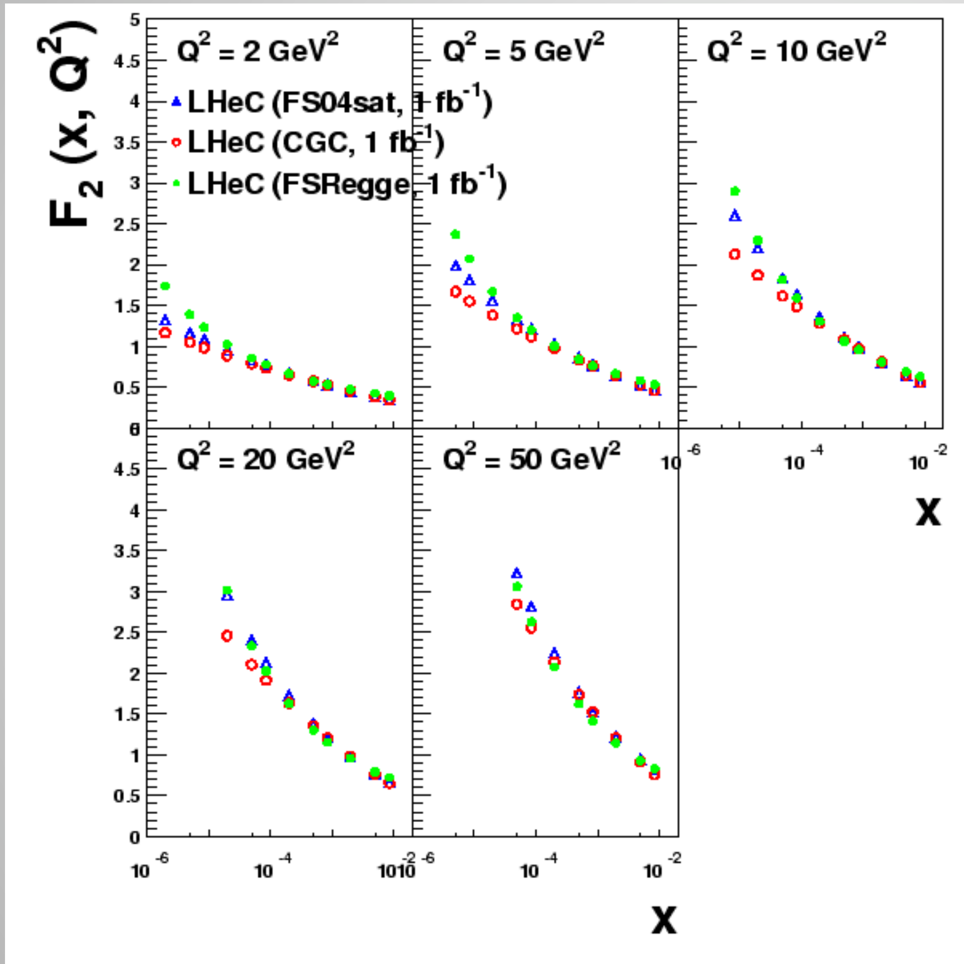
7 TeV protons

10^{33} $cm^{-2}s^{-1}$ luminosity

A fantastic opportunity to explore very low *x* dynamics at moderate Q^2



What can be done with F_2?



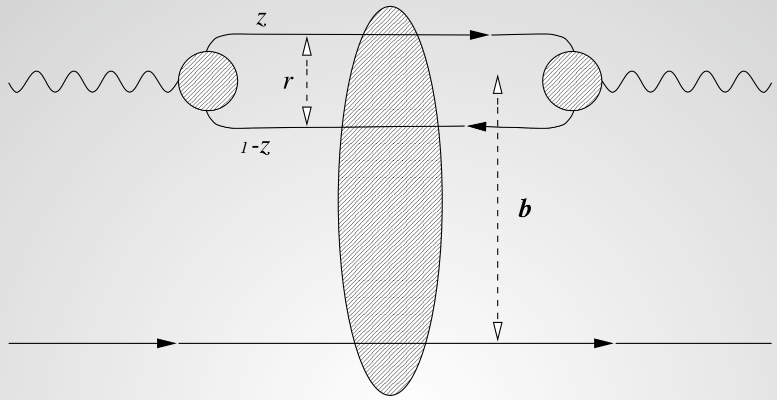
Three fits to HERA data, extrapolated to LHeC.

First glance looks very promising….

Systematics 1-3%

1 fb^{-1} of data ~ 1 year

Dipole model



$$\sigma_{\gamma^* p}^{L,T} = \int dz\, d^2 r\, |\psi_{L,T}(z,r)|^2 \sigma(s^*, r)$$

$$\sigma(s^*, r) \sim \alpha_s \frac{\pi^2 r^2}{3}\, xg(x, A^2/r^2)$$

Universal dipole cross-section:

- F_2 (and charm, beauty)
- F_L
- Diffractive DIS (high mass?)
- DVCS
- Exclusive vector mesons (meson wavefunction?)

Regge inspired dipole: FS04 no sat

Only dipoles with $r < r_0$ scatter with a $\sim x^{-0.3}$ cross-section. Larger dipoles scatter with a weaker $\sim x^{-0.07}$ cross-section.

No saturation: r_0 is constant.

Saturation dipole I: FS04 sat

Only dipoles with $r < r_s$ scatter with a $\sim x^{-0.3}$ cross-section. Larger dipoles scatter with a weaker $\sim x^{-0.06}$ cross-section.

Saturation: r_s decreases with decreasing *x.*

JF & Shaw: JHEP 0412:052 (2004).

Saturation dipole II: CGC

Dipoles with $r < r_s$ scatter with a ~ BFKL cross-section. Larger dipoles scatter with a constant cross-section.

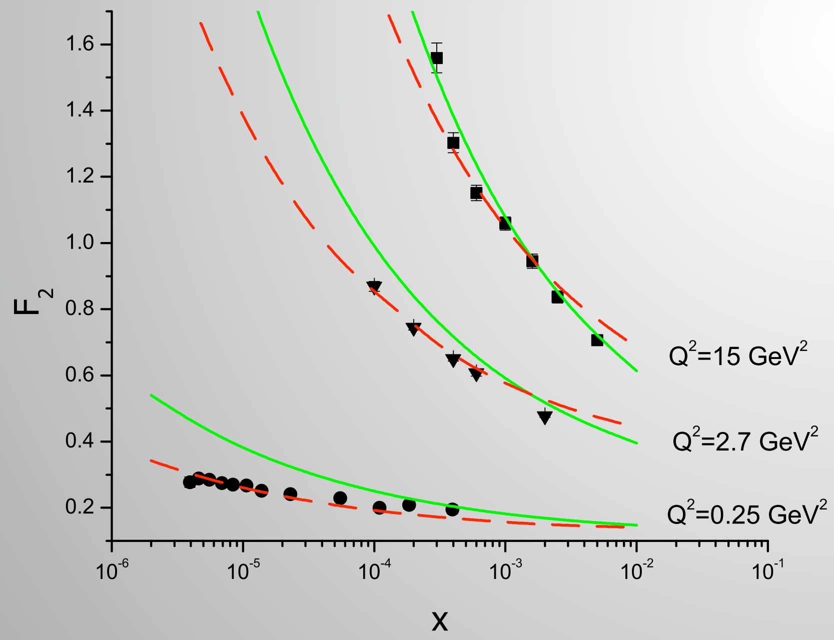
Saturation: r_s decreases with decreasing *x*

Iancu, Itakura, Munier: Phys.Lett.B590:199 (2004); Kowalski, Motyka, Watt: Phys.Rev.D74:074016 (2006).

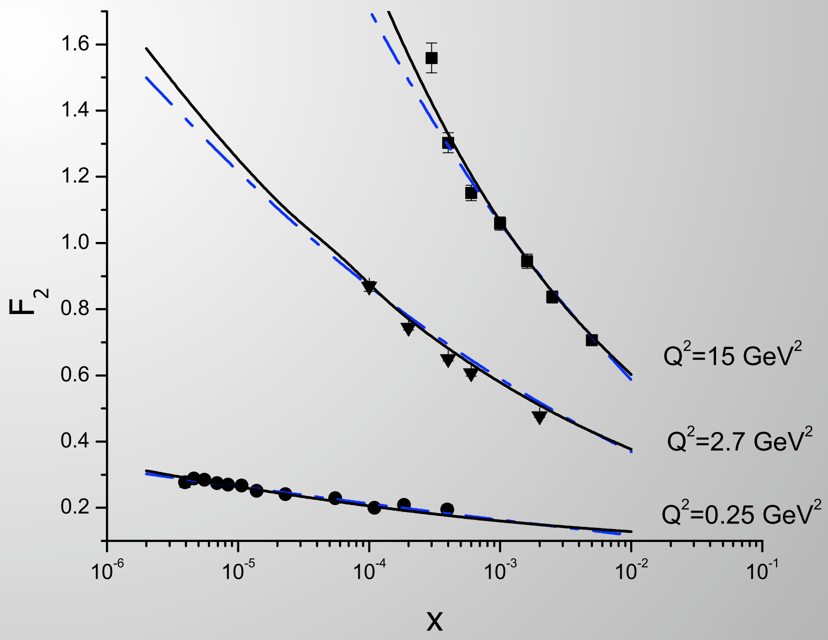
HERA data

- Some tentative evidence for saturation but it relies on F_2 data at Q^2 below 2 GeV^2. See also Kowalski, Motyka, Watt.

- All other data can be fitted using the Regge model or either of the saturation models.

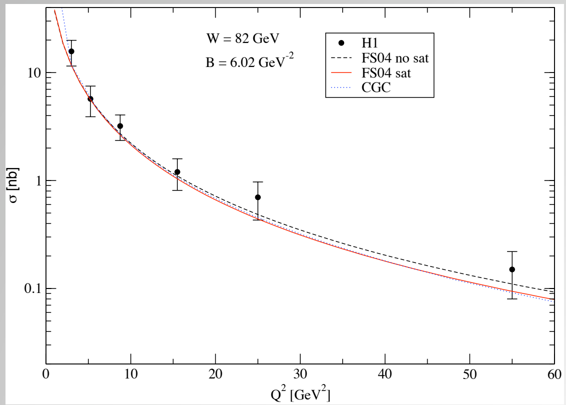


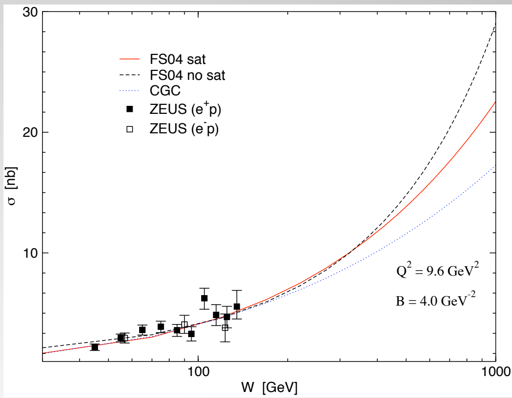
No saturation



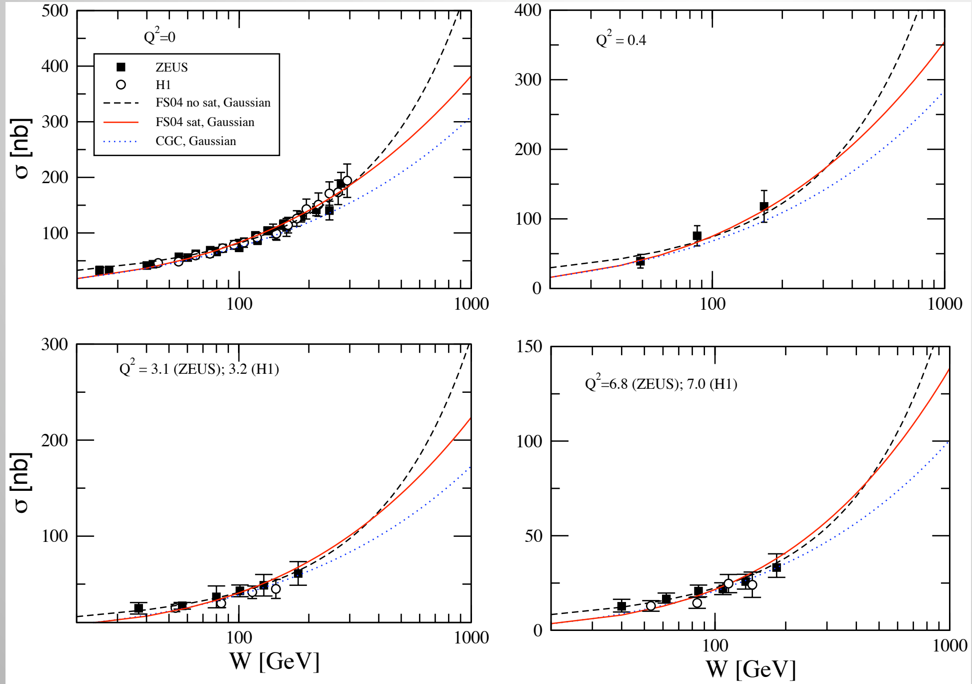
Saturation

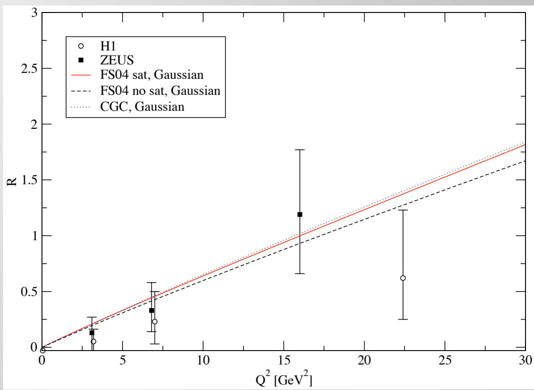
DVCS





J/Psi

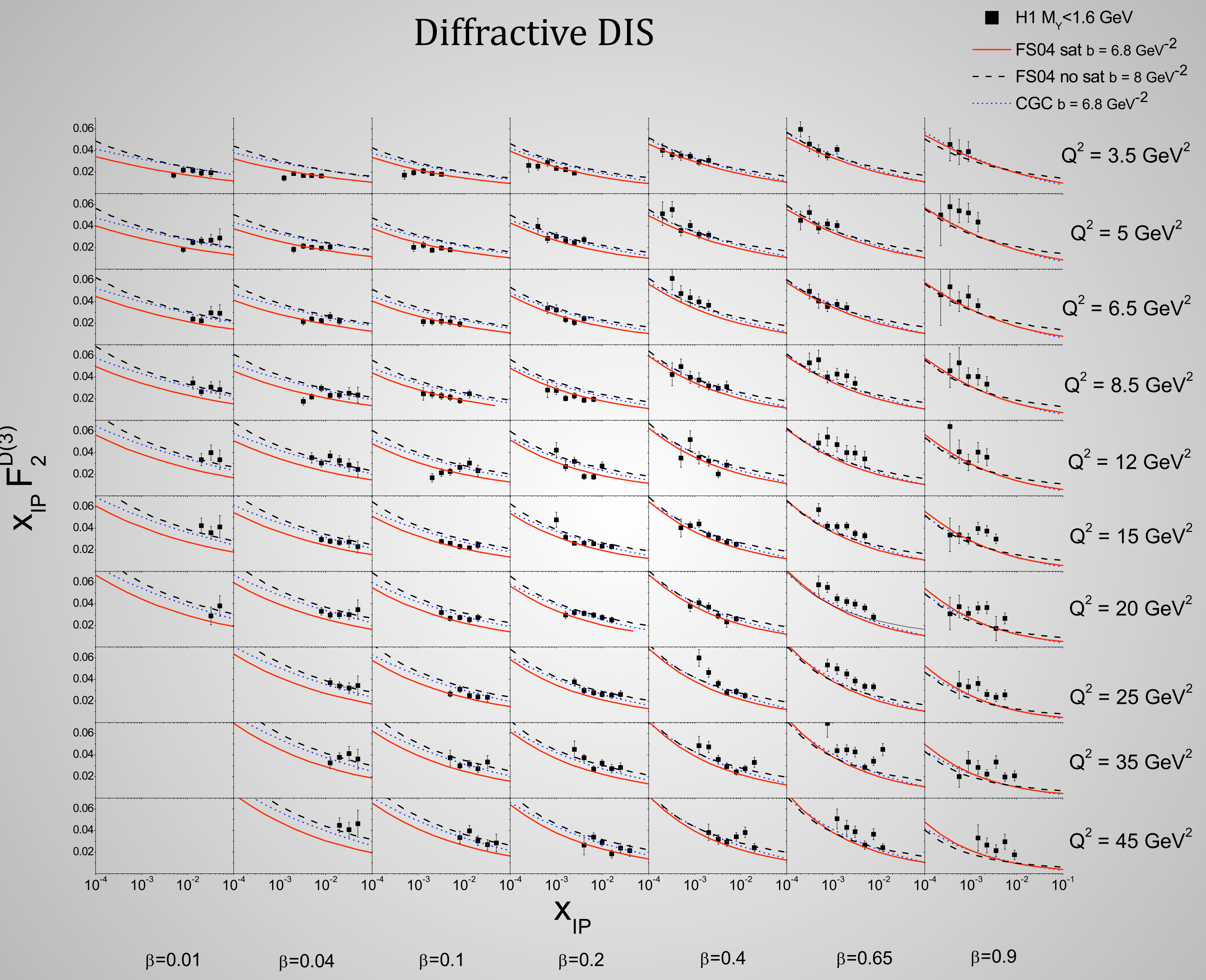




Also F_2^c

JF, Sandapen & Shaw: JHEP 0611:025 (2006)

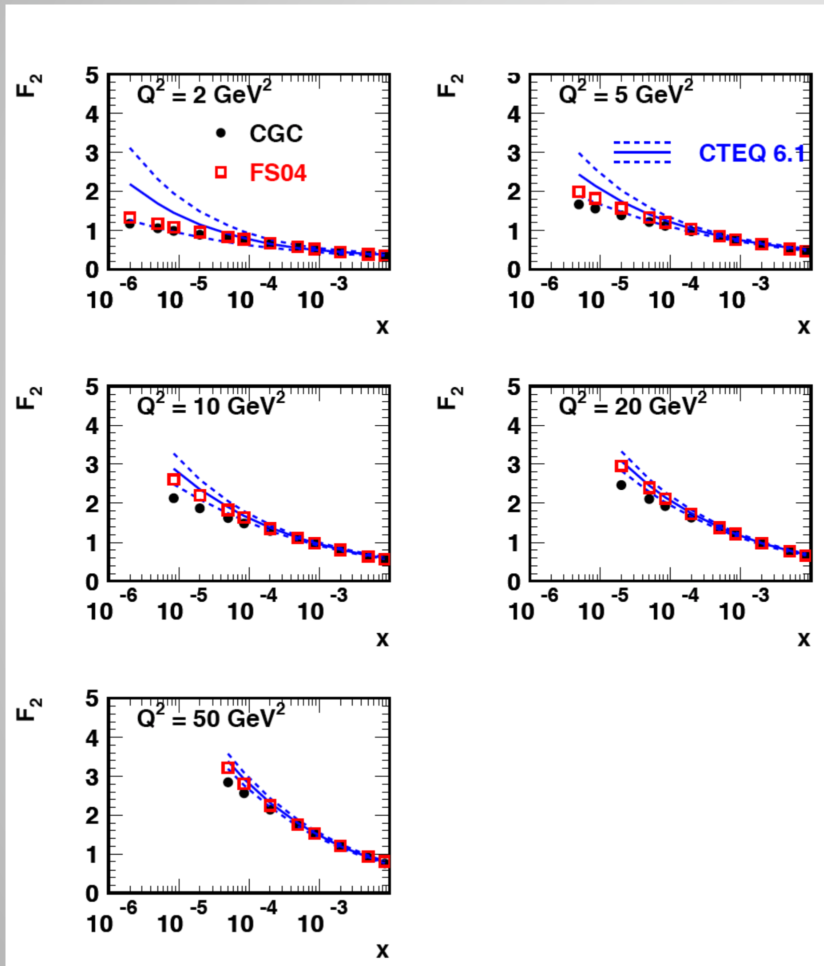
Diffractive DIS



Note 1: low beta region is theoretically uncertain

Note 2: theory does not include secondary exchanges relevant for xpom > 0.01

F_2 at LHeC



Can we see DGLAP fail at Q^2 > few GeV^2 ?

Can DGLAP be made to fit data which include saturation?

Curves: CTEQ 6.1 (extrapolated)

Points: Fake LHeC data using CGC & FS04 (1 fb^{-1})

But we should re-fit DGLAP before drawing conclusions:

$$
\begin{aligned}
x\bar{q}(x, Q_0) &= A_q x^{B_q} (1-x)^{C_q} \\
xg(x, Q_0) &= A_g (1 - \exp[-B_g \log^2((x_0/x)^\lambda)])(1-x)^{C_g}
\end{aligned}
$$

= Fit 6 parameters: $A_q, B_q, A_g, B_g, x_0, \lambda$ and C_g

= Use H1pdf2k for valence quarks and C_q

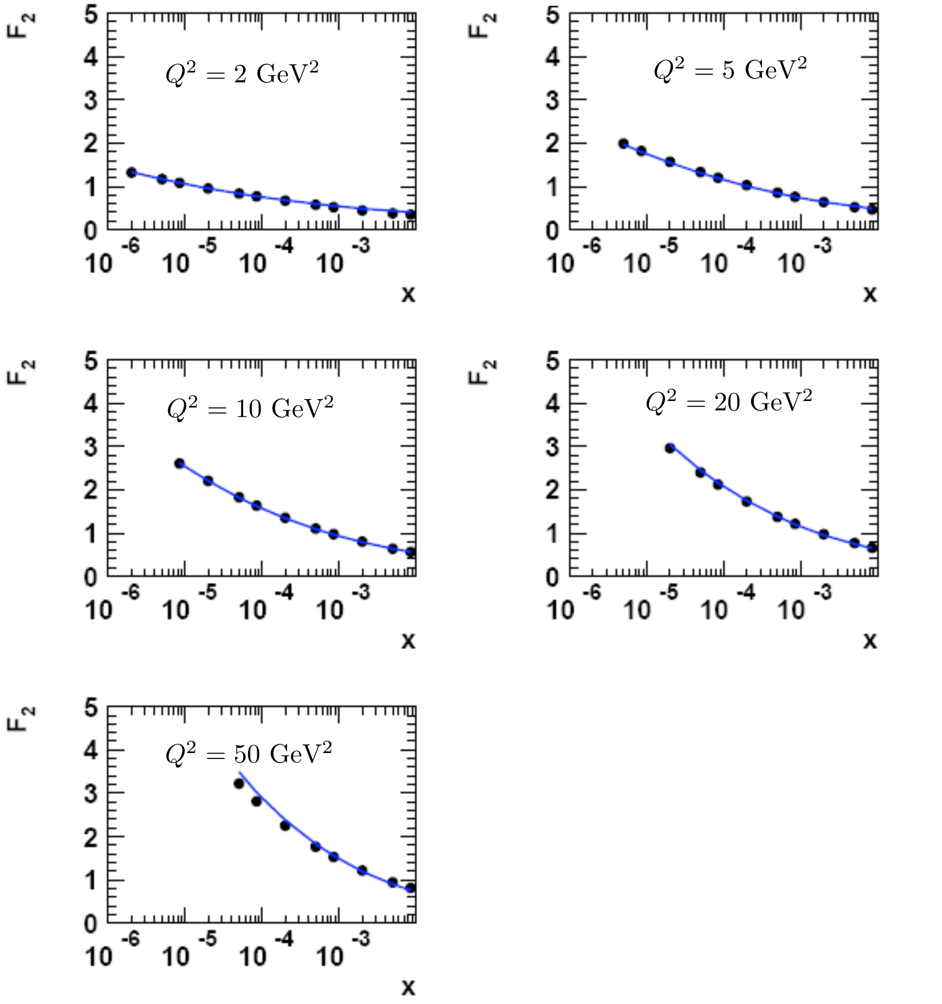
= NLO evolution ($\overline{MS}$)

= Fixed flavour number scheme $M_c = 1.4$ GeV and $M_b = 4.5$ GeV

= $\alpha_s(M_z) = 0.1185$ and $Q_0^2 = 1.9\ \text{GeV}^2$

Fitting the FS04 LHeC "data" + ZEUS data using DGLAP

FS04

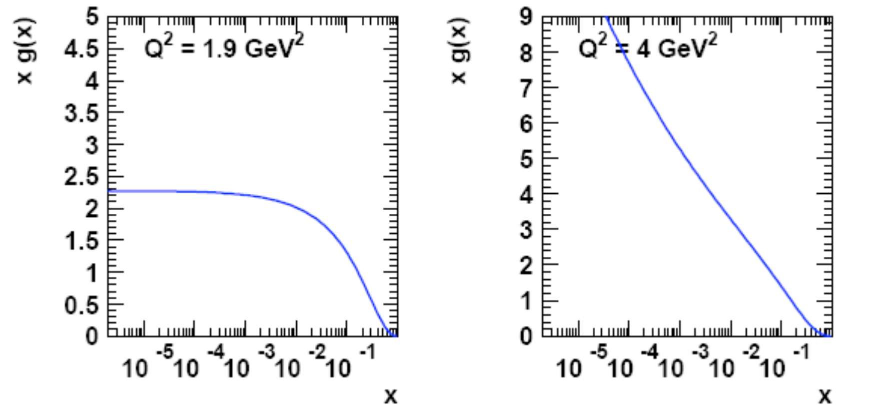


Fit is to data with $Q^2 \leq 20$ GeV^2
(χ^2 = 92 for 92 data points)

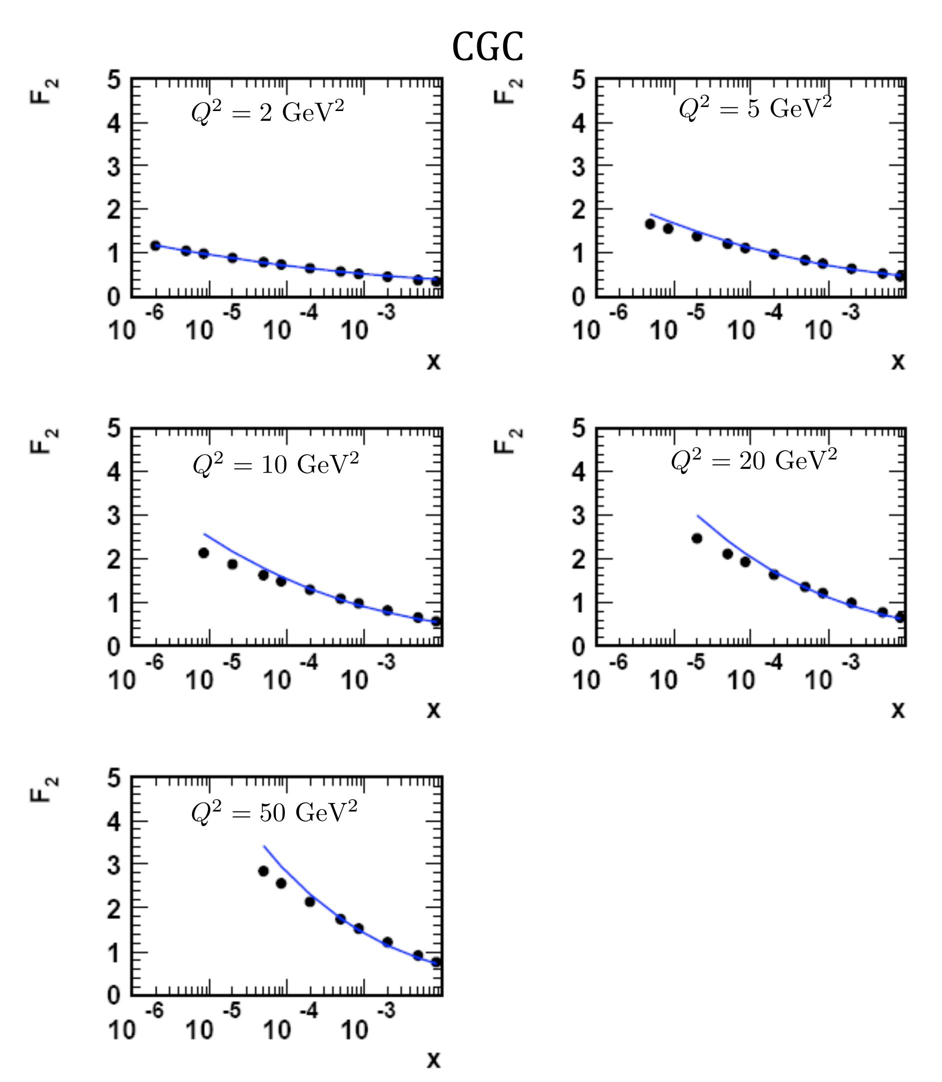
⇒ Consistent with what we saw extrapolating CTEQ

⇒ Only the 4 points at highest Q^2 and lowest x cause problems

Q^2 evolution of FS04 and CGC is an extrapolation of the fit to HERA data.



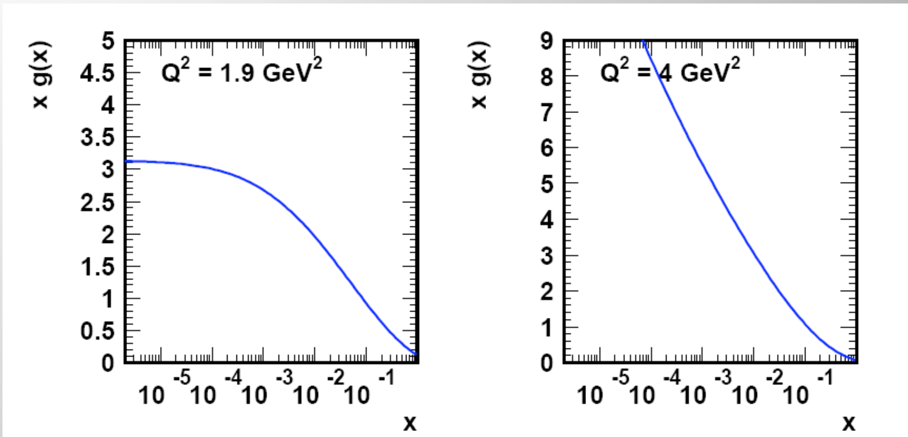
Fitting the CGC LHeC "data" + ZEUS data using DGLAP



Fit is to data with $Q^2 \leq 3$ GeV^2
(χ^2 = 10.5 for 14 data points)

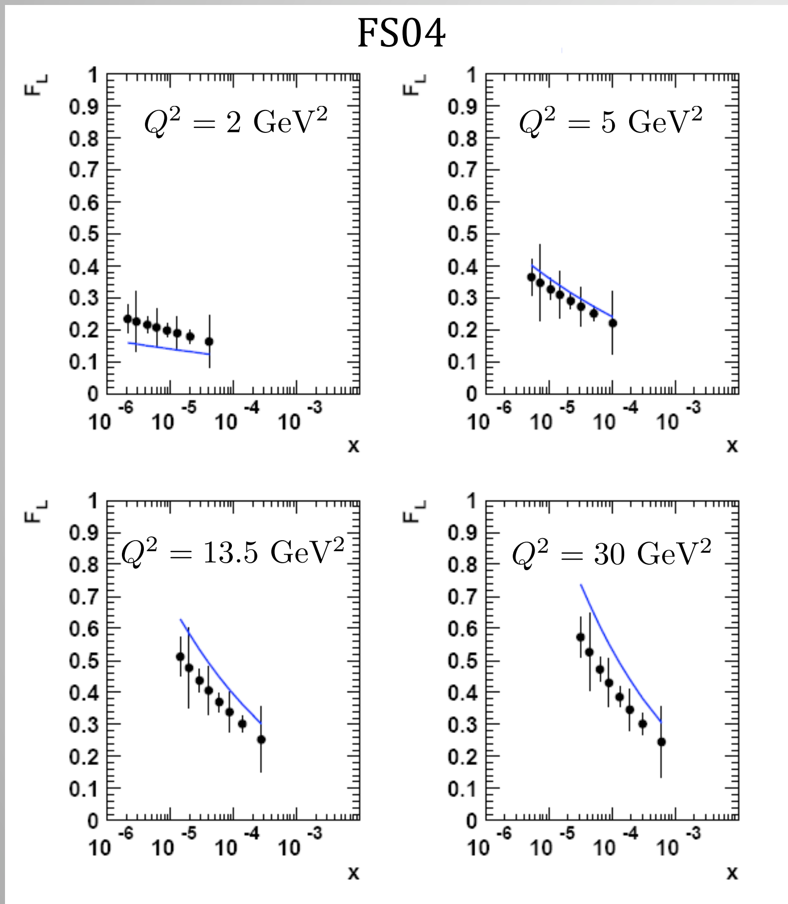
⇒ Consistent with what we saw extrapolating CTEQ

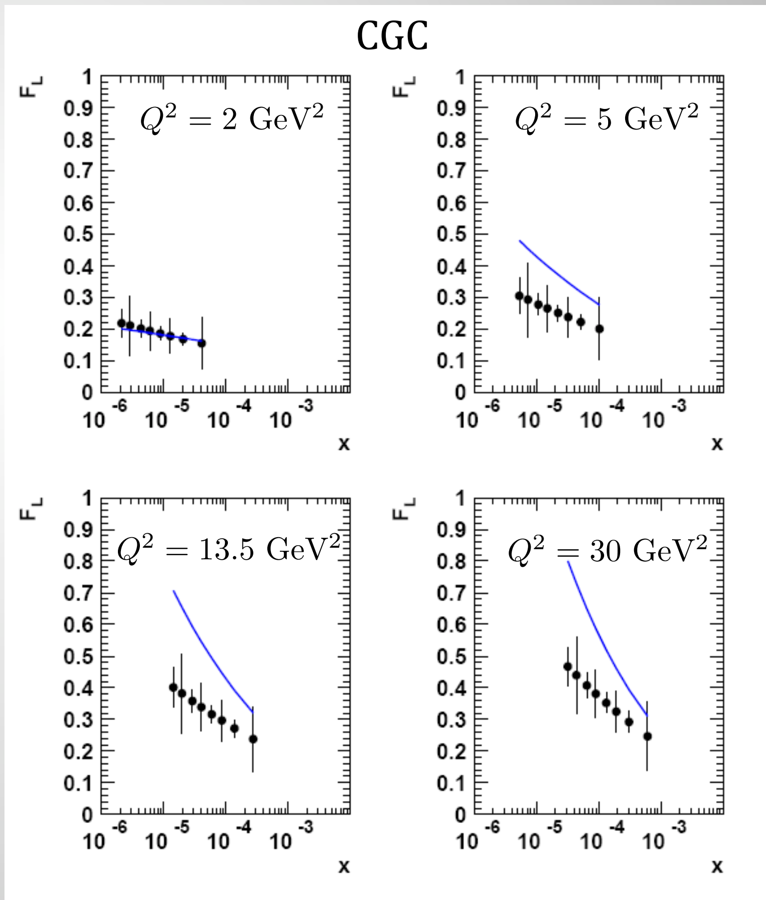
⇒ Cannot fit evolved data



F_L at LHeC

Varying proton beam energy from 7 TeV down to 450 GeV (or 1 TeV)



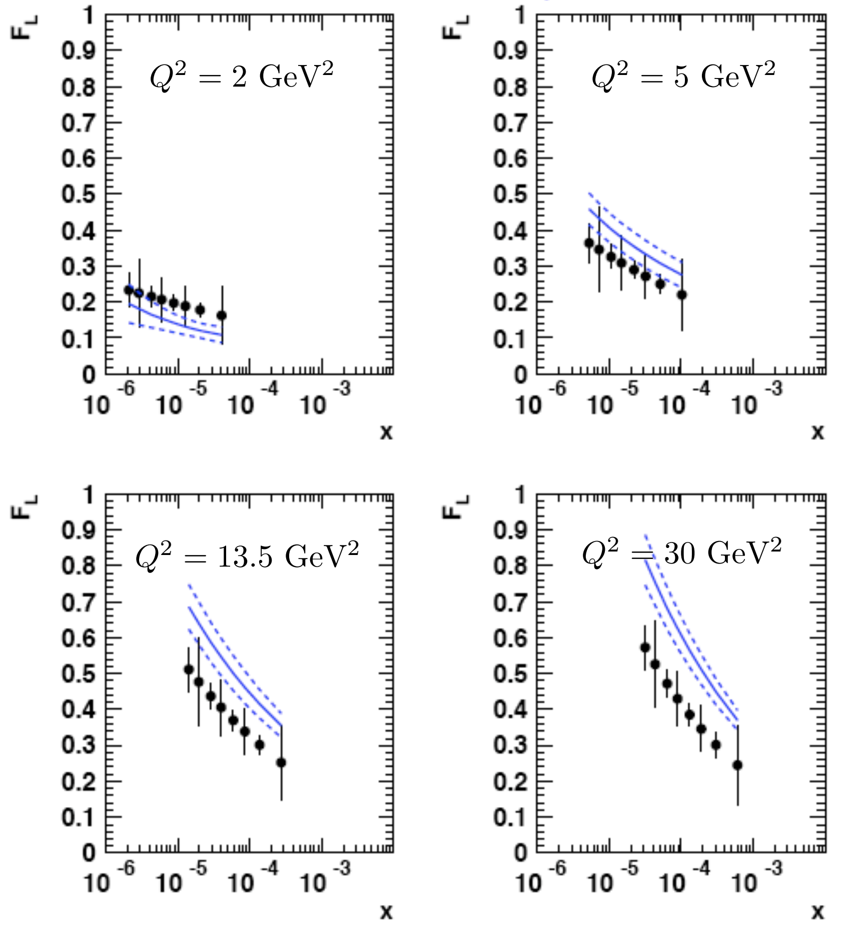


FS04 fitted to $Q^2 \leq 20$ GeV^2: F_2 and F_L

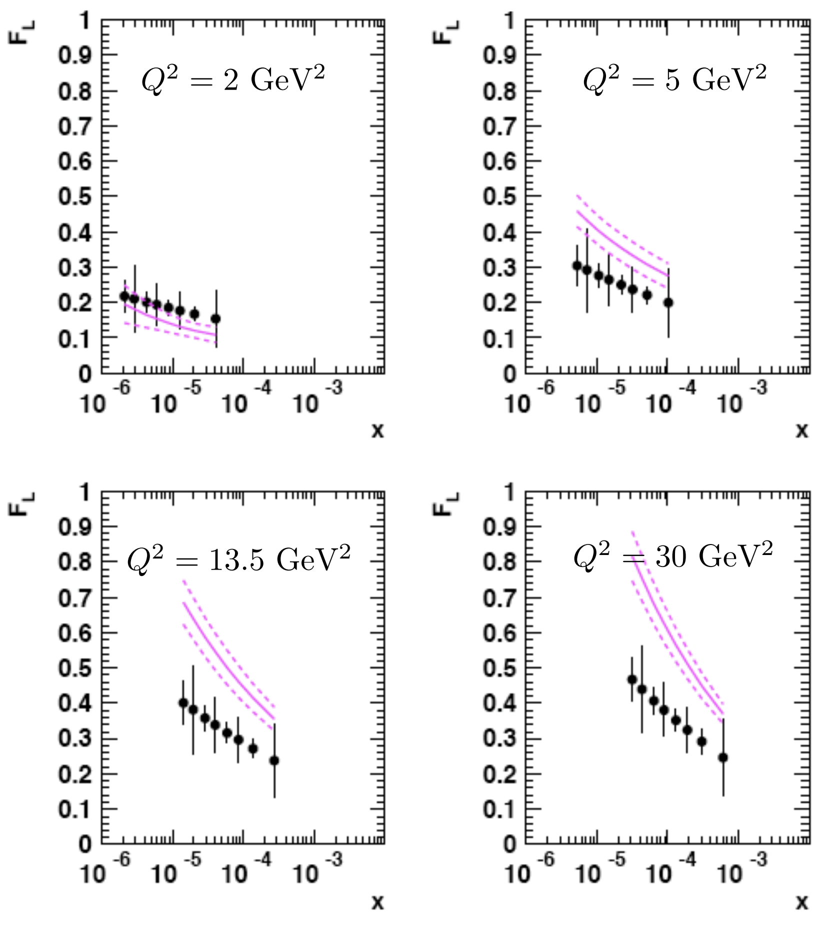
CGC fitted to $Q^2 \leq 3$ GeV^2: F_2 and F_L

Curves are the "predictions" after extrapolating CTEQ

FS04



CGC



Conclusions

- Saturation effects may well be present in HERA data but there is no evidence within the perturbative domain.
- Saturation models which fit the HERA data lead to predictions for LHeC which cannot be "faked" by DGLAP evolution.
- It would be very important to measure the longitudinal structure function.
- Other observables would also provide a handle: heavy quark structure functions, DVCS, exclusive vector mesons, diffractive deep inelastic scattering.