COLOUR DIPOLE PHENOMENOLOGY

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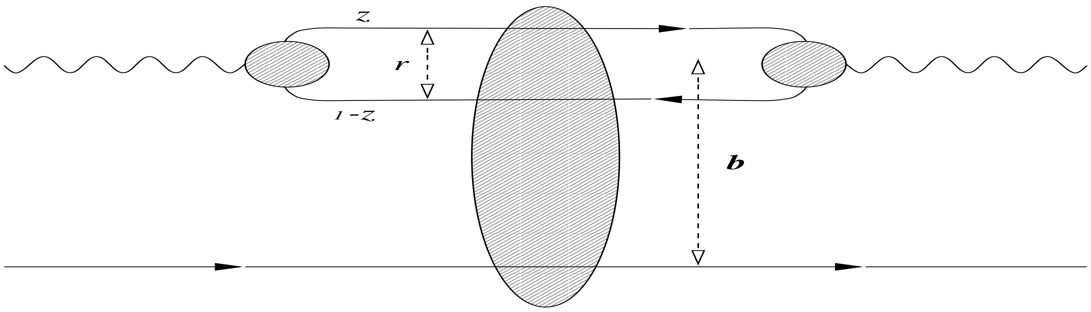
COLOUR DIPOLE PHENOMENOLOGY

- The colour dipole picture
- Evidence for saturation?
- Predictions for DDIS
- Predictions for DVCS
- Conclusions

I : The Dipole Picture

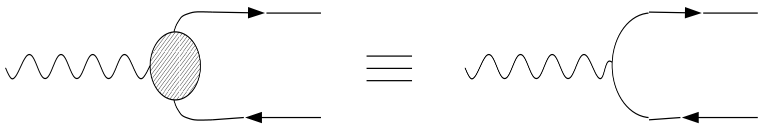


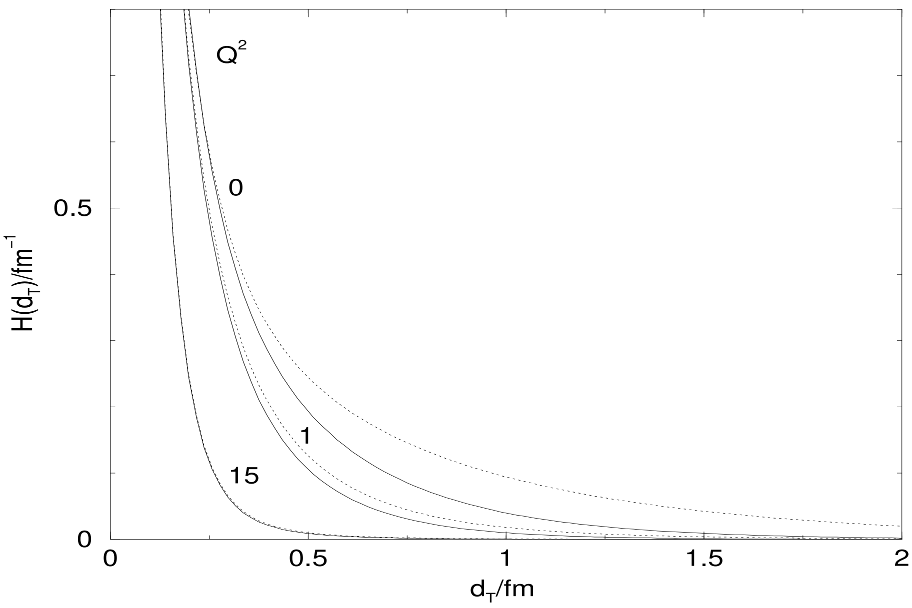
$$\sigma_{\gamma^* p}^{T,L} = \int \mathrm{d}z \mathrm{d}^2 r \; |\psi_\gamma^{T,L}(z,r,Q^2)|^2 \sigma(x,r,z)$$

- $z \equiv$ fractional light-cone energy
- $|z,r\rangle$ are eigenstates of the scattering matrix
- $\psi(z,r,Q^2)$ is the light cone wave function
- $\sigma(x,r,z)$ is the dipole cross-section.

The photon wavefunction

Use perturbative form



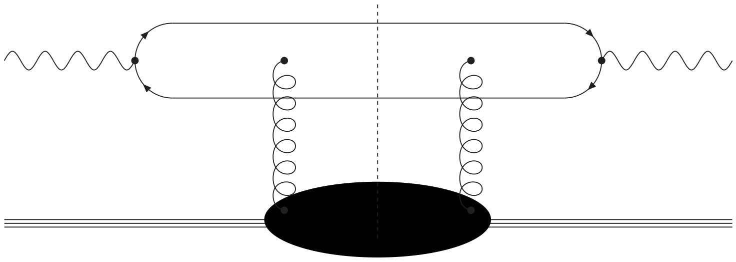


The DIS weight function $H(r, Q^2) \propto \int \mathrm{d}z |\psi(z, r, Q^2)|^2$.
$m_q^2 = 0.08$ (solid lines) and $m_q^2 = 0.02$ (dotted lines)

Treat m_q^2 as empirical parameter to parameterize the unknown large r behaviour.

The dipole cross-section

Small r : perturbative



At leading order

$$\sigma(r,x) = \frac{\pi^2 r^2}{3} \alpha_s x g(x, Q^2)$$

DGLAP $\rightarrow$ rapid rise as $x \rightarrow 0$.

Regge $\sigma \approx A_H r^2 x^{-\lambda_H}$ as $x \rightarrow 0$.

BUT - expect it to saturate by gluon recombination/unitarity effects at high s or at low-x(fixed Q^2).

I Make models, for example:

G-BW saturation model, 1999*

FKS Regge dipole model, 1999†

Colour Glass Condensate(CGC) model, 2004 ‡

II FIT parameters to DIS data:

$$0.045\text{GeV}^2 < Q^2 < 45\text{GeV}^2 \quad x < 0.01$$

III PREDICT results for DDIS, DVCS,... data

*K. Golec-Biernat and M. Wüsthoff, Phys. Rev **D59** (1999) 014017

†J. R Forshaw, G. Kerley and G. Shaw, Phys. Rev. **D60**, 074012 (1999)

‡E. Iancu, K Itakura, S. Munier, P.L. **B590** (2004)199.

II EVIDENCE FOR SATURATION?

Fits to $F_2(x, Q^2)$ data*

FS2004 Regge Fit

We find old FKS parameterization doesn't work very well - better fit with

$$\sigma = A_H r^2 x^{-\lambda_H} \qquad r < r_0$$

$$\sigma = A_S x^{-\lambda_S} \qquad r > r_1$$

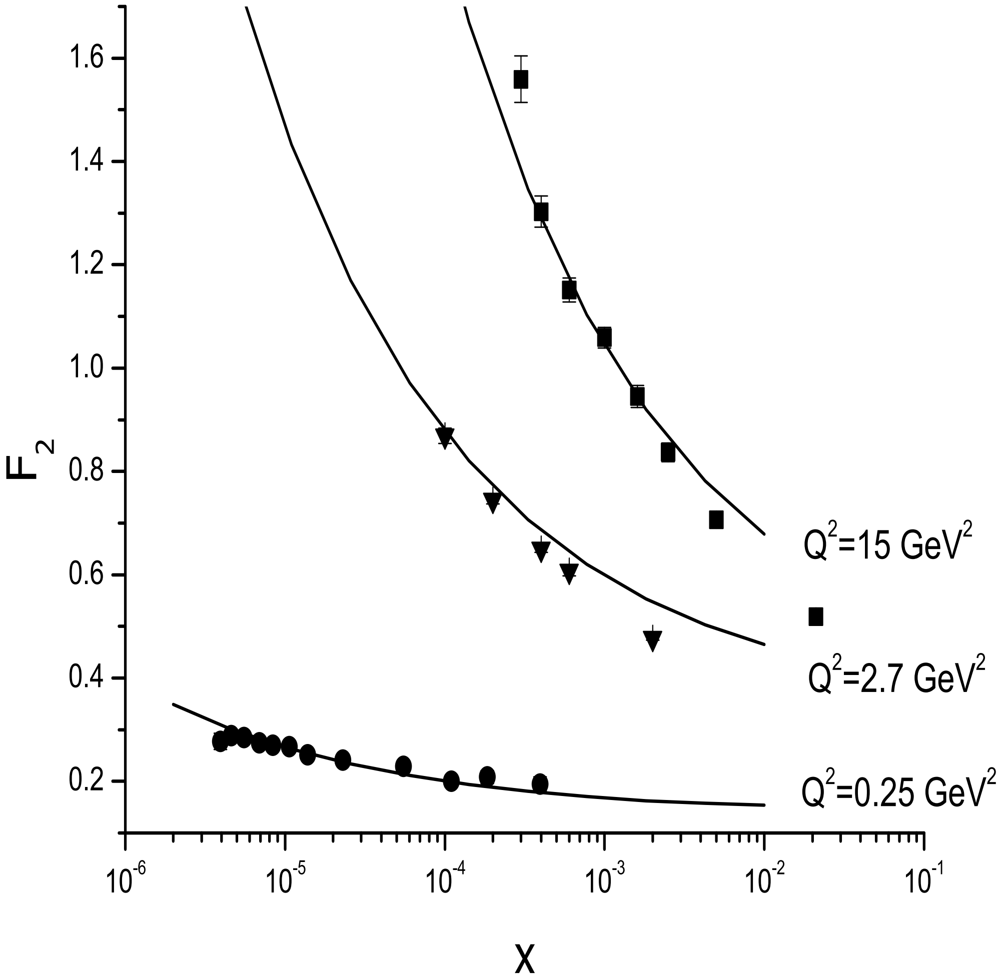
Linear interpolation $\qquad r_0 < r < r_1$

If r_0, r_1 are independent of x, this is an unsaturated model of "Regge form"

$$\sigma(r, x) = a_s(r) x^{-\lambda_S} + a_H(r) x^{-\lambda_H}$$

*J. R Forshaw and G. Shaw, JHEP 0412 (2004) 052

Best fit to precise HERA F_2 Data



Parameters very reasonable, but $\chi^2/d.o.f \approx 1.7$.

Problem - to fit, need steeper energy dependence at high x without changinging it much at smaller x - suggests saturation!

FS2004 saturation fit

Same parameterization

$$\sigma_H = A_H \, r^2 x^{-\lambda_H} \qquad\qquad r < r_0$$

$$\sigma_S = A_S \, x^{-\lambda_S} \qquad\qquad r > r_1$$

$$\text{Linear interpolation} \qquad\qquad r_0 < r < r_1$$

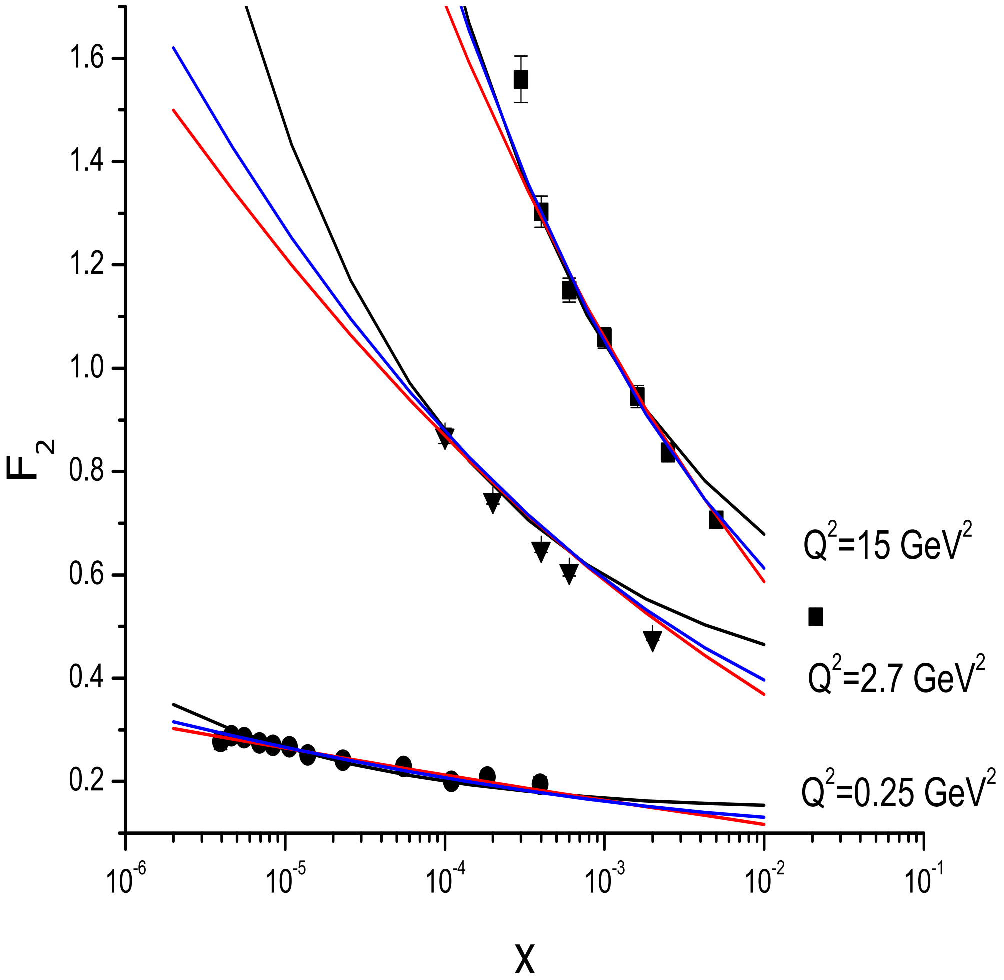
but now build in saturation by fixing r_0 by*

$$\frac{\sigma_S(r_0)}{\sigma_H(r_1)} = f \ .$$

Same number of parameters as unsaturated model

*Compare Frankfurt, Guzey, McDermott, Strikman 99

Saturation and Regge Fits: HERA F_2 Data



The FS2004 Regge fit(black line), the FS2004 saturation fit(blue line) and the CGC fit(red line). The last two both have $\chi^2/d.o.f \approx 1.0$

- For DIS data in the range

$$0.045\text{GeV}^2 < Q^2 < 45\text{GeV}^2 \quad x < 0.01$$

the CGC and FS2004 saturation fits are are satisfactory and much better than the unsaturated Regge fits

- BUT for DIS data in the range

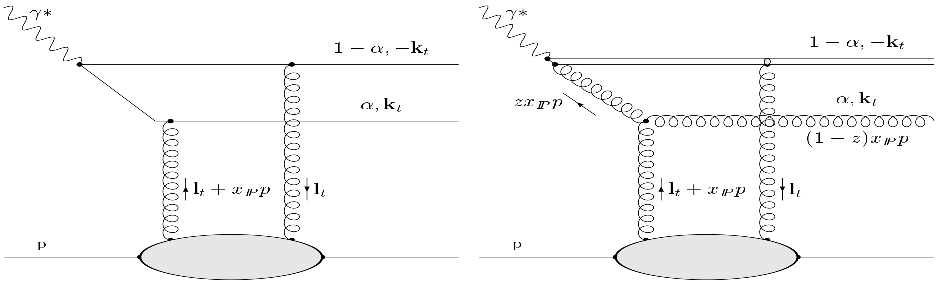
$$1\text{GeV}^2 < Q^2 < 45\text{GeV}^2 \quad x < 0.01$$

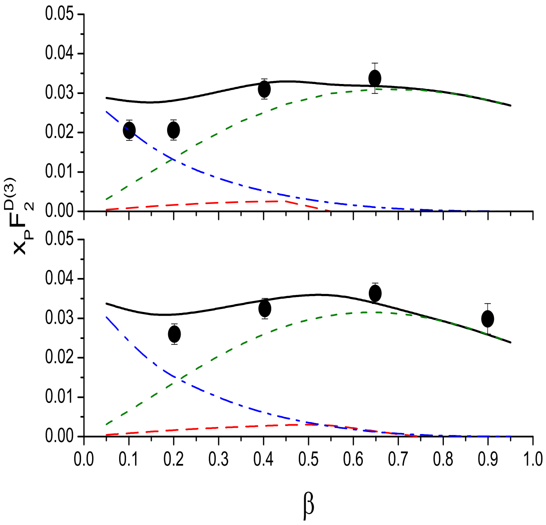
all three fits are satisfactory.

- The conclusion rests on the model correctly separating large and small dipole contributions in the low Q^2 region.

III : Open Diffraction(DDIS)

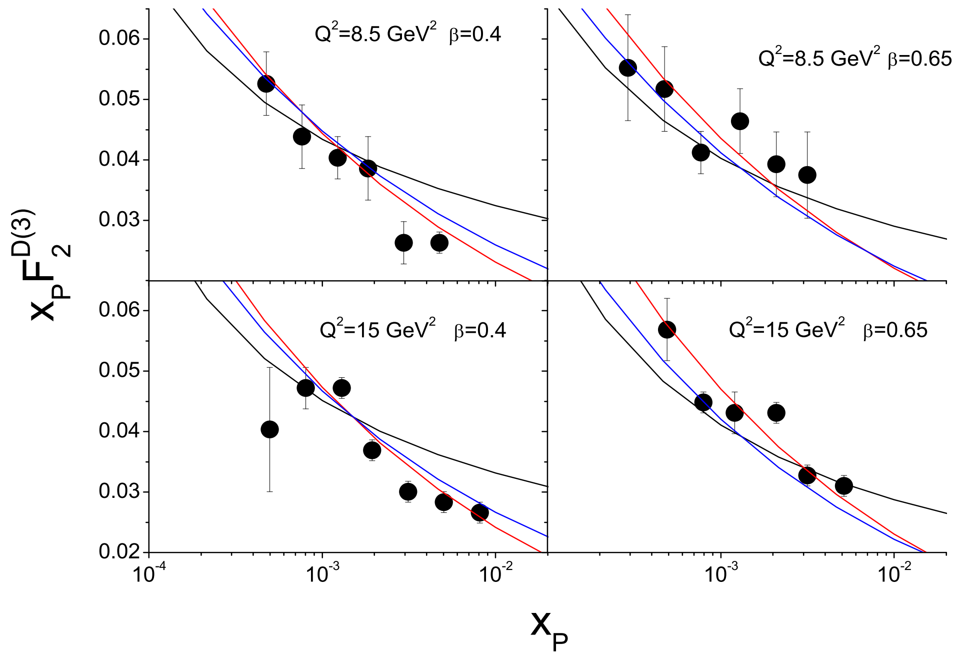
$$\gamma^* + p \to X + P$$





Contributions to $F_2^{D(3)}$ calculated using the CGC model: total (solid blackline); light $q\bar{q}$ (dashed green line); $q\bar{q}g$ (dash-dot blue line); $c\bar{c}$ (dashed red line). (Preliminary H1 data)

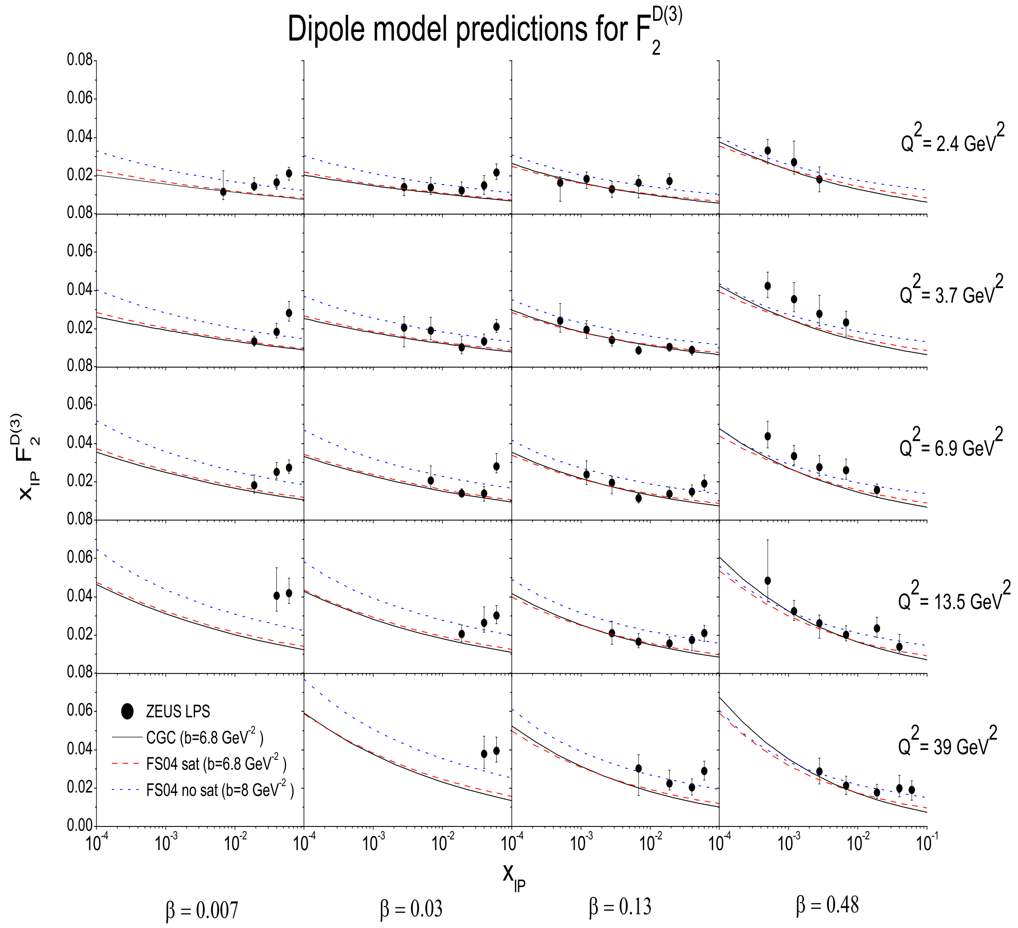
Predictions for the preliminary H1 Data*



The predictions from the FS2004 Regge fit (black line), the FS2004 saturated fit (blue line) and the CGC fit(red line), for kinematic values which are not very sensitive to the qqg contribution or the large r wavefunction.

*J. R Forshaw and G. Shaw, JHEP 0412 (2004) 052

Predictions for the ZEUS LPS data

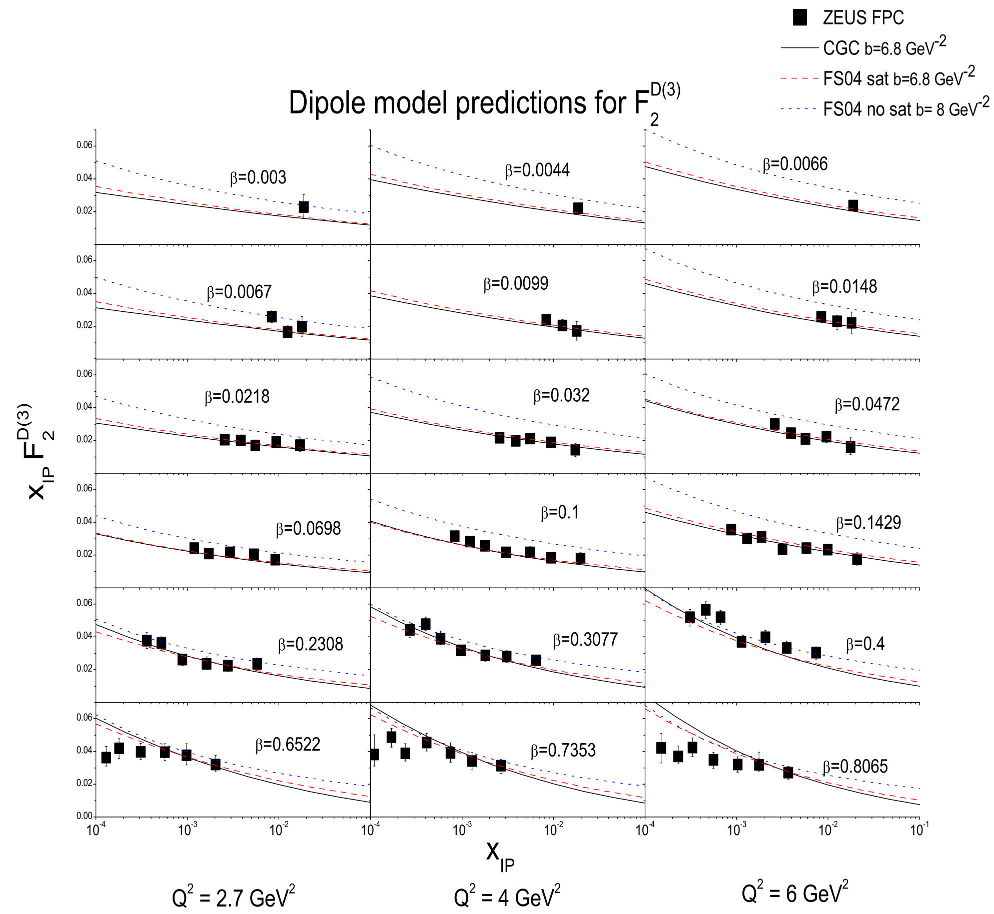


J.R. Forshaw & G. Shaw, JHEP 0412:052 (2004), hep-ph/0411337

The predictions of the FS2004 Regge fit (dotted blue line), the FS2004 saturation fit (dashed red line) and the CGC fit (solid line).*

*J.Forshaw and G.Shaw, to be published.

Predictions for ZEUS FPC data - low Q^2

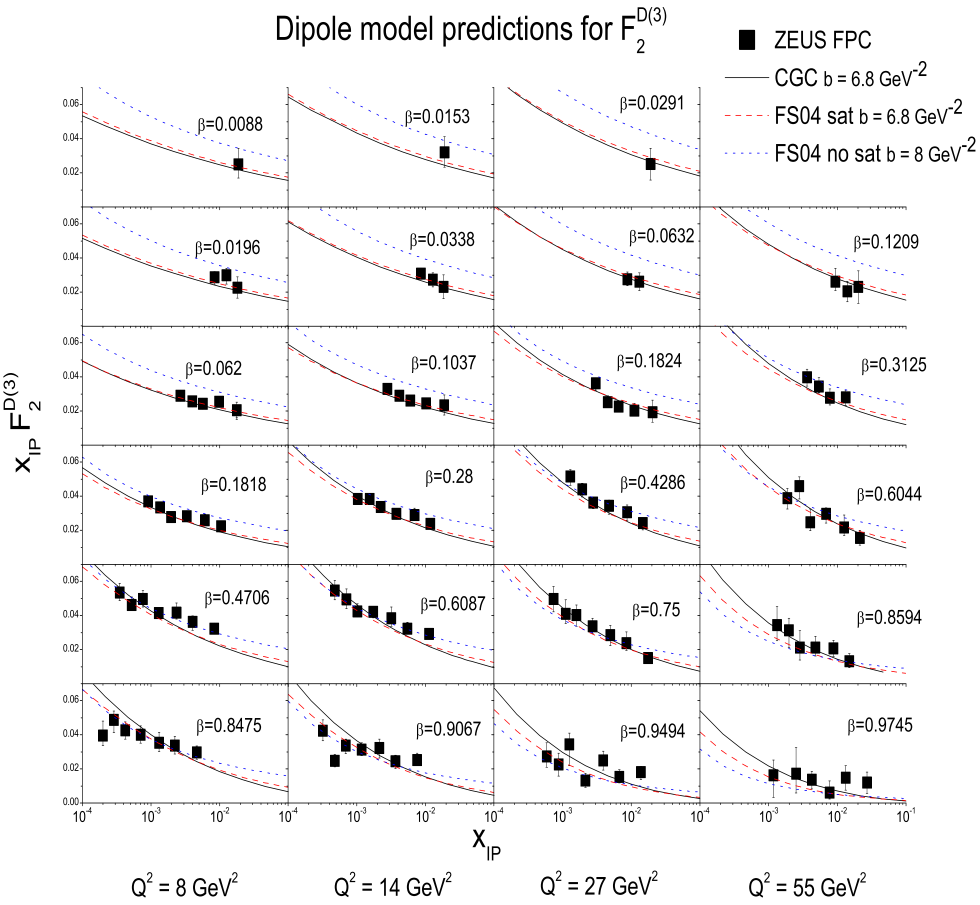


Note: theory curves are divided by 0.7 to estimate the contribution from proton dissociation (M_Y< 2.3 GeV)

The predictions of the FS2004 Regge fit (dotted blue line), the FS2004 saturation fit (dashed red line) and the CGC fit (solid line).*

*J.Forshaw and G.Shaw, to be published.

Predictions for the ZEUS FPC data - high Q^2



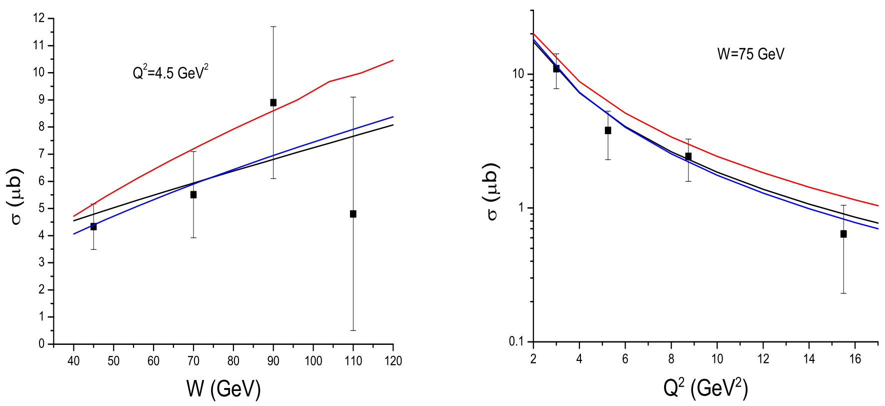
Note: theory curves are divided by 0.7 to estimate the contribution from proton dissociation (M_Y< 2.3 GeV)

The predictions of the FS2004 Regge fit (dotted blue line), the FS2004 saturation fit (dashed red line) and the CGC fit (solid line).*

*J.Forshaw and G.Shaw, to be published.

IV : DVCS

Predictions for HERA H1 Data



The predictions from the FS2004 Regge fit (black line), the FS2004 saturation fit (blue line) and the CGC fit (red line). The slope parameter $B = 7$ GeV^{-2}.*

*J.Forshaw and G.Shaw, to be published.

V CONCLUSIONS

- Within the context of the model, the DIS data on for $x < 0.01$ and $45 > Q^2 \geq 0.045$ GeV^2 shows clear evidence for saturation.

- The model successfully predicts DDIS and DVCS data without adjustment of dipole model parameters.

- There is lots of data to look at and learn from!