1) Total cross section:

$$\sigma_{tot}(\gamma^* p) = c\,(W^2)^{\lambda(Q^2)}$$

$Q^2 = 0$ | $Q^2 \neq 0$

"soft Pomeron" | transition | "hard Pomeron" = DGLAP

$\alpha_{\mathbb{P}}(0) = 1.08$

$$F_2(x, Q^2) = \sum_i C_i \otimes f_i(x, Q^2)$$

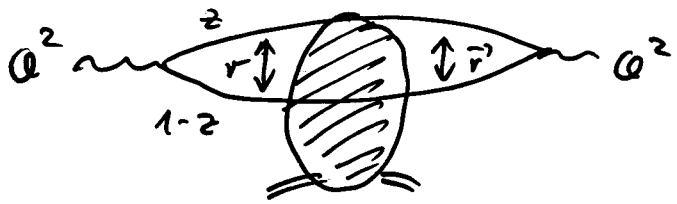
$$f_g \sim \exp\sqrt{c \ln 1/x \ln t/t_0}$$

$$t = \ln Q^2/\Lambda^2$$

Geometric scaling: $F_2(x, Q^2) = F_2(Q^2/Q_s^2(x))$, $Q_s^2 = Q_0^2 \left(\frac{1}{x}\right)^\lambda$, $\lambda \approx 0.3$

Framework for models: transition region

Color dipole $\quad \sigma_{\gamma^* p} = \int d^2 r \int_0^1 dz\, \psi^*(z, r, Q^2)\, \sigma_{q\bar{q}}(r, z)\, \psi(z, r, Q^2)$



proton rest frame

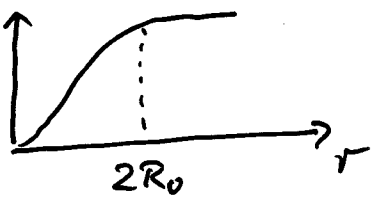
LO - BFKL result

$\sigma_{q\bar{q}}(r, z)$: dipole cross section

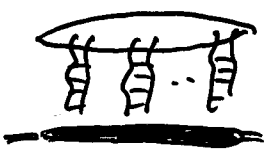
color transparency

Saturation model(s): GBW (BGK)

eikonal: $\sigma_{q\bar{q}} = \sigma_0 [1 - e^{-r^2/4R^2}]$



$R_0^2 \sim c \cdot x^\lambda$



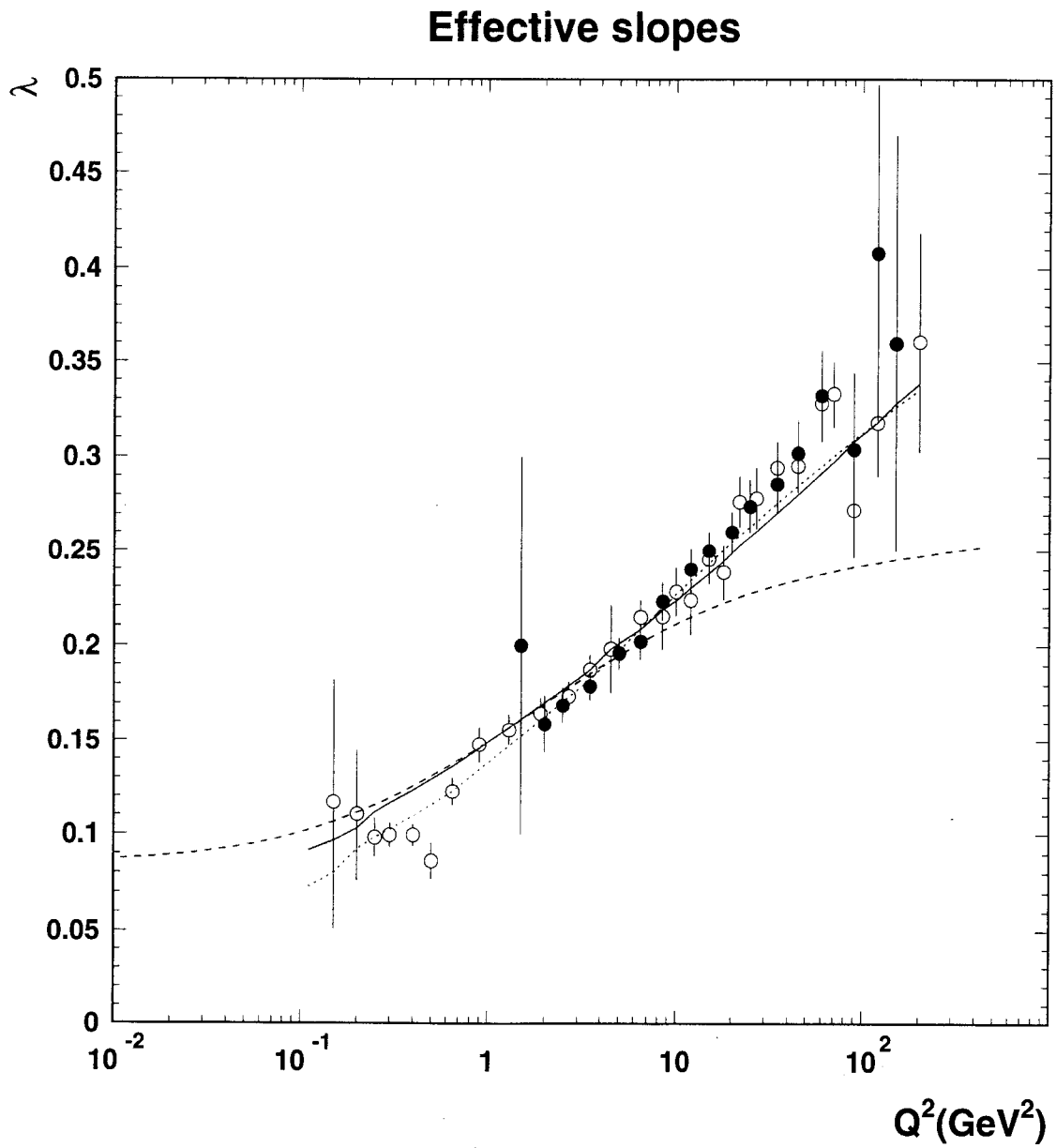


Figure 3: *The effective slope $\lambda(Q^2)$ from the parameterization $F_2 \sim x^{-\lambda(Q^2)}$ as a function of Q^2. The model with the DGLAP evolution (8): the solid line (FIT 1) and the dotted line (FIT 2). The saturation model (2): the dashed line. The open circles: ZEUS analysis and the full circles: H1 data [20].*

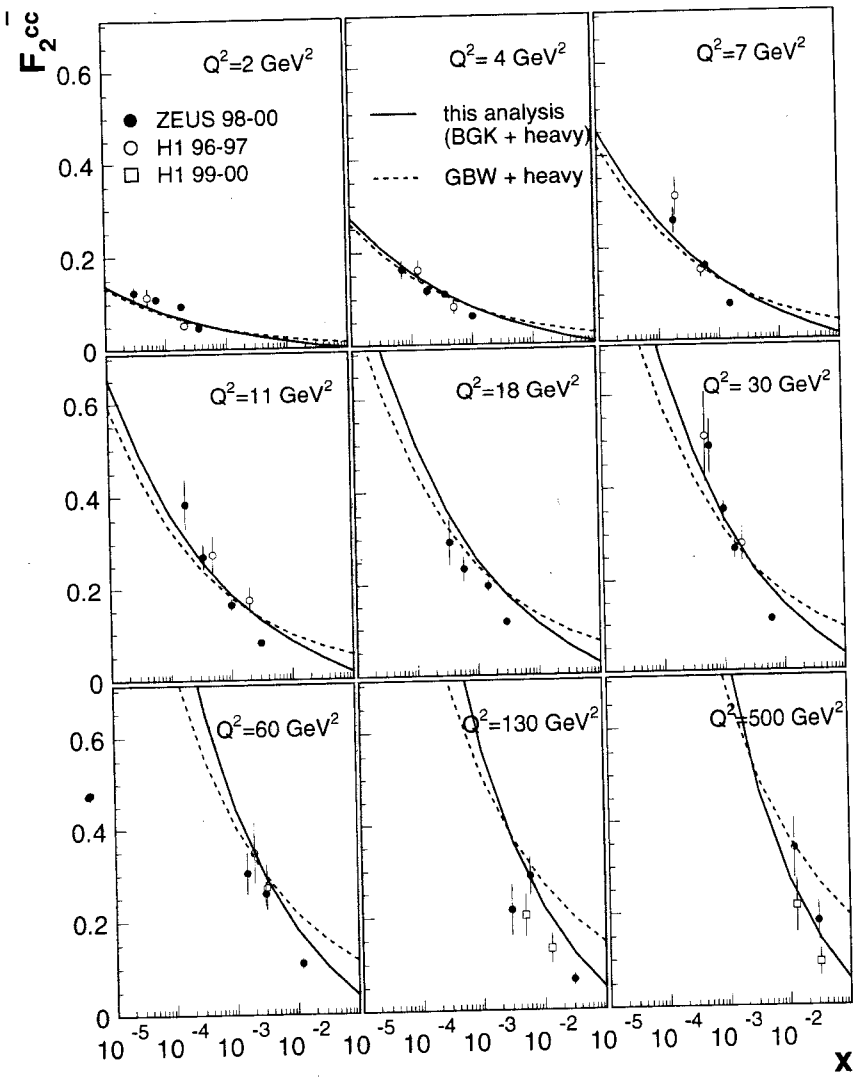
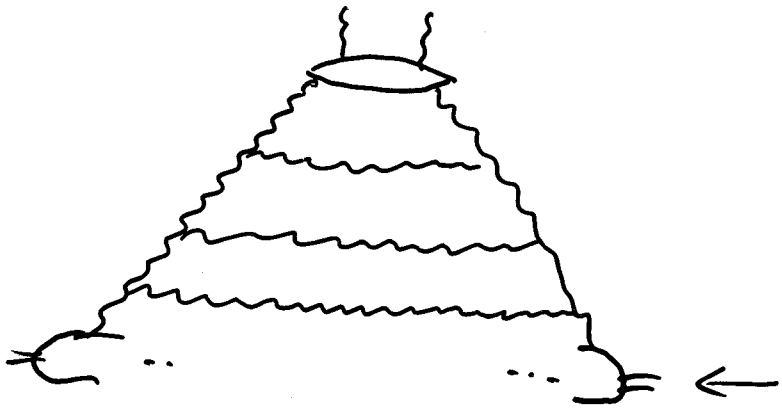


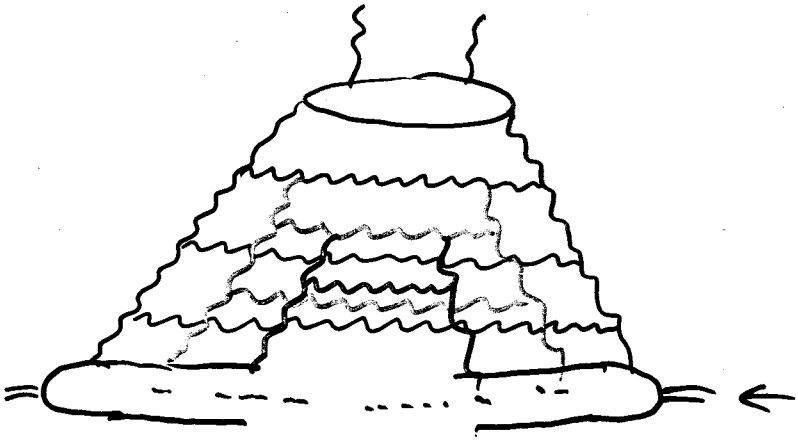
Figure 4: Predictions for the charm structure function $F_2^{c\bar{c}}$ in the BGK model with heavy quarks (solid lines). The predictions in the GBW model [1] are shown for reference (dashed lines).

Saturation in DIS: the idea

Bjorken frame (proton fast, photon "at rest"): $T_{\gamma^*\gamma^*}$



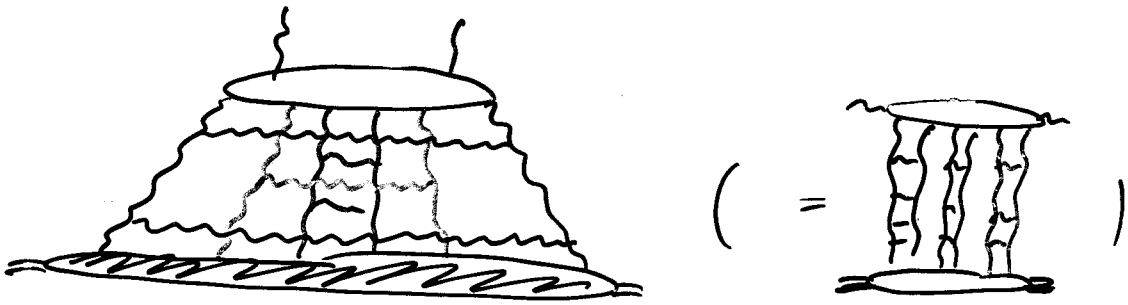
DGLAP



recombination

Balitsky-Kovchegov equation

GBW-model:



Essence of saturation: each ladder $\sim s^{\lambda(r^2)}$

Successes:

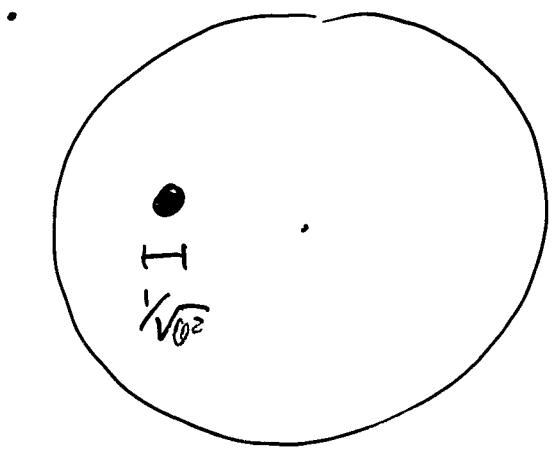
- successful fit to $\lambda(Q^2)$, F_2 : transition region
- geometric scaling

[- prediction for F_L (cf. DGLAP)]

Criticism:

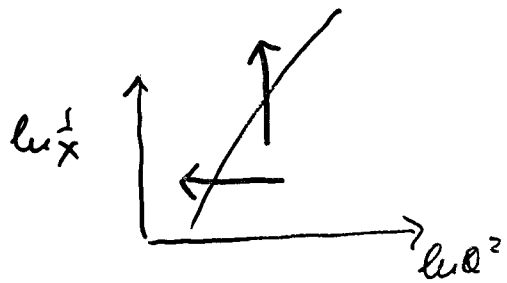
- only LO accuracy
- charm : done ✓
- simplistic – few parameters only!

Summary:



DGLAP: large Q^2, x-dependence

Saturation: transition to large size/high energy

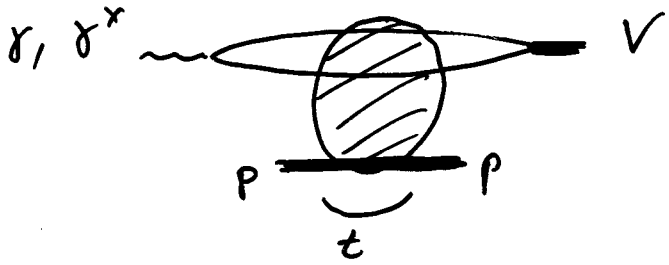


Average over $\vec{b}$.

Information on b-dependence : GPD, DVCS

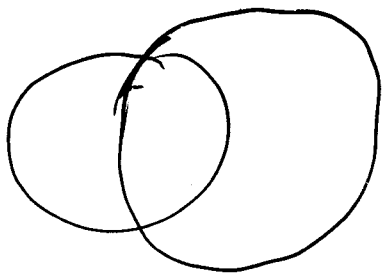
2. Vector production:

vector production = quasielastic

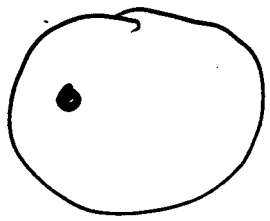


t-dependence

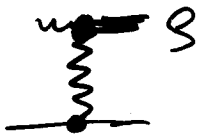
variation of Q^2, m_V^2 : variation of the size



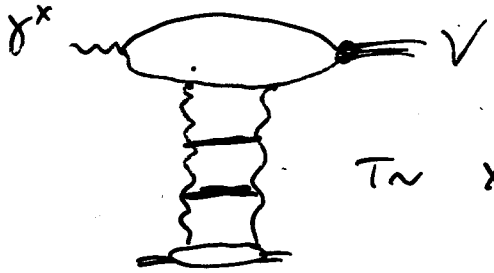
ρ- Photoproduction



ρ- electroproduction
J/ψ - production



soft Pomeron

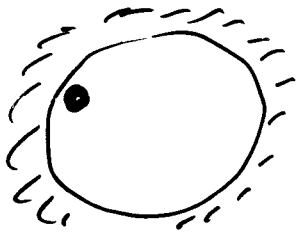


$T \sim xg(x, Q^2, t)$

Expect:
- energy dependence changes ✓
- transverse size changes ✓
- some diffusion: $\alpha' \sim 0.12 \lesssim \alpha'_P \approx 0.25$ ✓

mostly non perturbative

correct:



3. Saturation in DIS: has it been seen at HERA?

Most striking prediction:

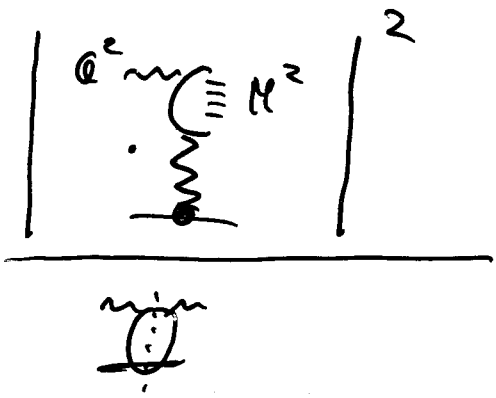
Flattening of $xg(x,Q^2)$ at small x — not seen at HERA

Indirect signals of saturation:

- successful model for transition region
- geometric scaling

Another signal: diffractive data

$$\frac{\sigma^{diff}}{\sigma_{tot}}$$ independent of W^2 (at fixed M^2, Q^2 or β)



$$\sim \frac{\left[(W^2)^{\alpha_{eff}}\right]^2}{(W^2)^{\lambda(Q^2)}}$$

looks accidental: $2\alpha_{eff} \approx \lambda(Q^2)$ why?

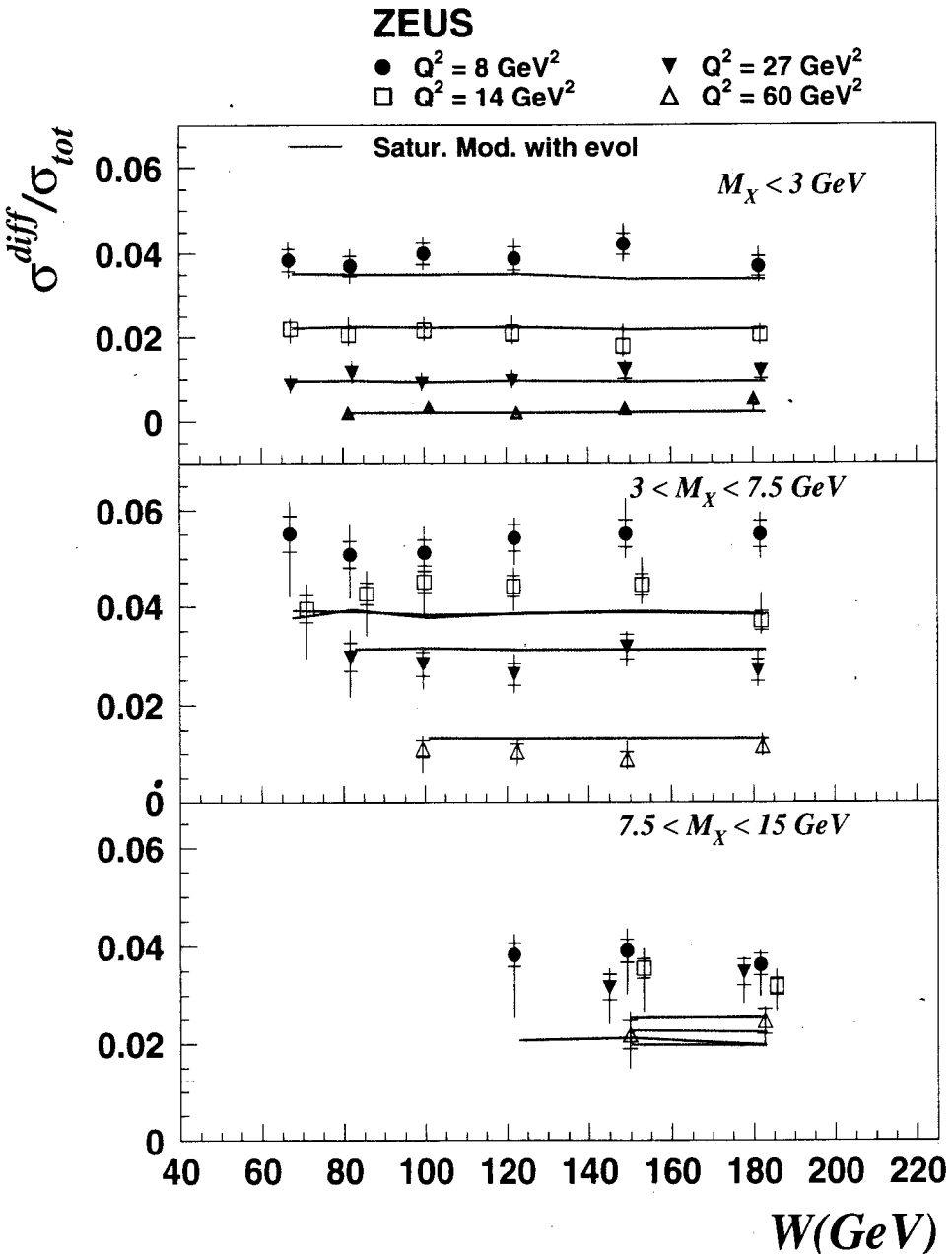


Figure 9: *The ratio of $\sigma_{diff}/\sigma_{tot}$ versus the $\gamma^* p$ energy W. The data is from ZEUS and the solid lines correspond to the results of the DGLAP improved model with massless quarks (FIT 2).*