12th International Conference on Elastic and Diffractive Scattering

Forward Physics and QCD

A Regge-pole model for DVCS

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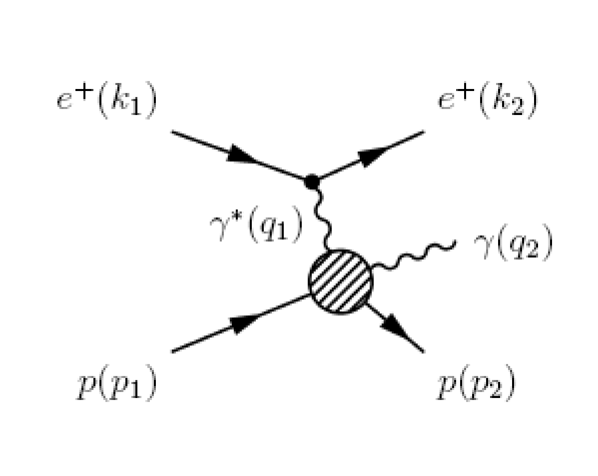
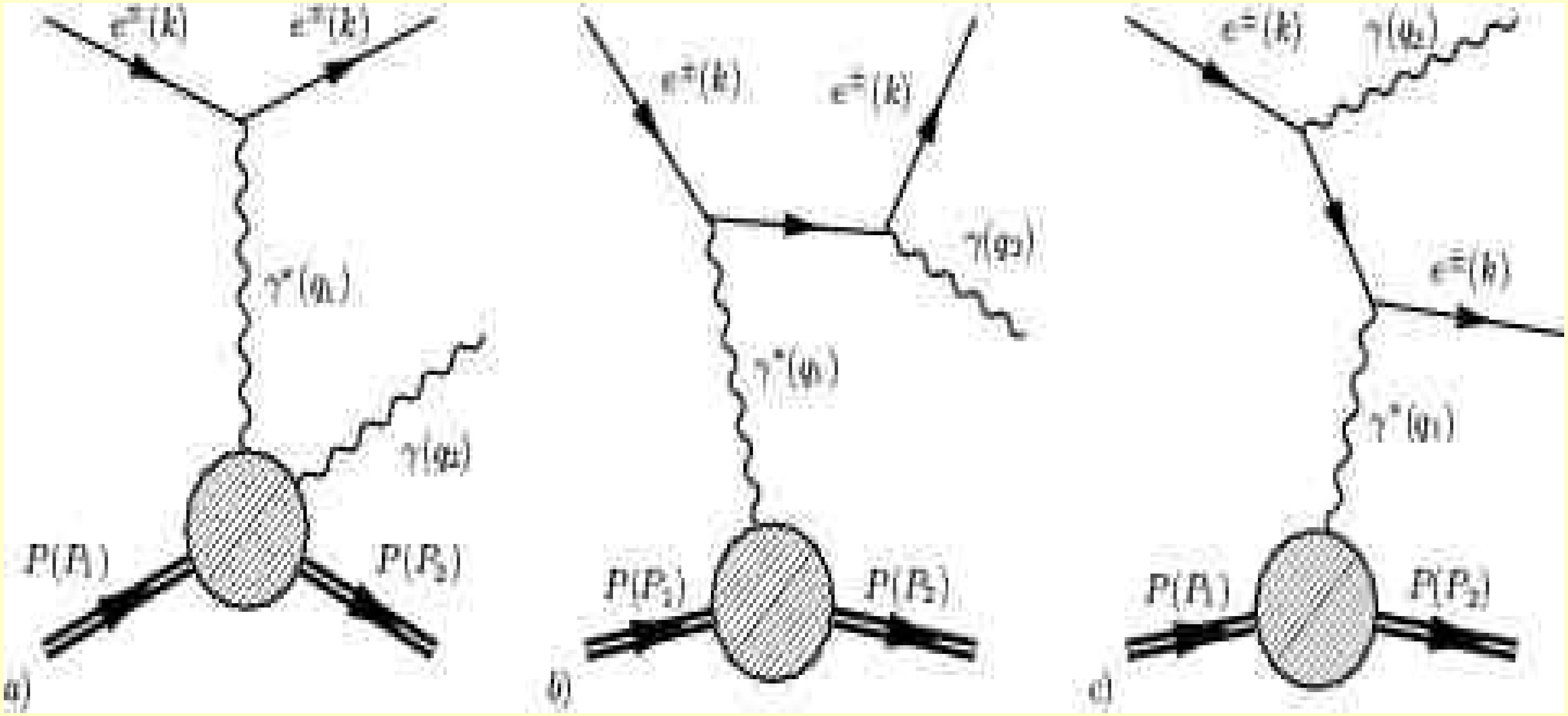
A factorized Regge-pole model for deeply virtual Compton scattering is suggested. The use of an effective logarithmic Regge-Pomeron trajectory provides for the description of both "soft" (small |t|) and "hard" (large |t|) dynamics. The model contains explicitly the photoproduction and the DIS limits and fits the existing HERA data on deeply virtual Compton scattering.

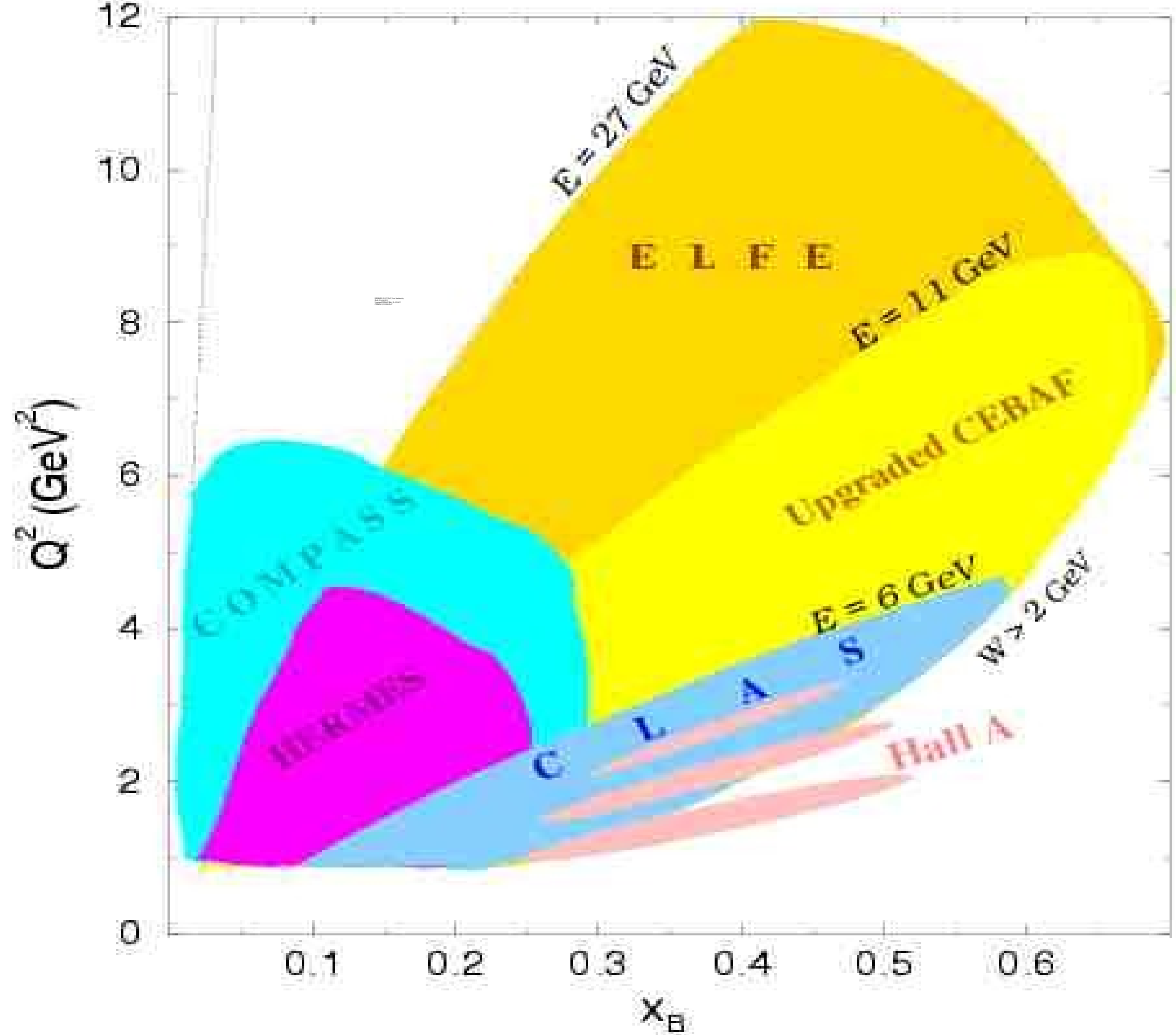
Based on: **M. Capua, S. Fazio, R. Fiore, L. Jenkovszky, and F. Paccanoni*A Deeply Virtual Compton Scattering Amplitude*, Phys. Letters B645 (2007) 161, arXiv: hep-ph/0605319** ***and***
R. Fiore, L.J., V. Magas, and A. Prokudin, *Interplay between Q^2- and t-dependences in DVCS*. In the Proceedings of the Crimean Conf., Yalta, 2005.

Electrpoproduction of a photon (γ), meson (M) or lepton pair ($l\bar{l}$),
e.g. DVCS $ep \to e\gamma p$ in a single photon exchange approximation



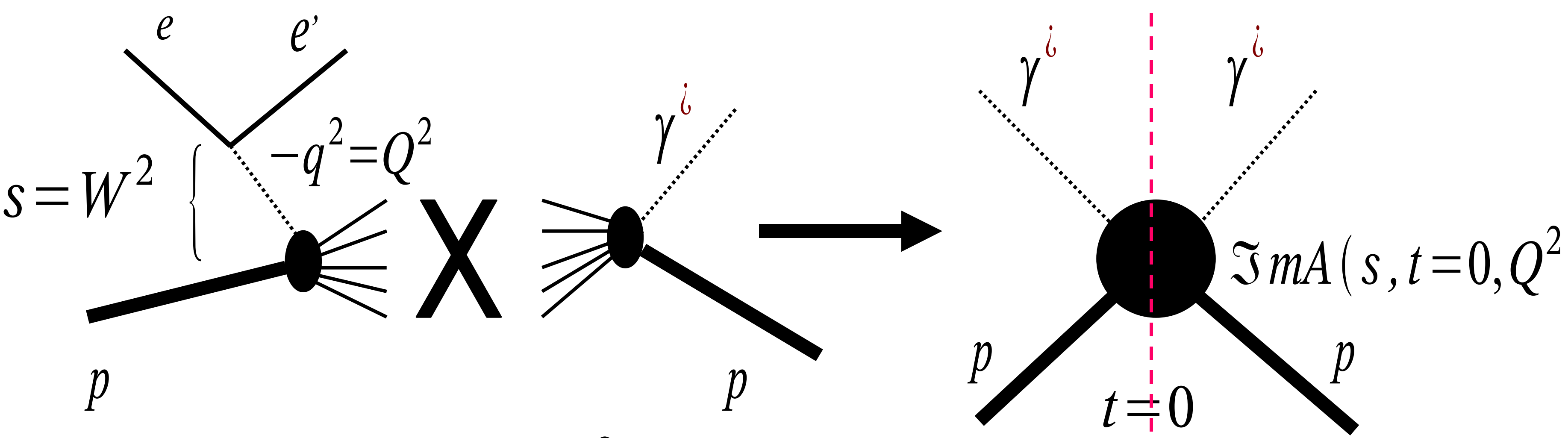
DVCS & Bethe-Heitler





12
10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
Q^2 (GeV^2)
x_B
E = 27 GeV
E L F E
E = 11 GeV
Upgraded CEBAF
COMPASS
HERMES
E = 6 GeV
W > 2 GeV
C L A S
Hall A

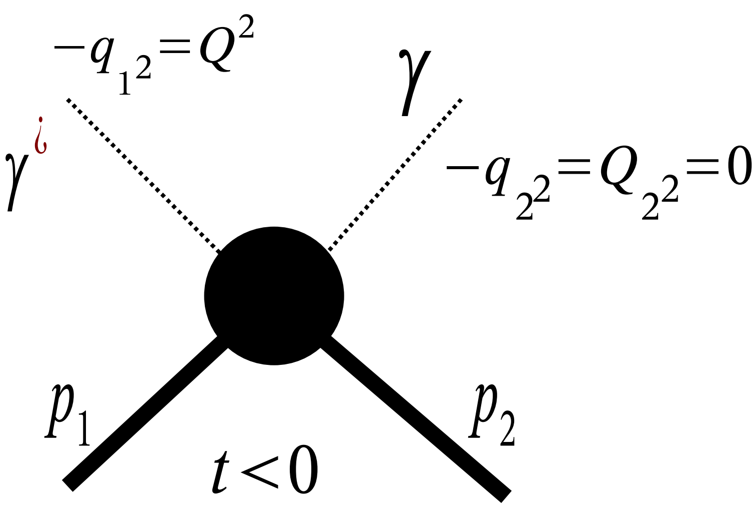
DIS (and ordinary parton distributions)



$$x=\frac{Q^2}{2pq} \qquad s=\frac{Q^2(1-x)}{x}+M^2\approx\frac{Q^2}{x},\; x<<1$$

The proton is smashed (completely destroyed)

DVCS kinematics



$$P=p_1+p_2,\quad q=(q_1+q_2)/2$$

$$\Delta=p_2-p_1,\quad t=\Delta^2$$

$$x_B=\frac{-q_1^2}{2\mathrm{p}_1 q_1}=\frac{Q^2}{2\mathrm{p}_1 q_1}$$

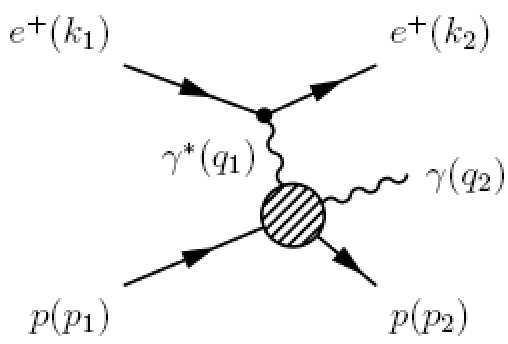
$$\xi=\frac{-q^2}{2Pq}=x_B\frac{1+\dfrac{\Delta^2}{2\mathrm{Q}^2}}{2-x_B+x_B\dfrac{\Delta^2}{Q^2}}$$

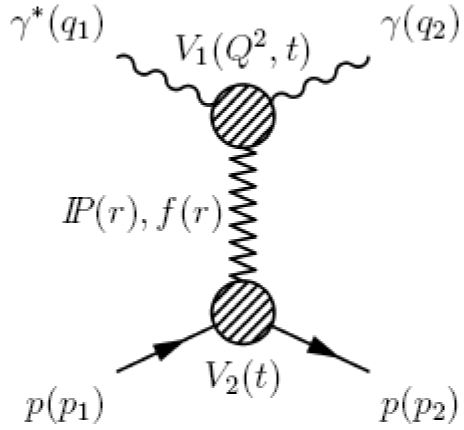
$$\eta=\frac{\Delta q}{Pq}=-\xi\left(1+\frac{\Delta^2}{2\mathrm{Q}^2}\right)^{-1}$$

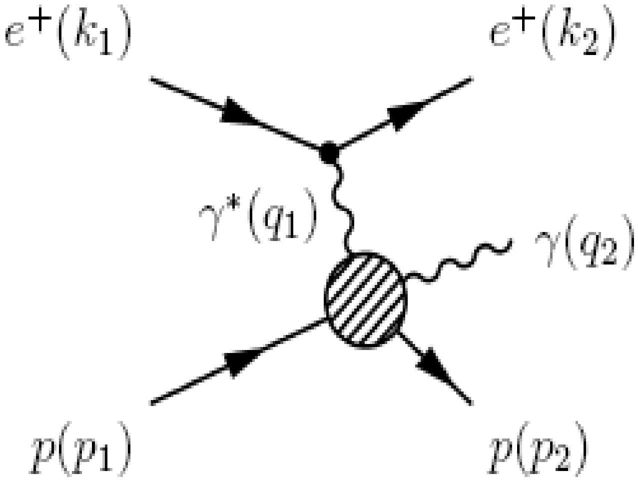
The sub-process $\gamma^* p \to \gamma p$ in a Regge-factorized form:

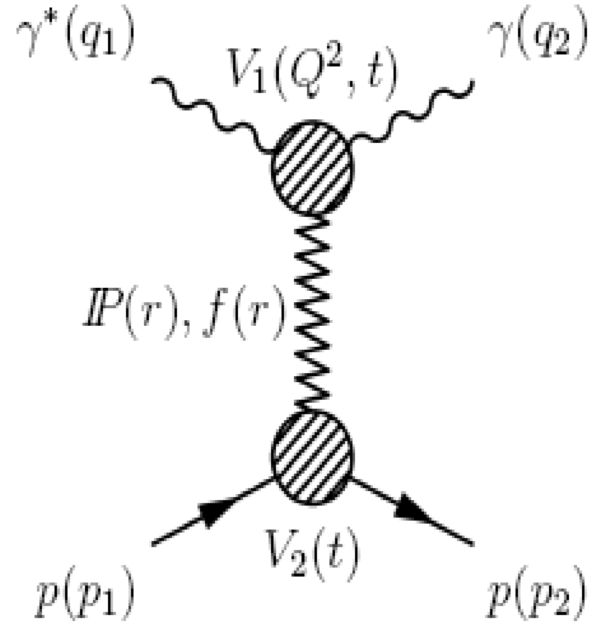
$$A(s,t,Q^2) \sim V_1(Q^2,t)V_2(t)s^{\alpha(t)}$$

$r^2 = t = (q_1 - q_2)^2$ r is the four-momentum of the Reggeon exchanged in the t channel,and $s = W^2 = (q_1 + p_1)^2$ is the squared centre-of-mass energy of the incoming system.









The γ*p scattering amplitude by Regge-pole factorization, is a product of the vertices times the propagator. Also, by this factorization, virtuality enters only the upper vertex, however, since the scattering amplitude is a sum of several Regge-exchanges, one can consider an effective amplitude that absorbs various different exchanges and thus does not obey Regge factorization any more. In this amplitude virtuality can be present also in the lower (effective) vertex and in the propagator.

The basic idea is that Q^2 and t, both having the meaning of a squared mass of a virtual particle (photon or Reggeon), should be treated on the same footing, by means a new variable, defined as

$$z = aq_1^2 + t = t - aQ^2, \tag{1}$$

where a is a parameter (for simplicity we set $a = 1$), in the same way as the vector meson mass squared is added to the squared photon virtuality, giving $\tilde{Q}^2 = Q^2 + M_V^2$ in the case of vector meson electroproduction

For convenience, and following the arguments based on duality, the t dependence of the pPp vertex is introduced via the $\alpha(t)$ trajectory: $V_2(t) = e^{b\alpha(t)}$ where b is a parameter. A generalization of this concept is applied also to the upper, $\gamma^* P\gamma$ vertex by introducing the trajectory

$$\beta(z) = \alpha(0) - \alpha_1 \ln(1 - \alpha_2 z),$$

where the value of the parameter α_2 may be different in $\alpha(t)$ and $\beta(z)$.

Hence the scattering amplitude, with the correct signature, becomes

$$A(s,t,Q^2)_{\gamma^* p\to\gamma p} = -A_0 e^{b\alpha(t)} e^{b\beta(z)} (-is/s_0)^{\alpha(t)} =$$

$$-A_0 e^{(b+L)\alpha(t)+b\beta(z)},$$

where $L \equiv \ln(-is/s_0)$.

Photoproduction- and DIS limits (a consistency check)

In the $Q^2 \to 0$ limit the scattering amplitude becomes

$$A(s,t) = -A_0 e^{2b\alpha(t)}(-is/s_0)^{\alpha(t)}$$

where we recognize a typical Regge-behaved photoproduction (or, for $Q^2 \to m_H^2$, on-shell hadronic (H)) amplitude. The related deep inelastic scattering structure function is recovered by setting $Q_2^2 = Q_1^2 = Q^2$ and $t = 0$, to get a typical elastic virtual forward Compton scattering amplitude:

$$A(s,Q^2) = -A_0 e^{b(\alpha(0)-\alpha_1 \ln(1+\alpha_2 Q^2))} e^{(b+\ln(-is/s_0))\alpha(0)} \propto$$

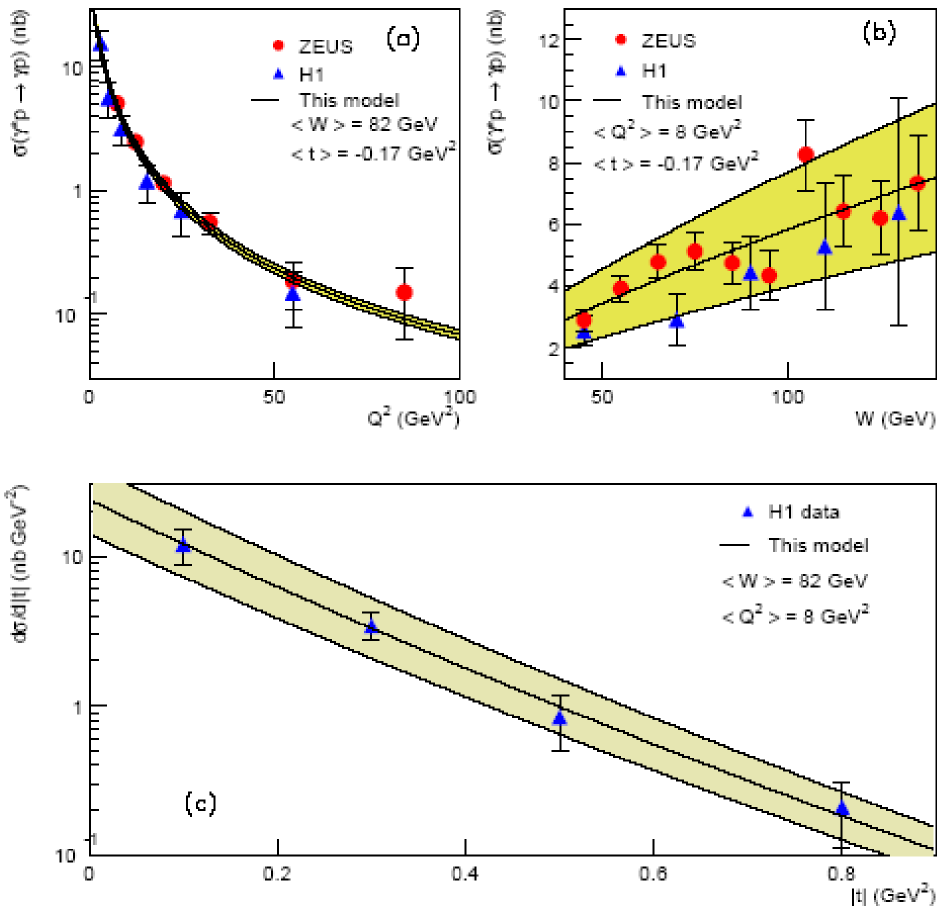
$$-(1+\alpha_2 Q^2)^{-\alpha_1}(-is/s_0)^{\alpha(0)}.$$

In the Bjorken limit, when both s and Q^2 are large and $t = 0$ (with $x \approx Q^2/s$ valid for large s), the structure function is given by:

$$F_2(s,Q^2) \approx \frac{(1-x)Q^2}{\pi\alpha_e} \Im A(s,Q^2)/s,$$

Fits to the $ep \to e\gamma p$ data

$$\frac{d\sigma}{dt}(s,t,Q^2) = \frac{\pi}{s^2}|A(s,t,Q^2)|^2 \qquad A = A^P + A^f$$



parameter	σ_{DVCS} vs Q^2	σ_{DVCS} vs t	σ_{DVCS} vs W
$\lvert A_0\rvert^2$	0.08 ± 0.01	0.11 ± 0.24	0.06 ± 0.01
b	0.93 ± 0.05	1.04 ± 0.91	1.08 ± 0.10
$\chi^2/ndof$	0.57	0.15	1.15

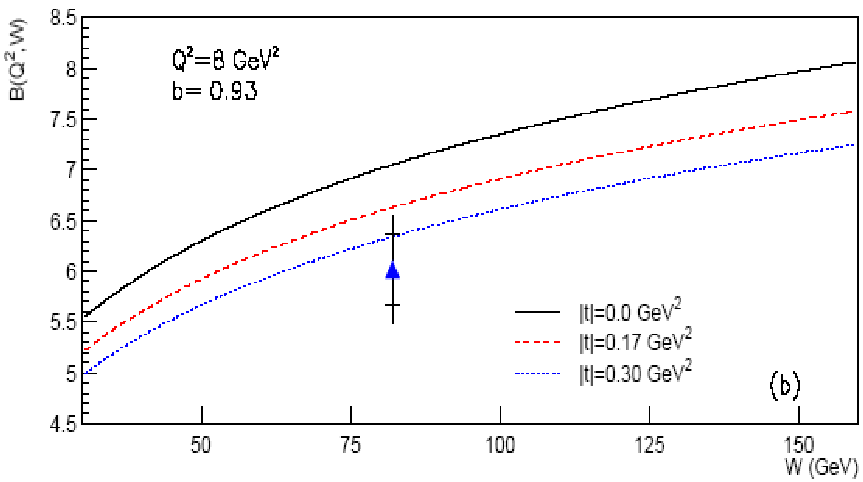
SLOPE OF THE DIFFRACTION CONE

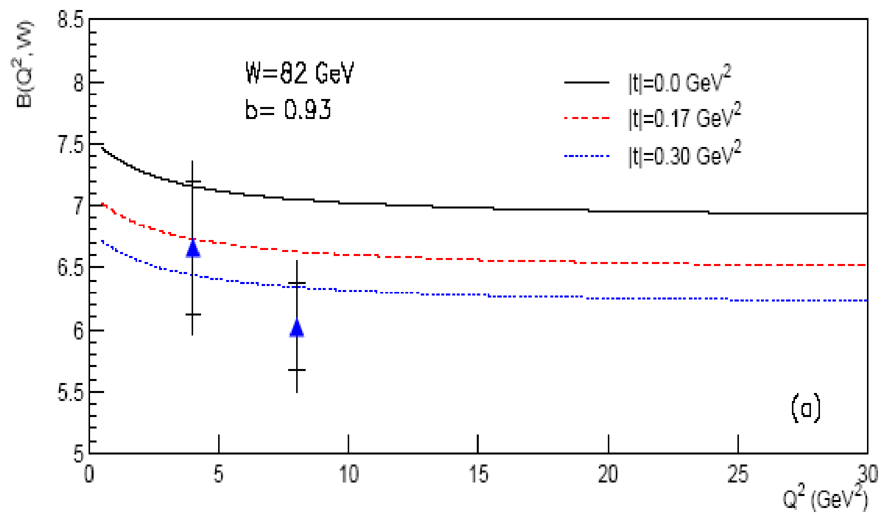
$$B(s,Q^2,t)=\frac{d}{dt}\ln|A|^2=2\left[b+\ln\left(\frac{s}{s_0}\right)\right]\frac{\alpha'}{1-\alpha_2 t}+2b\frac{\alpha'}{1-\alpha_2 z},$$

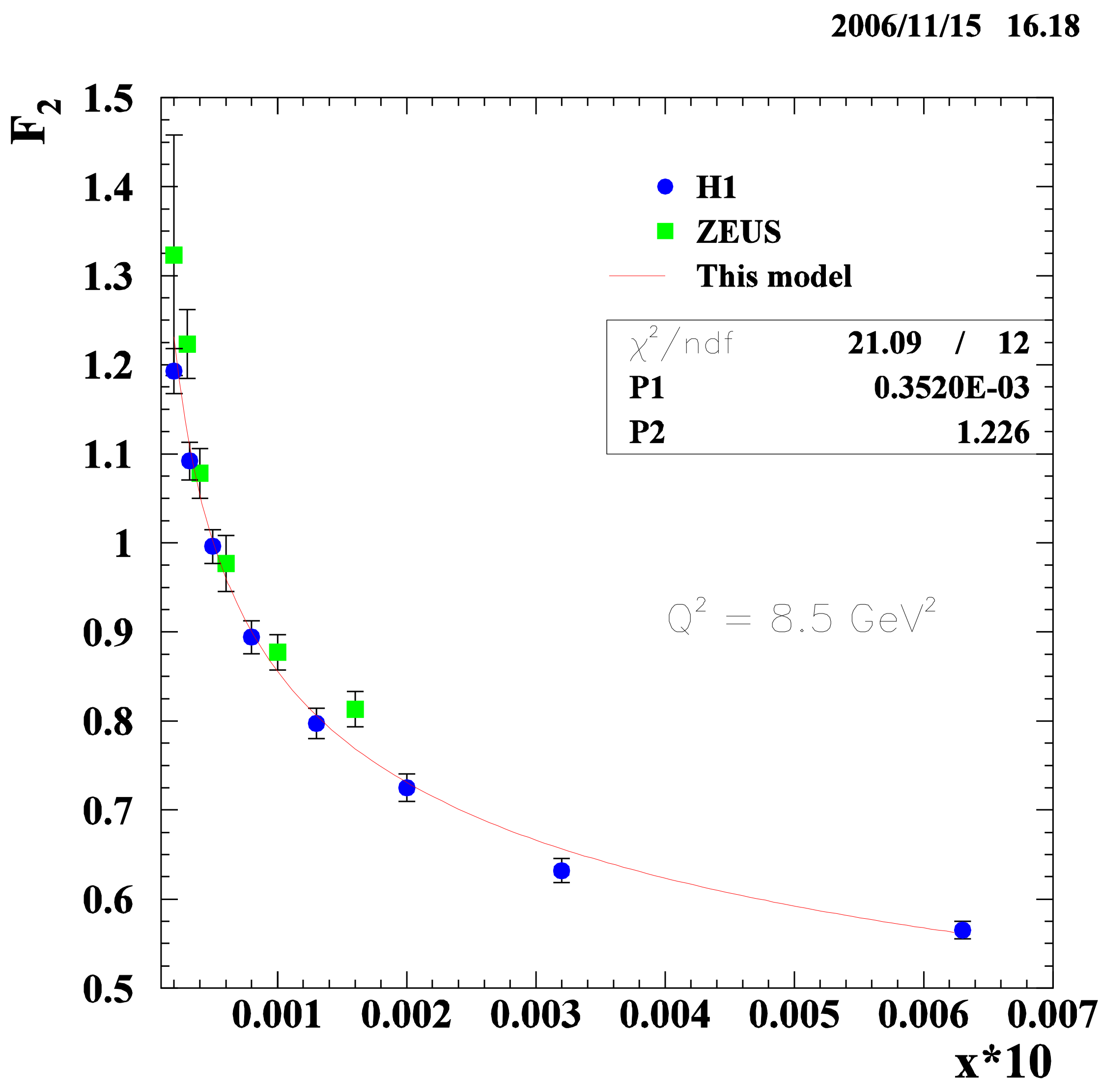
shows shrinkage in s and antishrinkage in Q^2.

In the forward limit, $t=0$ it reduces to

$$B(s,Q^2)=2\left[b+\ln\left(\frac{s}{s_0}\right)\right]\alpha'+2b\frac{\alpha'}{1+\alpha_2 Q^2}.$$






2006/11/15 16.18
F2
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
H1
ZEUS
This model
χ²/ndf 21.09 / 12
P1 0.3520E-03
P2 1.226
Q² = 8.5 GeV²
0.001
0.002
0.003
0.004
0.005
0.006
0.007
x*10

QCD-evolution of a DVCS amplitude

Evolution in DVCS (similar to the DGLAP equation) was studied in an early paper by L.N.Lipatov et al. and more recently in V.Gusey and M.V.Polyakov, hep-ph/0507183; an M.Kirsh, A.Manashov, A. Schafer, Phys. Rev. D72 (2005) 114006; A.V. Vinnikov, hep-ph/0604248.

Interpolation between a Regge-behaved (for small x and fixed Q^2 DIS SF:

$$F_2(x, Q^2) \sim \Big(\frac{Q^2}{A^2 + a}\Big)^{1+\tilde{\Delta}(Q^2)} (\frac{x}{x_0})^{\tilde{\Delta}(Q^2)}$$

and its large Q^2 behavior as given by DGLPA:

$$F_2(x, Q^2) \sim \exp\Big(\sqrt{\gamma \ln\ln \frac{Q^2}{Q_0^2} \ln \frac{x_0}{x}}\Big).$$

Further applications (HERMES, COMPAS)

- Electroproduction of the phi meson is dominated by a Pomeron pole exchange in the spin density matrix or the scattering amplitude (W.D. Nowak, DESY 05-003, hep-ex/0503010; A.Borissov, S. Manayenkov, HERMES Collab. Meeting, DESY,4.7.06; M.Diehl, DESY 07-049).

Testing z-scaling

If z is a new scaling variable, then vector meson production and on DVCS cross sections, generally depending on two variables – t and Q2 (the energy dependence being scaled out) – should become functions of a single variable
z=t-aQ2.

Conclusions

1. Where is QCD? Its place is in large - Q^2 evolution, to replace Regge behavior;

2. Experimental verification of the "z-scaling": $\sigma(t, Q^2) \Rightarrow \sigma(z)$

3. More refined fits of the model to the present and future data, with:
b) the f (and other) trajectory(ies) Q^2- and their modified forms added;
c) b) unitarity effects (cuts) included; c) spin and polarization;
d) d) extrapolation to lower energies (COMAPAS, HERMES, JLab) (resonances in s, large-x factor of the SF, quark-hadron duality etc.);

4. Use of the explicit DVCS amplitude to calculate GPD.