Deeply Virtual Compton Scattering in the Saturation Approach

Magno V.T. Machado* (invited) - L. Favart** (replacing)

∗ Instituto de Física e Matemática, Universidade Federal de Pelotas

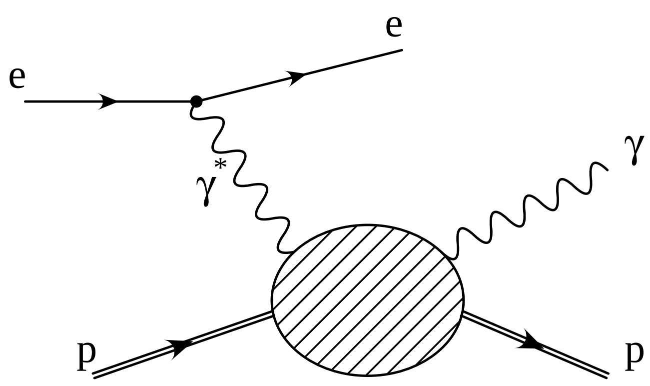
High Energy Physics Phenomenology Group, GFPAE IF-UFRGS

∗∗ I.I.H.E., Université Libre de Bruxelles.

`http://www.h1-desy.de/˜favart/dvcs`

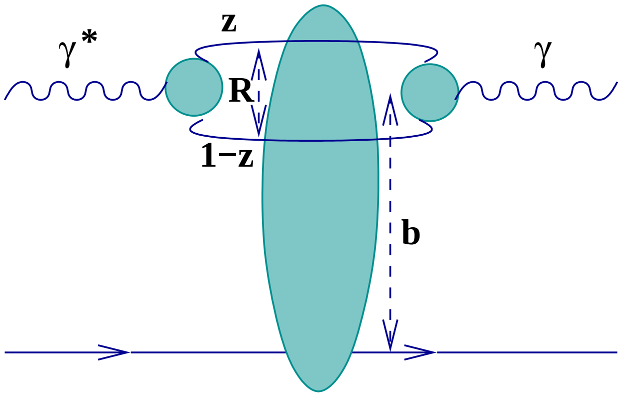
`http://www.if.ufrgs.br/˜magnus/`

Motivation



- DVCS is a very clear QCD process, having a real photon in the final state.
- DVCS can give access to real and imaginary parts of the QCD scattering amplitude through the interference with QED Bethe-Heitler (BH).
- At HERA, H1 and ZEUS measured DVCS in perturbative virtualities Q^2, and high energy.
- Saturation models can be easily extended to DVCS process.

DVCS in Color Dipole



L.Favart-M.V.Machado,

Eur. Phys. J. C 29 (2003) 365-371.

$$\mathcal{I}m\,\mathcal{A} = \int_0^1 dz \int d^2\boldsymbol{r}\,\Phi_T(z,\,\boldsymbol{r},\,Q^2)\,\sigma_{dip}(x,\,\boldsymbol{r}^2)$$

$$\begin{aligned}
\Phi_T(z,\,\boldsymbol{r},\,Q^2) &\equiv \Psi_T^*(z,\,\boldsymbol{r},\,Q_1^2 = Q^2)\,\Psi_T(z,\,\boldsymbol{r},\,Q_2^2 = 0) \\
&= \frac{6\alpha_{\rm em}}{4\,\pi^2}\sum_f e_f^2\,\{[z^2 + (1-z)^2]\,\varepsilon_1\,K_1(\varepsilon_1\,r)\,\varepsilon_2\,K_1(\varepsilon_2\,r) \\
&\qquad + \; m_f^2\,K_0(\varepsilon_1\,r)\,K_0(\varepsilon_2\,r)\} \\
\varepsilon_{1,2}^2 &= z(1-z)\,Q_{1,2}^2 + m_f^2; \qquad Q_1^2 = Q^2 \text{ and } Q_2^2 = 0
\end{aligned}$$

- The saturation models are input for $\sigma_{dip}(x,\,\boldsymbol{r}^2)$.

The Saturation Model

- Golec-Biernat, Wusthoff: **Phys. Rev. D 59 (1999) 014017**.
- Model provides color transparency behavior at small $\boldsymbol{r}$ and constant dipole cross section at large $\boldsymbol{r}$, with transition given by the saturation scale $Q_{\rm sat}(x)$.

$$\sigma_{dip}(\tilde{x}, \boldsymbol{r}^2) = \sigma_0 \left[1 - \exp\left(-\frac{Q^2_{\rm sat}(x)\, \boldsymbol{r}^2}{4} \right) \right]$$

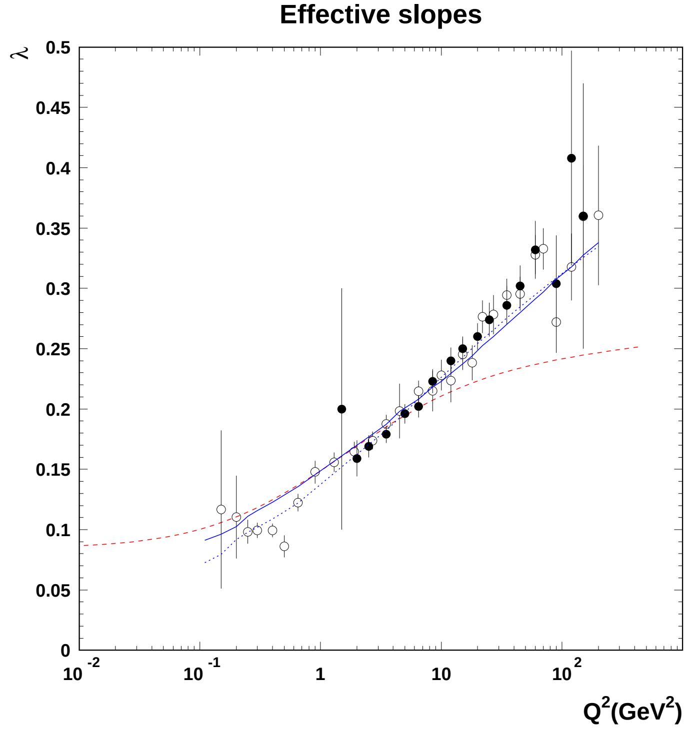
$$Q^2_{\rm sat}(x) = \left(\frac{x_0}{\tilde{x}} \right)^{\lambda} \mathrm{GeV}^2; \quad \tilde{x} = x_{Bj} \left(1 + \frac{4\, m_f^2}{Q^2} \right)$$

- Parameters fitted from small $x \leq 10^{-2}$ DESY-HERA data.
- 3-flavor (4-flavor) fit to $\sigma_{tot}^{\gamma^* p}$: $\lambda = 0.288\,(0.277)$, $x_0 = 3 \times 10^{-4}\,(0.34 \times 10^{-4})$, $\sigma_0 = 23\,(29)$ mb.

Entering DGLAP evolution . . .

- Bartels, Golec-Biernat, Kowalski: **Phys. Rev. D 66 (2002)**.
- Improvement at high Q^2 through DGLAP evolution.

$$\sigma_{dip}(\tilde{x}, \boldsymbol{r}^2) \quad = \quad \sigma_0 \left[1 - \exp\left(- \frac{\pi^2 \boldsymbol{r}^2 \alpha_s(\mu^2)\, \tilde{x}\, G(\tilde{x}, \mu^2)}{3\,\sigma_0} \right) \right]$$

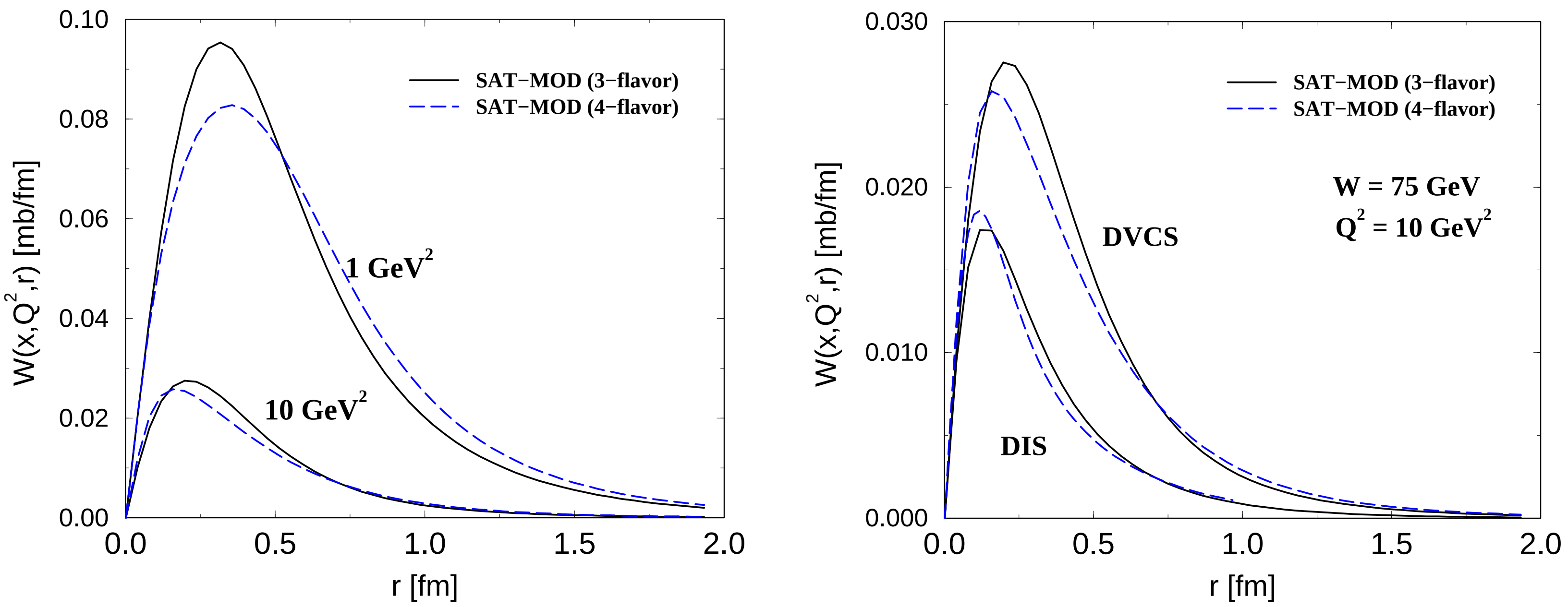


$$x\, G(x, Q_0^2) = A_g\, x^{-\lambda_g}\, (1-x)^{5.6}$$

$$\mu^2 = \frac{C}{\boldsymbol{r}^2} + \mu_0^2$$

Qualitative results . . .

- DVCS contains important contributions from $r^2 \leq 1/Q^2_{\mathrm{sat}}(x)$ in contrast to DIS.



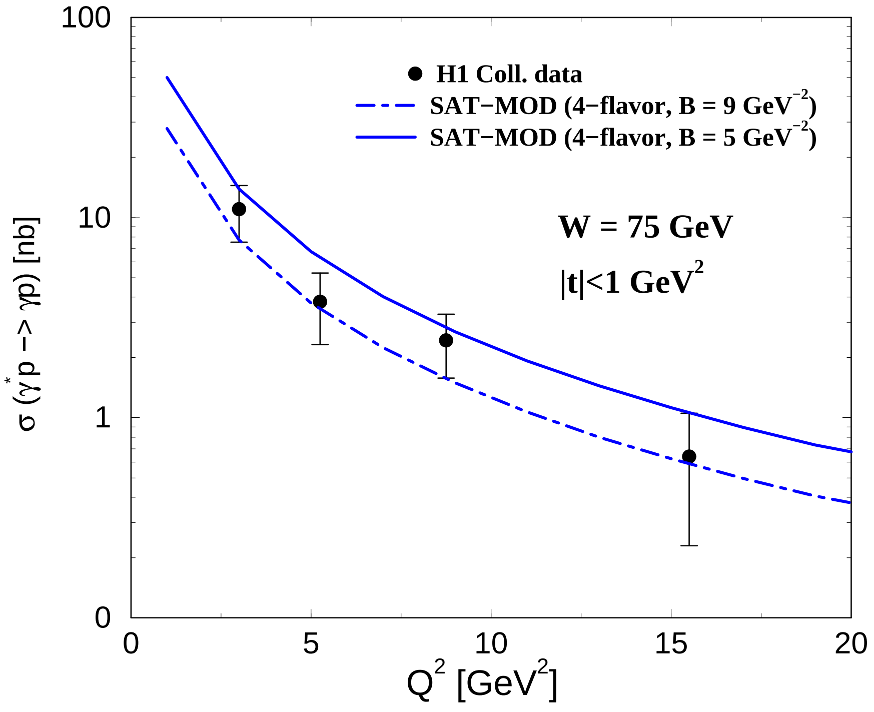
- Saturation model offers a qualitative picture for DVCS.

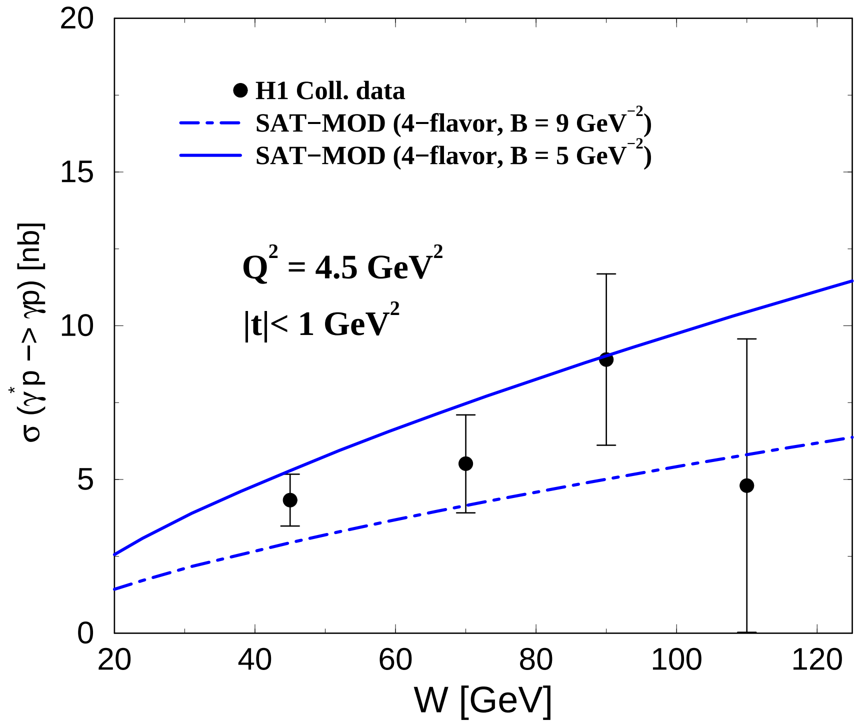
Large Q^2 : $\sigma_{tot} \propto \dfrac{W^{4\lambda}}{Q^4}$ Small Q^2 : $\sigma_{tot} \propto \mathcal{C}\, \log^2 (W^2)$

Results versus DVCS data at HERA

- DVCS cross section is obtained in a parameter free way.

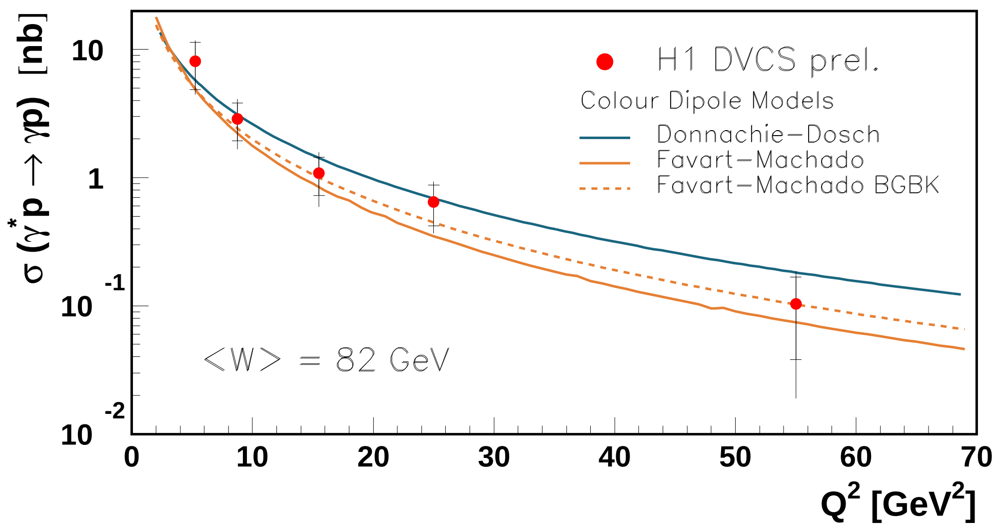
$$\sigma(\gamma^* p \to \gamma\, p) = \frac{[\,\mathcal{I}m\,\mathcal{A}(s,0)\,]^2}{16\,\pi}\,(1+\rho^2); \quad \rho : \text{real by imaginary part}$$

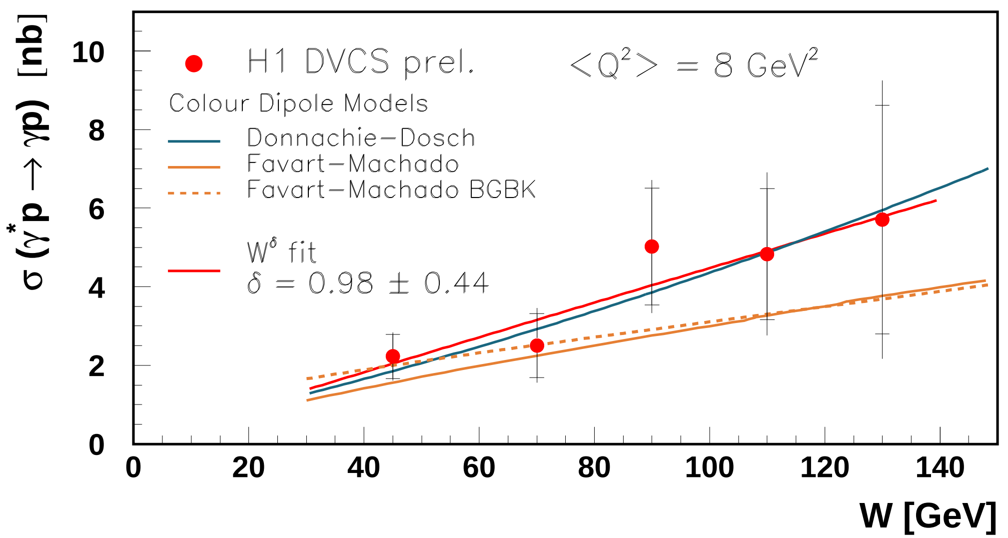




Results versus new H1 DVCS data

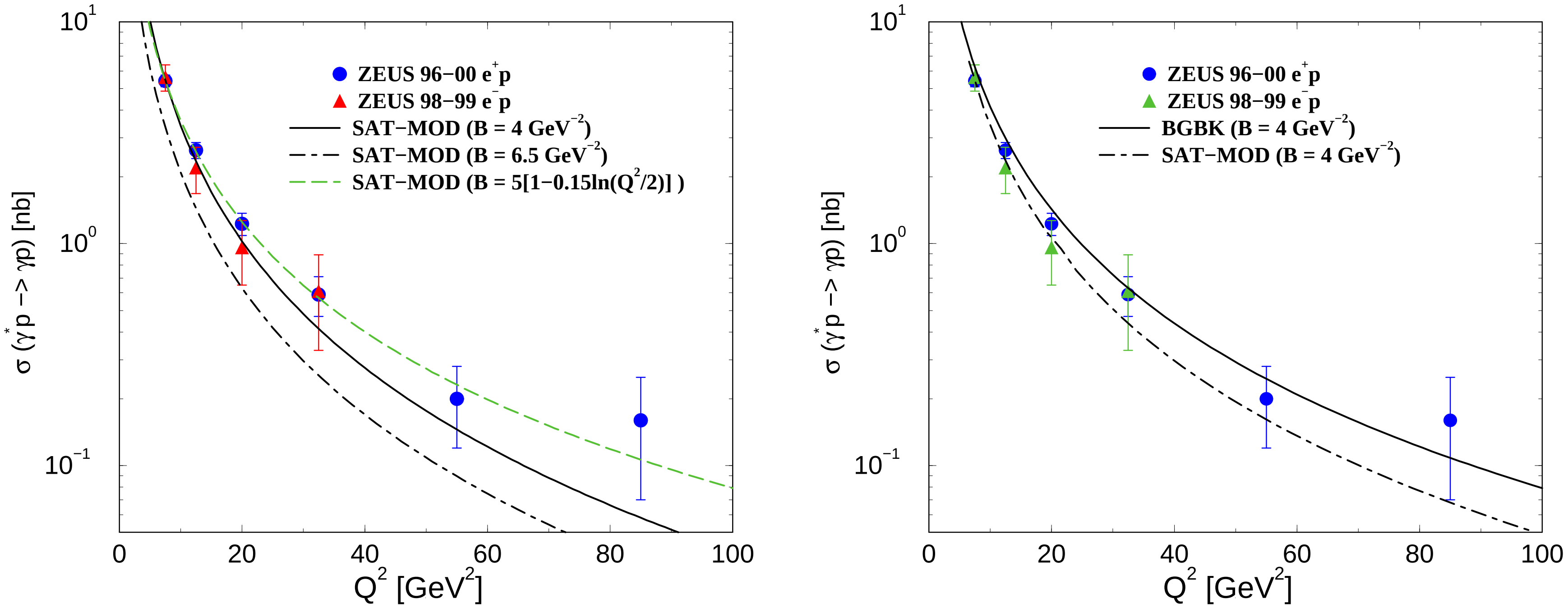
- **hep-ex/0312013** (proceedings of EPS HEP2003).





QCD evolution at high Q^2

- Saturation model underestimates large Q^2 ZEUS data.
- Investigating DGLAP QCD evolution (BGBK).

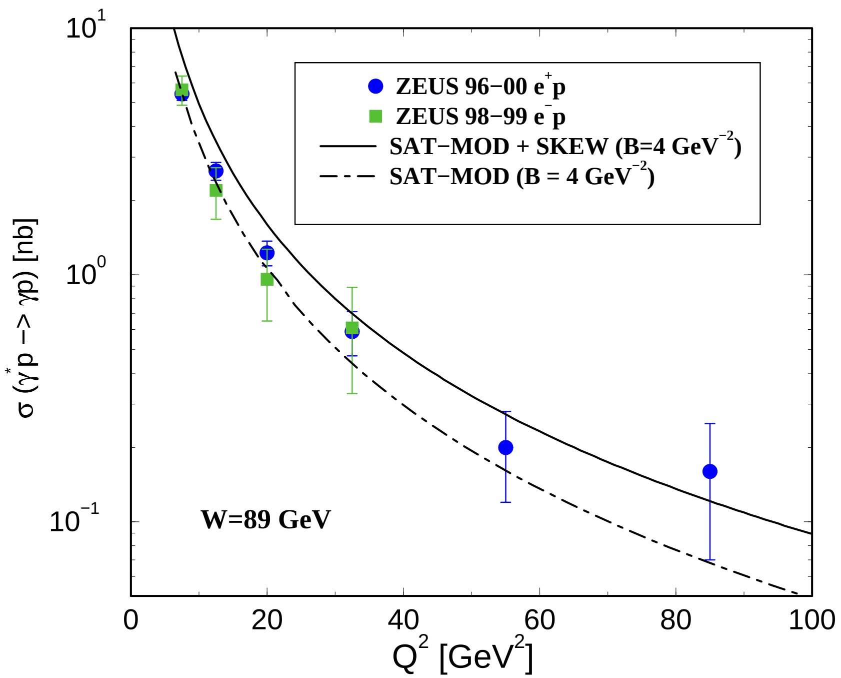


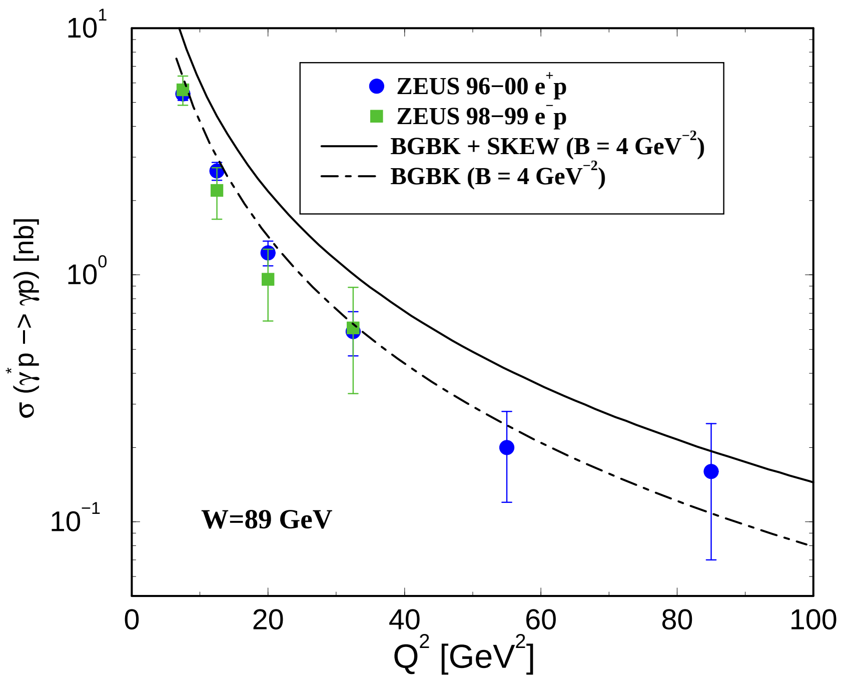
- Favart-Machado, **hep-ph/0402018** (EPJC)
- Skewedness effects are increasingly important at Q^2.

Off-forward (skewed) correction

- Ratio of off-forward to forward pdf's [Shuvaev at al., **Phys. Rev D60 014015 (1999)**]

$$R_g\left(Q^2\right) = \frac{2^{2\lambda+3}}{\sqrt{\pi}} \frac{\Gamma\left(\lambda+\frac{5}{2}\right)}{\Gamma\left(\lambda+4\right)}, \qquad \lambda = \frac{\partial\, \mathcal{I}m\, \mathcal{A}_{\mathrm{DVCS}}}{\partial\, \ln(1/x)}$$

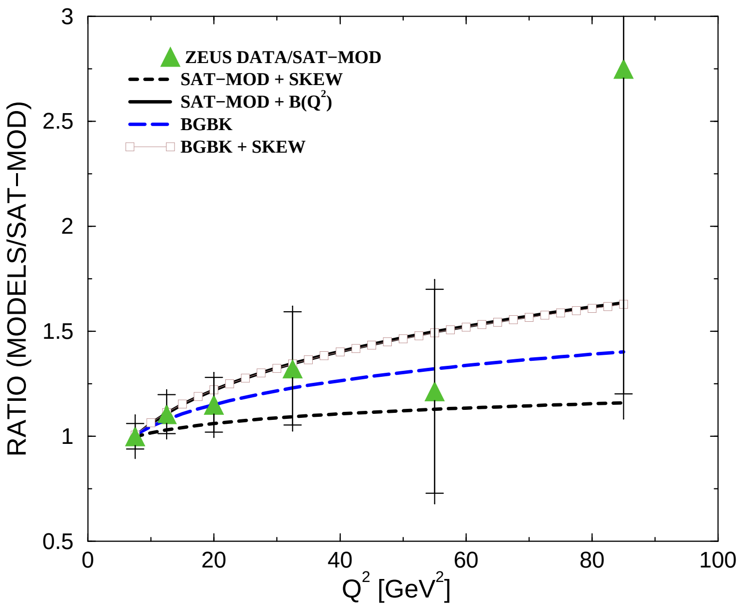


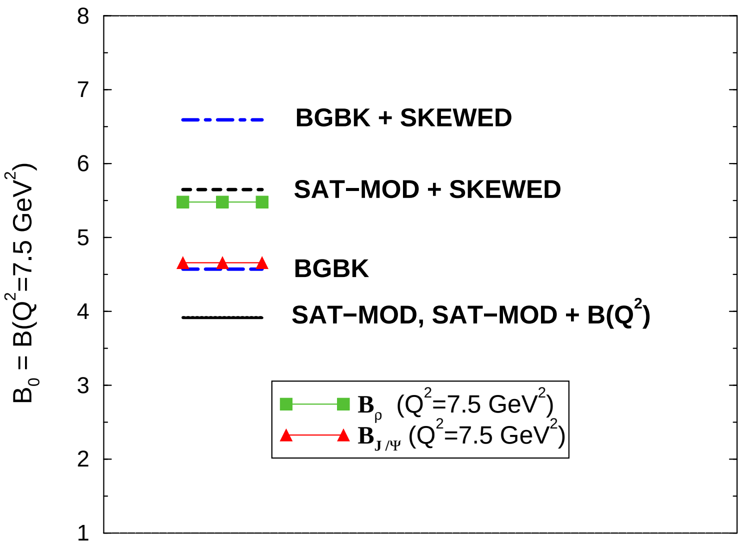


- Sizable contribution, mostly at large Q^2.

Investigating both effects . . .

- Hard to disentangle models: slope parameter B has never been measured for DVCS.
- Analysing separately effects on Q^2 dependence and overall normalization.





- Combination of effects can not be distinguished with the present experimental precision

Summary

- DVCS process is an important tool to study QCD predictions and test phenomenological models.
- Dipole models, in particular those including saturation, describe in a parameter free way DVCS data.
- Saturation models and its extension to higher Q^2 do excellent job in describing H1 and ZEUS measurements.
- Needed of an accurate slope measurement in a wide range of Q^2.
- Large Q^2 data required to see QCD evolution/skewedness corrections.
- Hard to disentangle models/effects within current data precision.