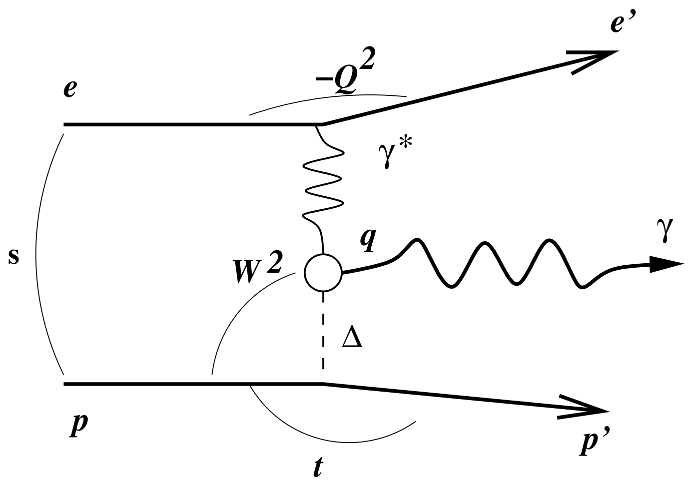
Deeply Virtual Compton Scattering

H. Abramowicz, Tel Aviv University
(for the ZEUS Collaboration)

OUTLINE

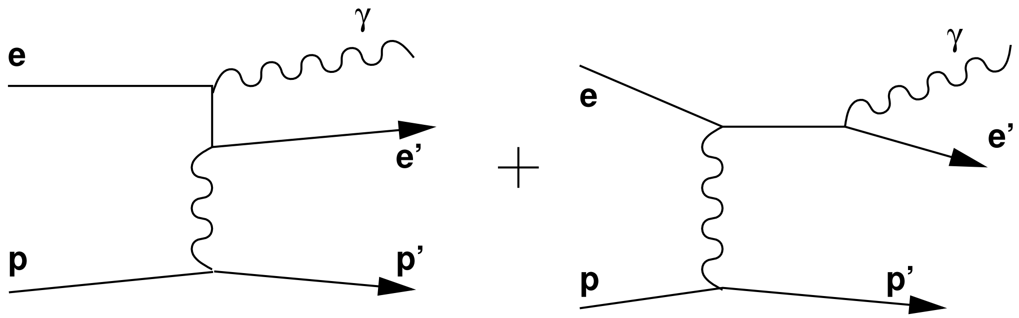
- Introduction
- Data selection and Analysis
- Cross section measurements
- Comparison with models/expectations

DVCS: QCD process



$$s = (e+p)^2 \qquad (\sqrt{s} = 300, 320\ \mathrm{GeV})$$
$$Q^2 = -q^2 = -(e-e')^2 \qquad (Q^2 > 5\ \mathrm{GeV}^2)$$
$$W^2 = (q+p)^2 \qquad (40 < W < 140\ \mathrm{GeV})$$
$$t = \Delta^2 = (p-p')^2 \approx -p_T'^2$$

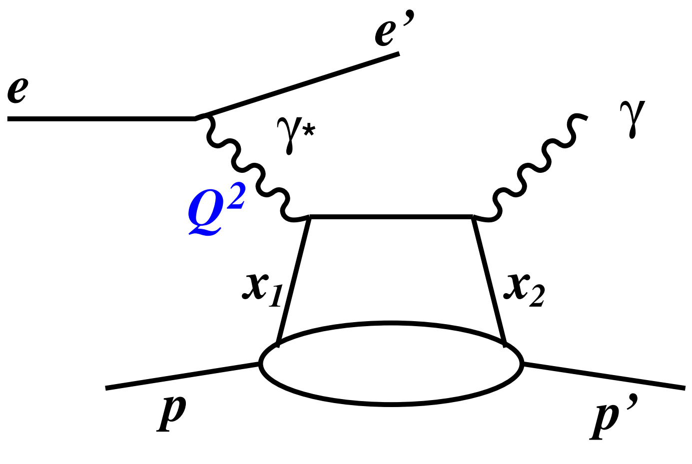
Competing: QED Bethe-Heitler process



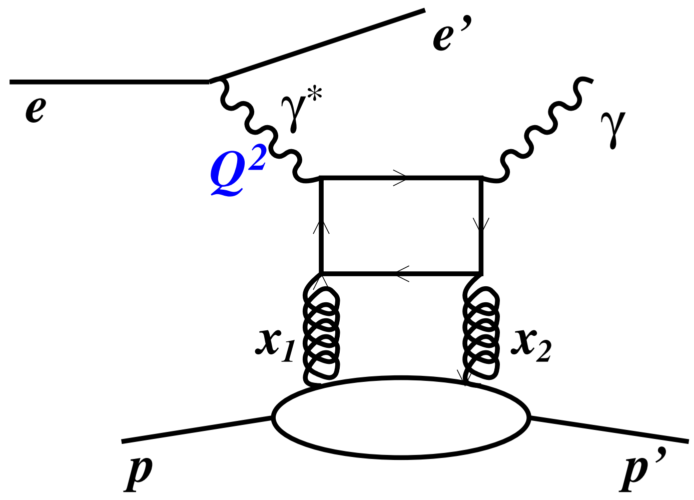
DVCS PROCESS IN QCD

Handbag diagram

$$\boxed{x_1 \neq x_2}$$



Dominant contribution at low-x



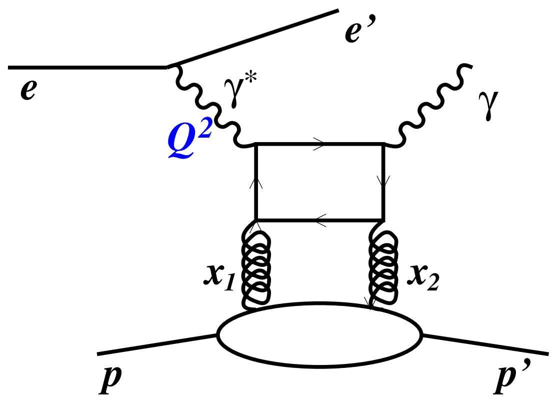
Why is DVCS interesting?

- Interference between QCD with QED amplitudes $\rightarrow$ rich structure in ϕ, angle between the hadronic and leptonic planes $\rightarrow$ asymmetries (angular, charge)
- BH-DVCS Interference term $\propto Re\mathcal{A}_{\mathrm{QCD}}$
- $Re\mathcal{A}_{\mathrm{QCD}}(x, Q^2) \sim \int \frac{dx_1}{x_1} ReC_i(x/x_1, Q^2) G_i(x_1, x, Q^2) \rightarrow$ Generalized Parton Distributions GPD

At low x

$$\int_0^{2\pi} \frac{d\sigma}{d\phi} \simeq \sigma_{\mathrm{DVCS}} - \sigma_{\mathrm{BH}}$$

Models for DVCS

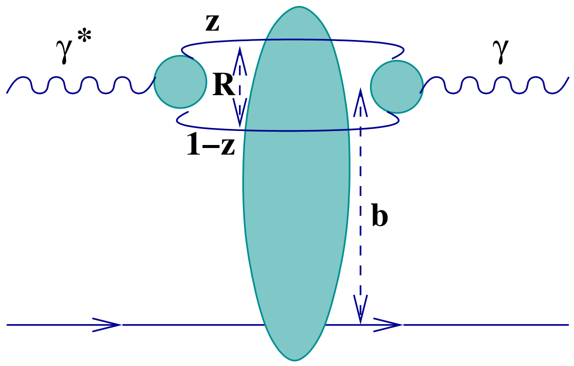


GPD-based Model (Frankfurt, Freund and Strikman FFS)

$$\frac{d^3\sigma_{\rm DVCS}}{dx dQ^2 dt} = \frac{\pi^2\alpha^3}{2xR^2Q^6}[1+(1-y)^2]e^{bt}F_2{}^2(x,Q^2)(1+\rho^2)$$

$$R = Im\mathcal{A}(\gamma^\star p \to \gamma^\star p)|_{t=0} / Im\mathcal{A}(\gamma^\star p \to \gamma p)|_{t=0}$$

$$\rho = Re\mathcal{A}(\gamma^\star p \to \gamma p)|_{t=0} / Im\mathcal{A}(\gamma^\star p \to \gamma p)|_{t=0}$$

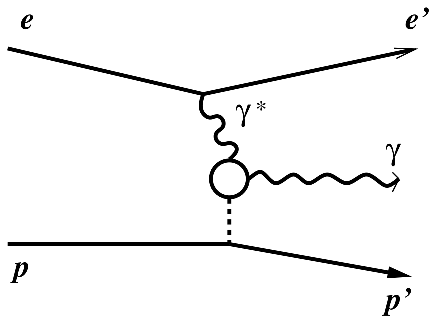


Colour Dipole Model

$$\mathcal{A} \sim \int_{R,z} \psi_{ini}^{\gamma^*} \sigma_D \psi_{out}^{\gamma}$$

σ_D - dipole-p cross section

QCD-BASED PREDICTIONS AT LOW x, HIGH y



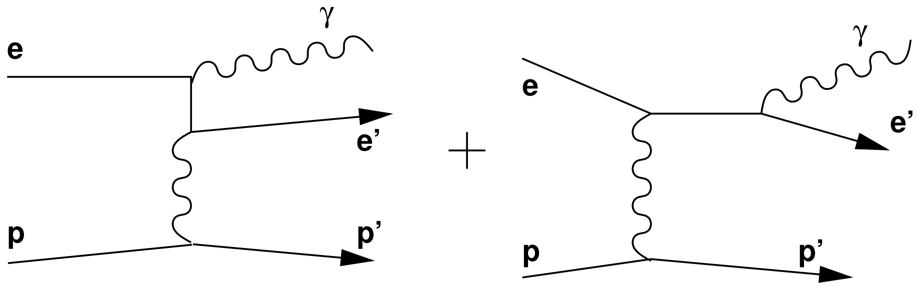
$$\frac{d^4\sigma^{DVCS}}{dxdydtd\phi} \sim \frac{1}{Q^6} e^{-b|t|}(1+\eta^2)$$

$$\eta = \frac{Re(A(\gamma^* p \to \gamma p))}{Im(A(\gamma^* p \to \gamma p))}$$

$$\frac{d^4\sigma^{INT}}{dxdydtd\phi} \sim \pm \frac{1}{Q^5}\eta \frac{e^{-b|t|/2}}{\sqrt{|t|}} \cos\phi$$

$$\phi = \phi'_e - \phi'_p$$

b-not predicted by models

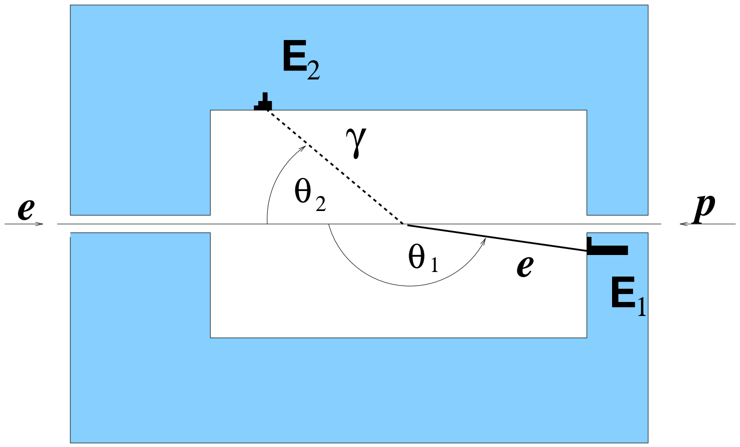


$$\frac{d^4\sigma^{BH}}{dxdydtd\phi} \sim \frac{1}{Q^4}\frac{1}{|t|}$$

MC generator based on FFS $\rightarrow$ GenDVCS (Patrick Saull)

EVENT SELECTION

e^+p sample – $95\,\mathrm{pb}^{-1}$ e^-p sample – $17\,\mathrm{pb}^{-1}$



- 2 EM clusters: $E_1 > 15\,\mathrm{GeV}$, $E_2 > 2.5(3)\,\mathrm{GeV}$ and $0.6 < \theta_2 < 2.75\,\mathrm{rad} \rightarrow \theta_1 > \theta_2$
- 0 or 1 track; if 1, must be matched to EM cluster
- $40 < E - p_Z < 70\,\mathrm{GeV}$ to reject γp and hard ISR
- No other activity above noise level to reject events where the proton dissociated

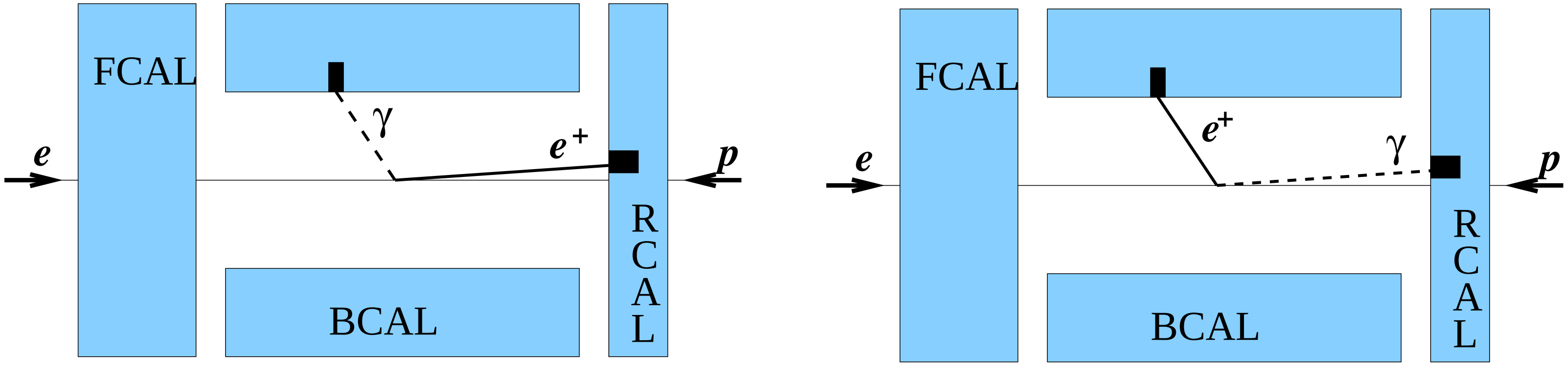
DVCS - Event Topology

Case 1 γ SAMPLE (ENRICHED DVCS)

Both BH and DVCS contribute

Case 2 e^+ SAMPLE (CONTROL SAMPLE)

Only BH contributes

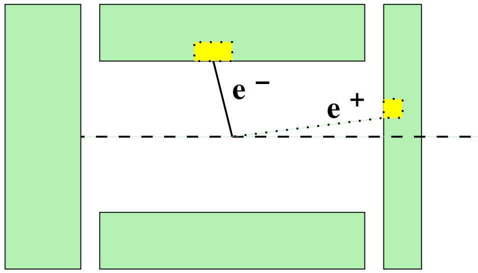


If BH MC describes data in case 2, use it to subtract BH contribution in case 1

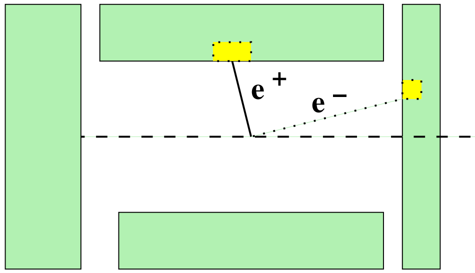
BACKGROUND STUDY e^+ sample

- Dilepton production ($e^+p \to e^+e^-e^+p$) – 4% of e-sample (75% non-resonant, $25\% J/\psi$)

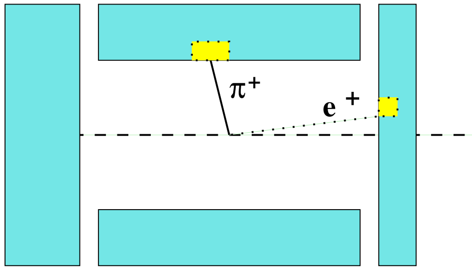
(1)



(2)



- Diffractive ρ production ($ep \to e\rho p$, $\rho \to \pi^+\pi^-$) (negligible for $Q^2 > 5\,\mathrm{GeV}^2$)

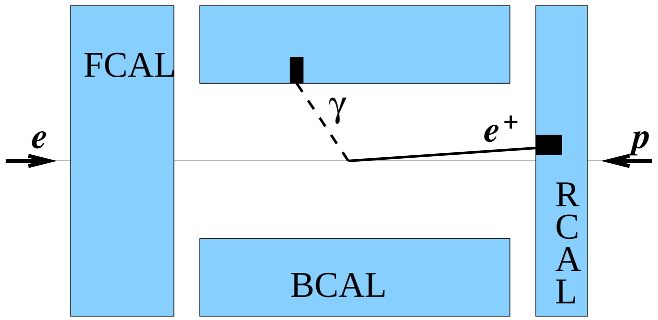


- Proton dissociative BH ($ep \to e\gamma X$) – $(17.8 \pm 1.2)\%$ in 96-97 (PRT), $(10.5 \pm 1.0)\%$ in 98-00 (FPC)

Good agreement with BH - GRAPE MC

BACKGROUND STUDY CONT'D

γ sample

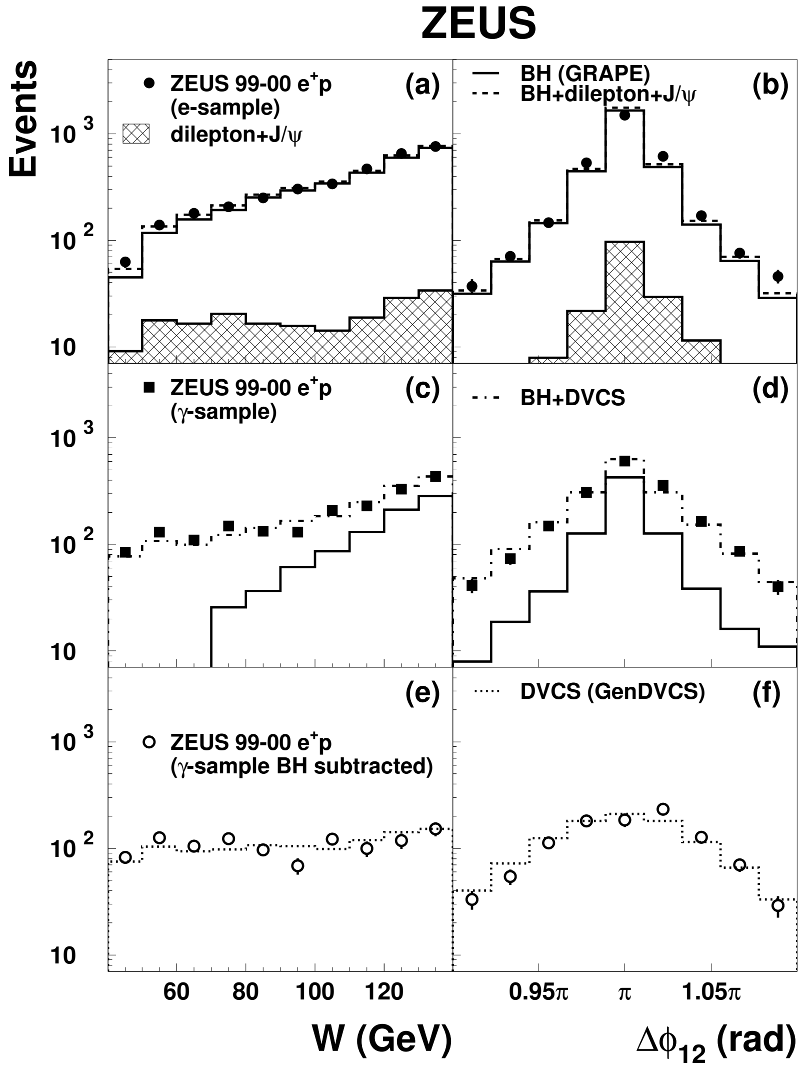


- BH process ($ep \to e\gamma p$) - use normalised MC from e^+ sample
- Diffractive ω or ϕ production below 1% – neglected
- low-multiplicity process like $ep \to e\pi^0 p$, $ep \to e\pi^0\pi^0 p$, $ep \to e\pi^0 \eta p$ (negligible)
- Proton dissociative DVCS ($ep \to e\gamma X$) – taken from J/ψ analysis

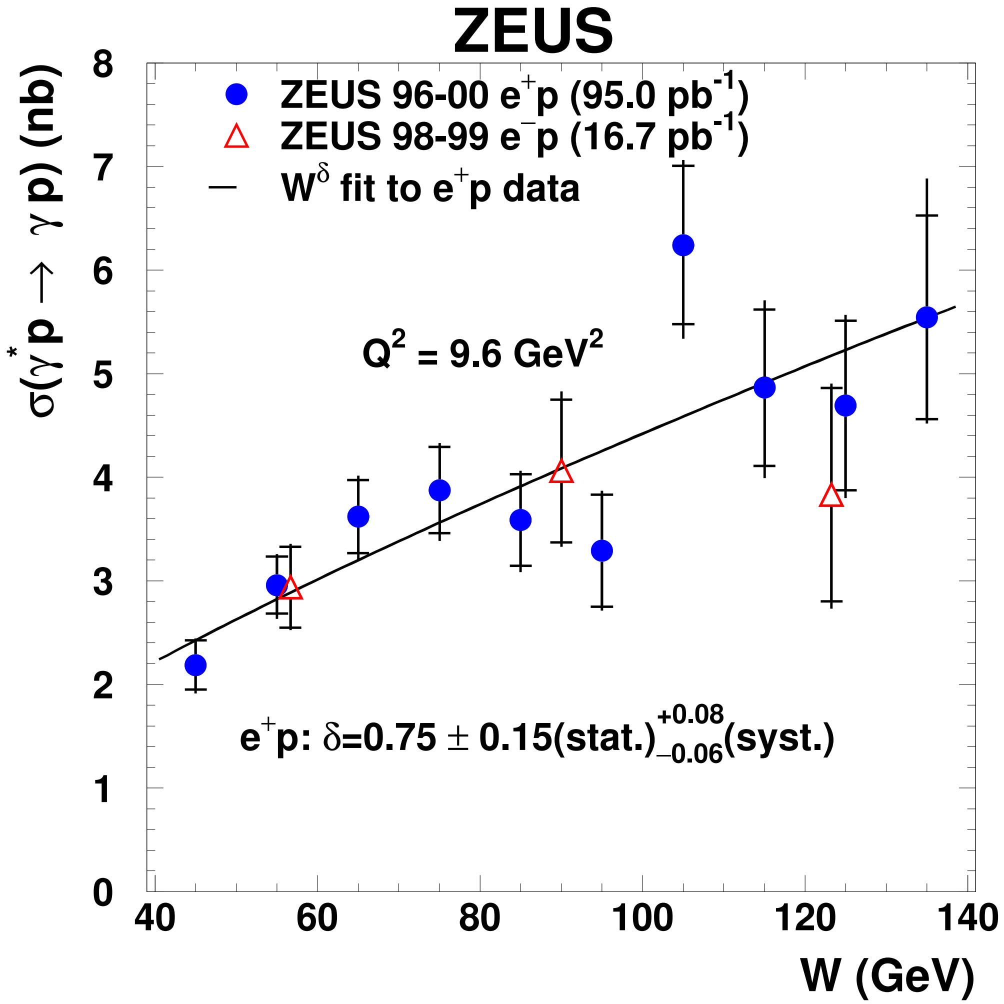
$$f_{\mathrm{p-diss}} = 22.0 \pm 2.0(\mathrm{stat.}) \pm 2(\mathrm{syst.})\% \qquad \text{for } 96-97 \text{ data}$$

$$f_{\mathrm{p-diss}} = 17.5 \pm 1.3(\mathrm{stat.}) \pm^{+3.7}_{-3.2}(\mathrm{syst.})\% \qquad \text{for } 98-00 \text{ data}$$

CONTROL PLOTS e^+p 99-00 SAMPLE

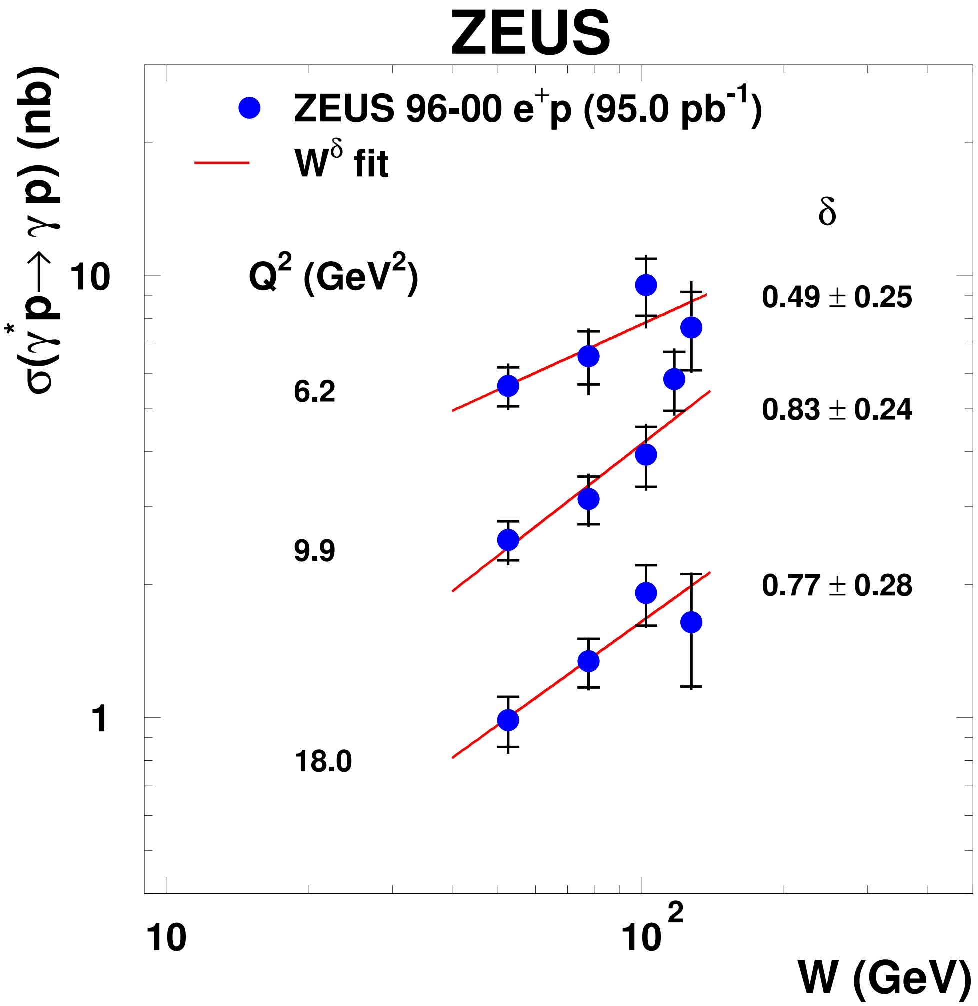


e^+p VS e^-p, $5 < Q^2 < 100\,\mathrm{GeV}^2$

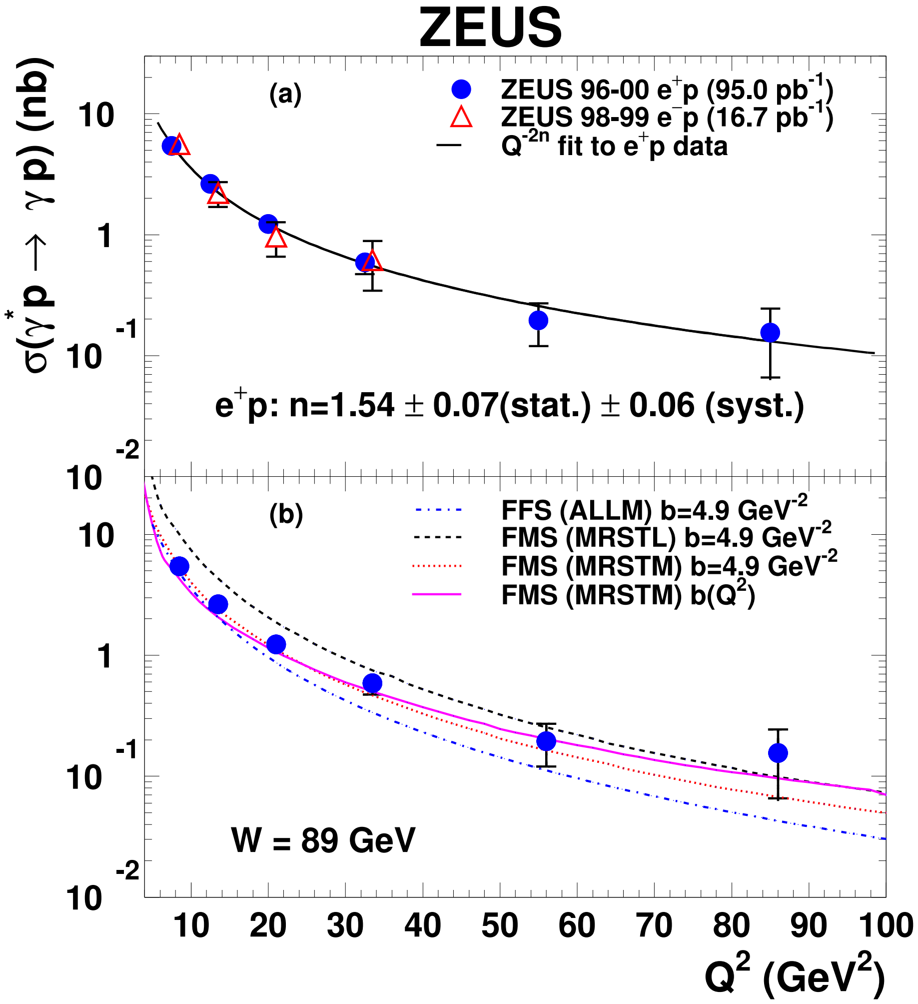


- No significant differences
- $\sigma(\gamma^* p \to \gamma p) \propto W^{0.75}$

W DEPENDENCE AS A FUNCTION OF Q^2

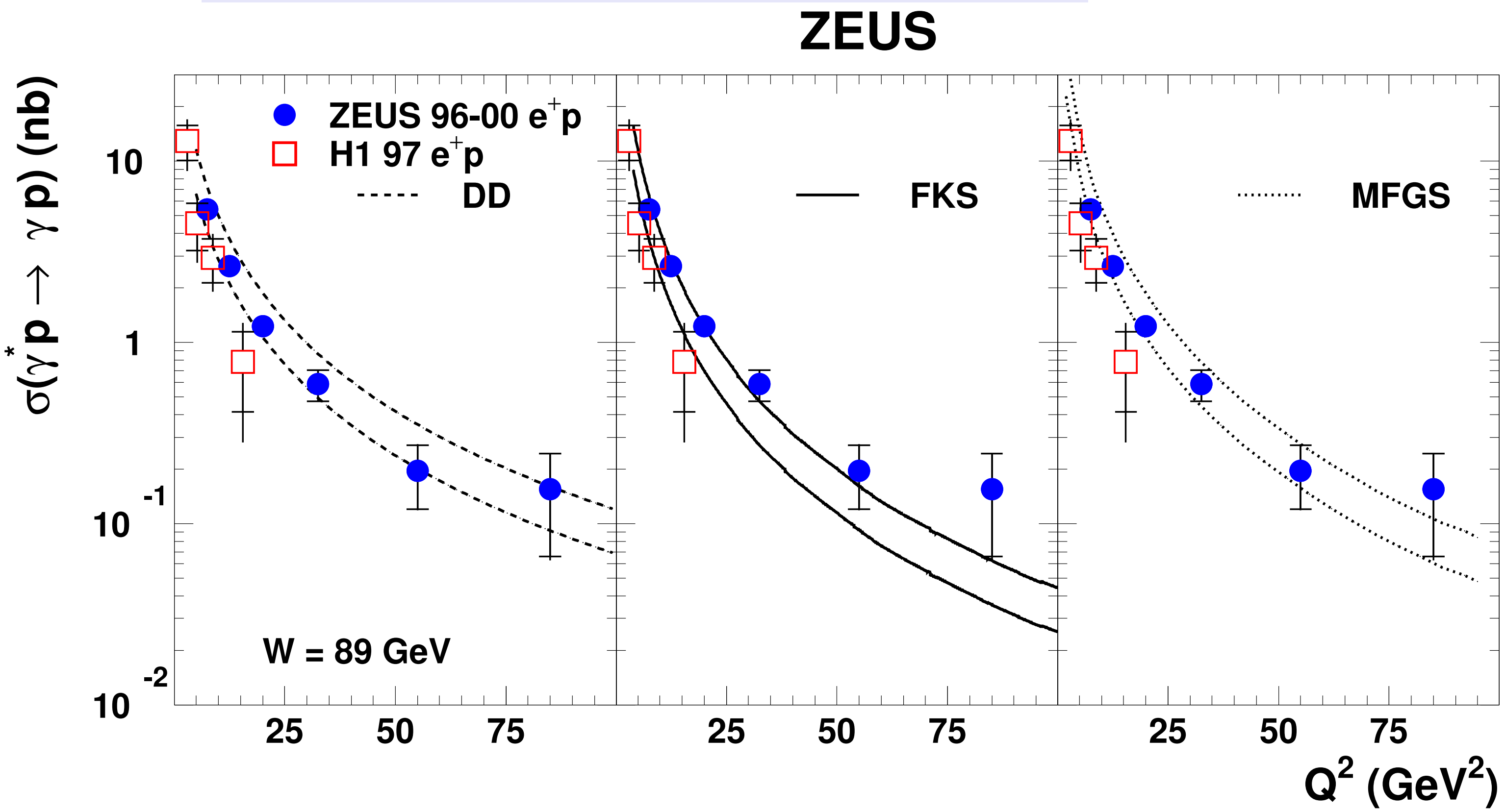


Q^2 DEPENDENCE FOR $W = 89\,\mathrm{GeV}$



$b(Q^2) = 8(1 - 0.15\ln(Q^2/2))\,\mathrm{GeV}^{-2}$ (Freund, McDermott and Strikman)

Comparison with Models



upper curves $b = 4\,\mathrm{GeV}^{-2}$ lower curves $b = 7\,\mathrm{GeV}^{-2}$

SUMMARY

- $\sigma(\gamma^* p \to \gamma p)$ measured in the range $5 < Q^2 < 100\,\mathrm{GeV}^2$ and $40 < W < 140\,\mathrm{GeV}$
- No significant difference between e^+p and e^-p
- Q^2 dependence is $\approx Q^{-3}$
- $\sigma(\gamma^* p \to \gamma p)$ rises steeply with W $\to$ hard process
- Q^2 dependence of b may be crucial in extracting GDPs, however t dependence cannot be measured at this time