PHOTON 2007

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Diffractive Vector Meson Production and DVCS at HERA

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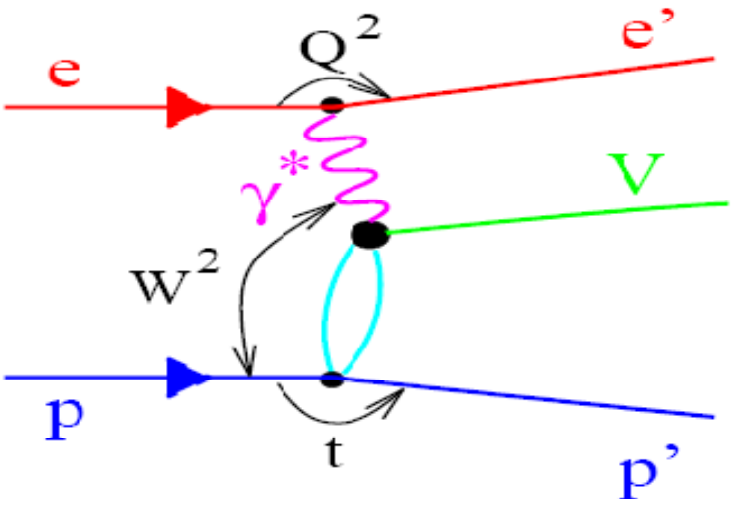
on behalf of the ZEUS and H1 Collaborations

Outline:

- Introduction
- Deeply Virtual Compton Scattering (DVCS)
- Elastic Electroproduction of Vector Mesons
- Pomeron trajectory
- Summary

Elastic Vector Mesons production

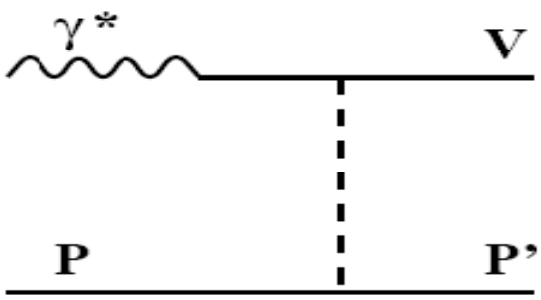


$V = (\rho^o, \omega, \phi, J/\psi, \Upsilon)$

$V = \gamma\,(DVCS)$

- $Q^2 = -(e - e')^2$ photon virtuality
- W is $\gamma^* p$ center of mass (CM) energy
- $t = (p - p')^2$ momentum transfer squared at the proton vertex

VDM and Regge theory (soft diffraction)



- The photon fluctuates into a vector meson, V, which carries the same quantum numbers as the photon ($\gamma p \longrightarrow$ Vp)
- The vector meson scatters elastically off the incoming proton (Vp $\longrightarrow$ Vp)

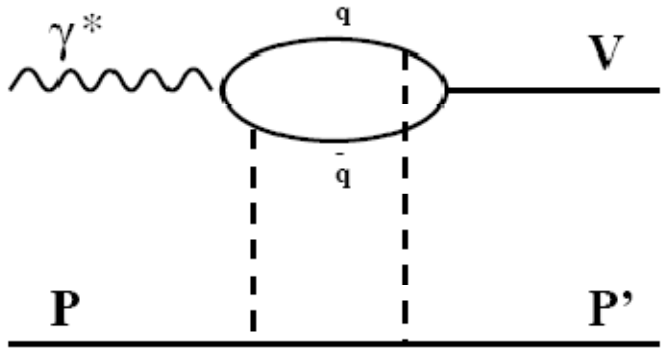
Predictions :

- $\frac{d\sigma(\gamma p \to Vp)}{dt} \propto e^{-b_0|t|}(W^2/W_0^2)^{2(\alpha(t)-1)}$

Experimental observations :

- $\alpha(t) = 1.08 + 0.25t$ (DL parametrization, Soft Pomeron)
- Shrinkage of the diffractive peak
  $b(W) = b_0 + 2\alpha' \ln(W^2/W_0^2)$ $\qquad b_0 \sim 10$ GeV^{-2}
- Weak energy dependence of cross section
  $d\sigma/dt \propto W^{\delta}$, $\qquad \delta \simeq 0.2$

pQCD models, (hard diffraction)

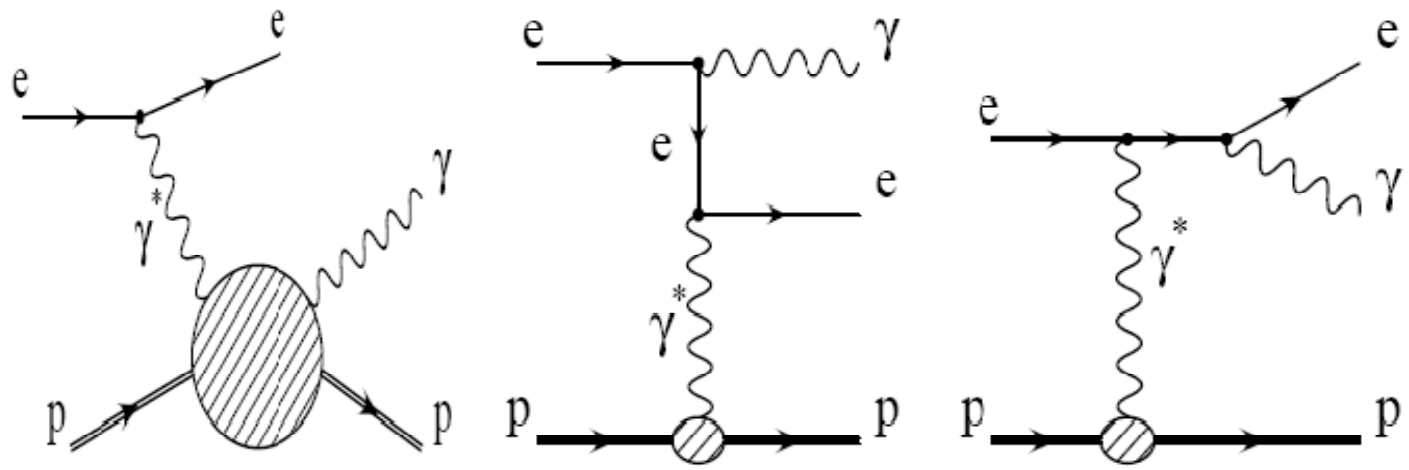


- the photon fluctuates into a $q\bar{q}$ state,
- the $q\bar{q}$ pair scatters off the proton target, (color dipole model)
- the scattered $q\bar{q}$ pair turns into a vector meson.

Predictions :

- $\sigma_L \propto \frac{\alpha_S^2(Q)}{Q^6}|xG(x,Q^2)|^2$
- A fast increase of the $\gamma^* p \to Vp$ cross section with energy W (longitudinal cross section dominates at large Q^2)
- Universal exponential t dependence, $b \sim 4-5\,\mathrm{GeV}^{-2} \implies \alpha' \to 0$?

DVCS $\gamma^* p \to \gamma p$

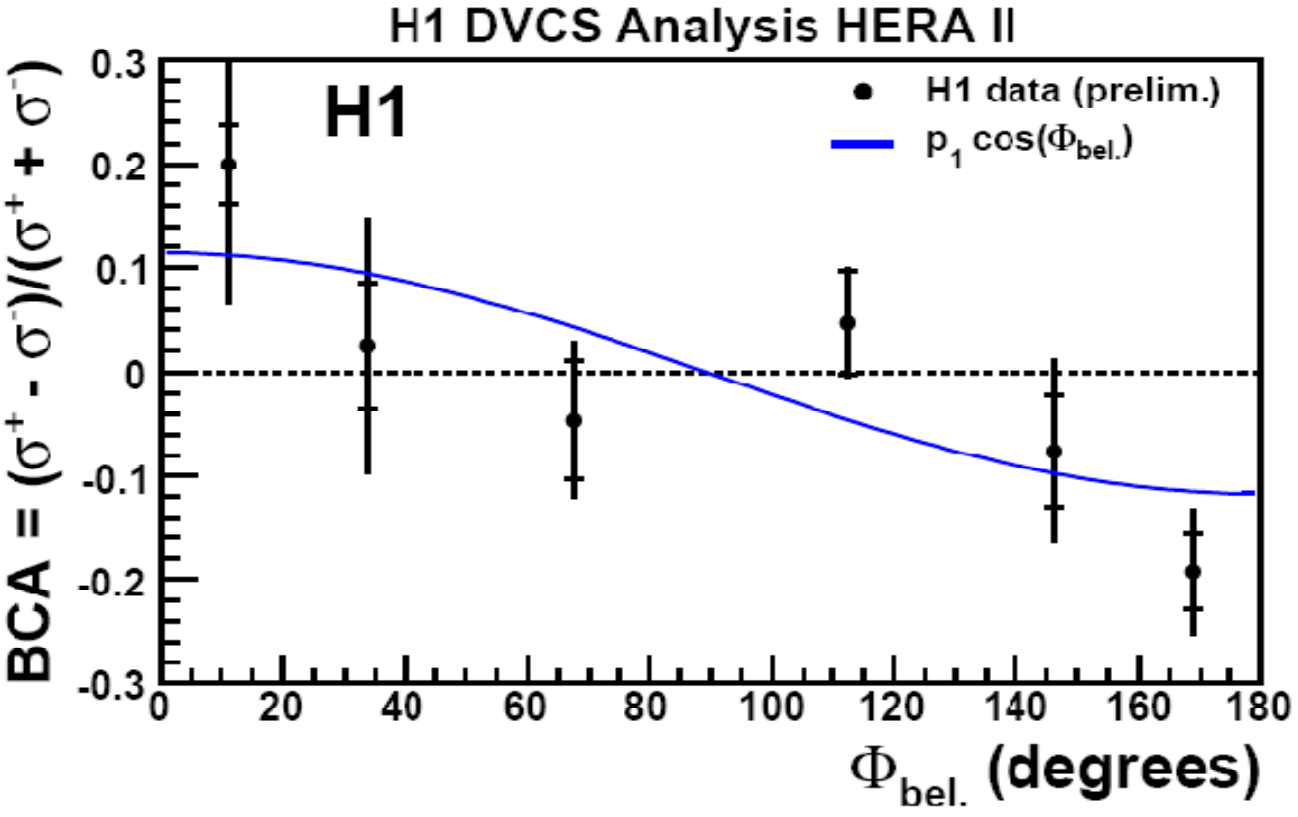


- DVCS $\Longrightarrow$ pQCD
- Bethe-Heitler $\Longrightarrow$ QED

Why is DVCS interesting ?

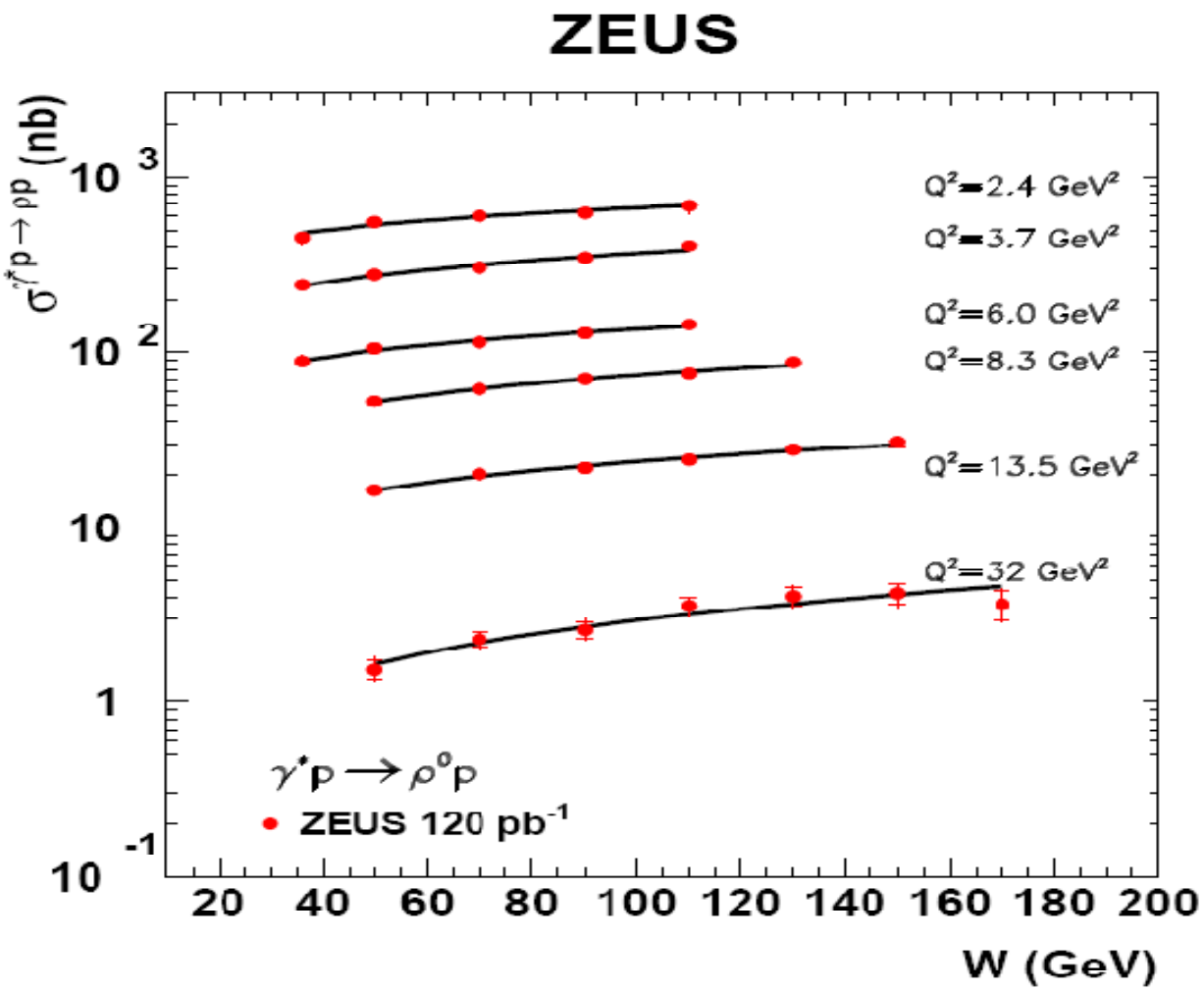
- Generalised (Skewed) Parton Distributions
- Interference of QCD amplitude with QED amplitude
- Allows for measurement of real part of a QCD amplitude

DVCS $\gamma^* p \rightarrow \gamma p$



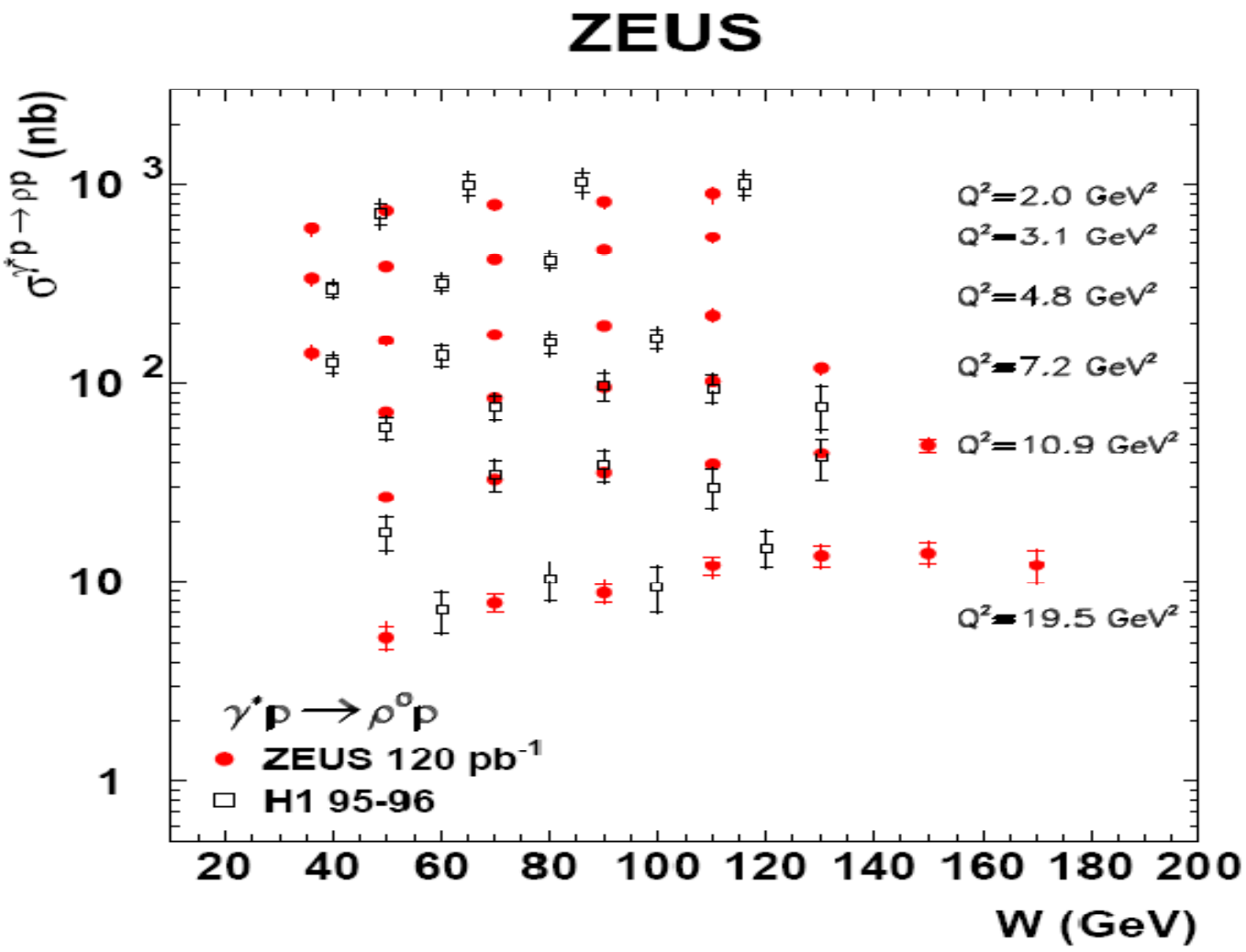
- Beam Charge Asymmetry
- BCA=$(\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-)$
- H1: BCA first measurement $\Longrightarrow$ DVCS/BH interference

Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$



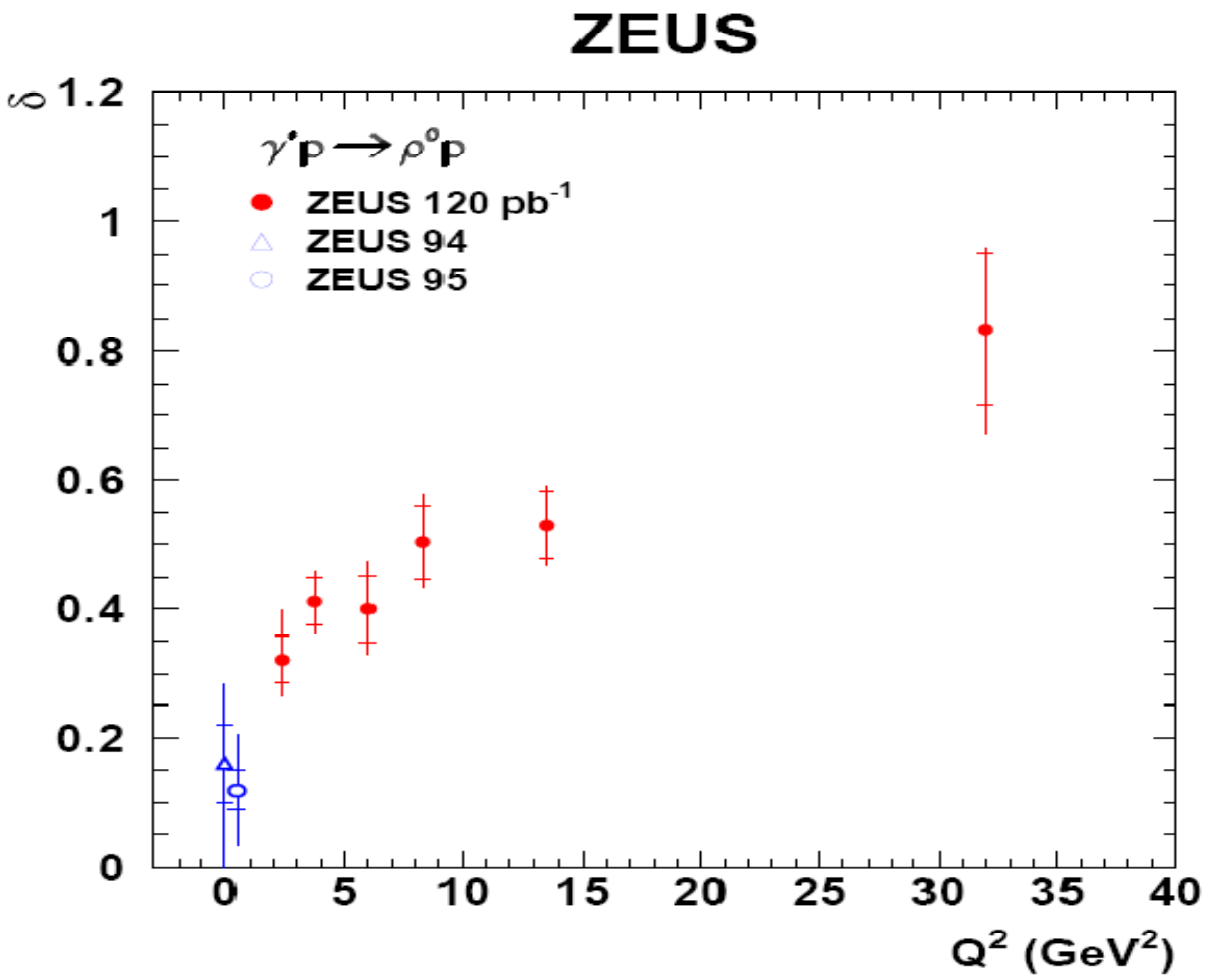
- Cross section W dependence becomes steeper at high Q^2

Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$



- similar behavior measured by H1

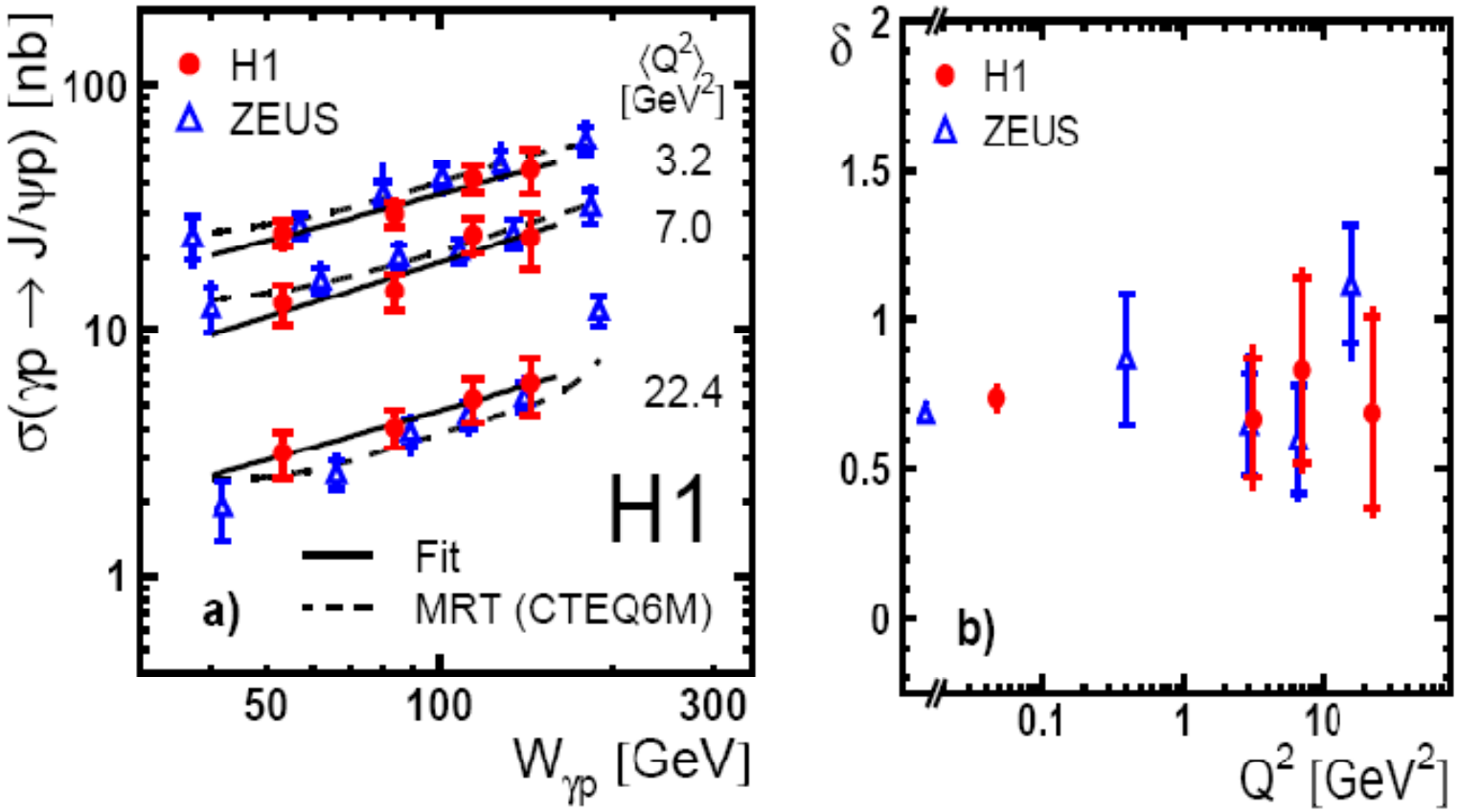
Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$



- Soft physics predicts for energy dependence $\delta \sim 0.2$

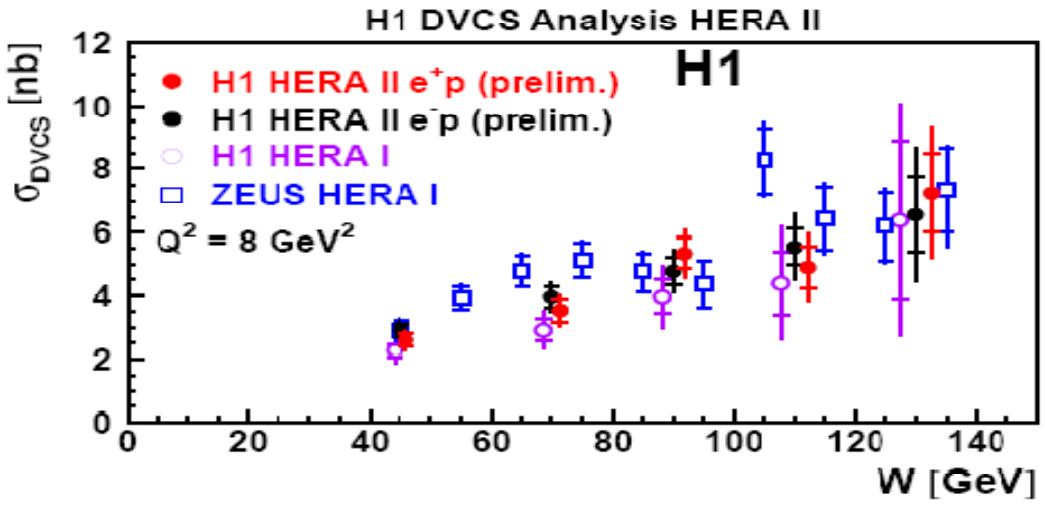
$$\sigma \sim W^{\delta(Q^2)}$$

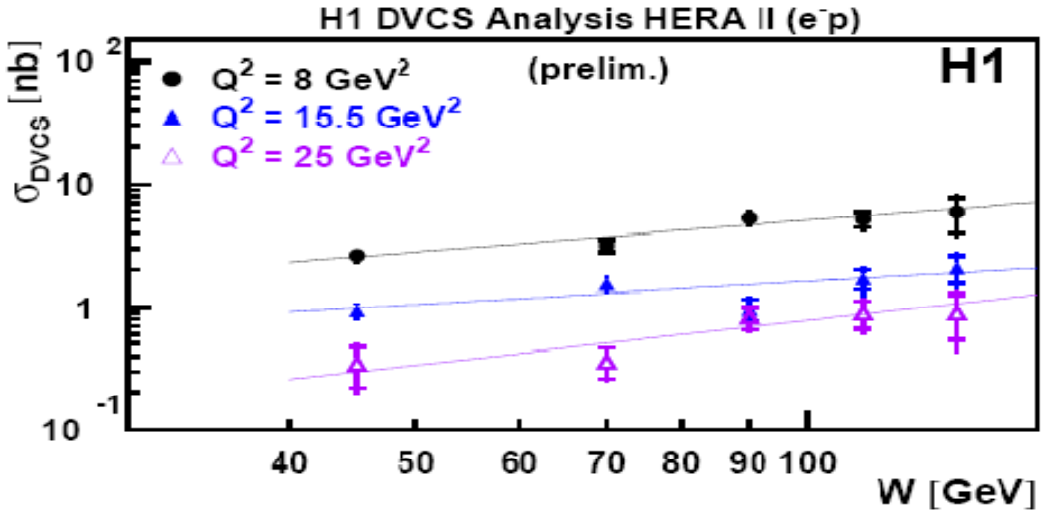
Elastic Electroproduction $\gamma^* p \to J/\Psi p$



- **Total cross section for elastic J/Ψ production as a function of W.** $\delta(Q^2 = 0) \sim 0.7$

DVCS $\gamma^* p \to \gamma p$

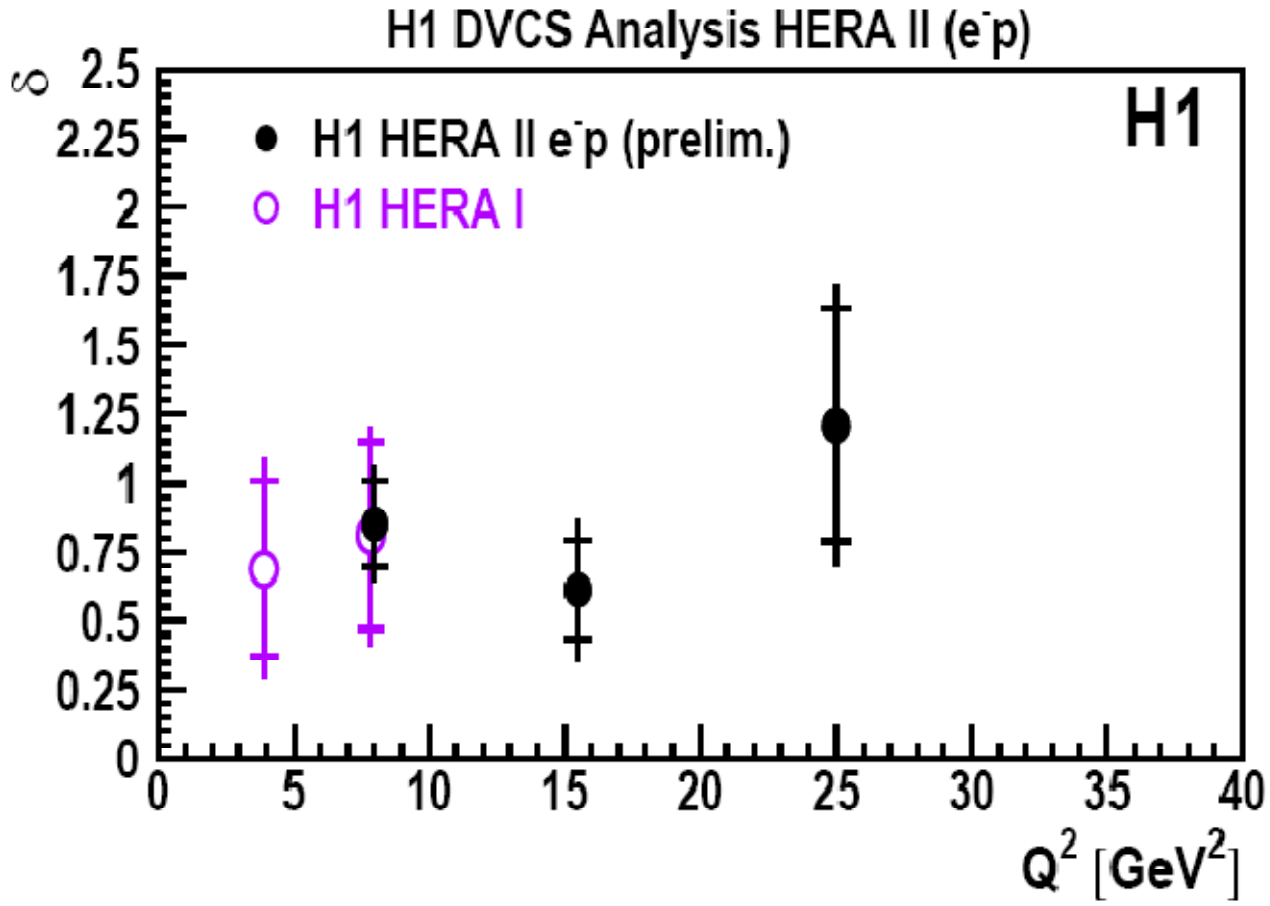




- The $\gamma^* p \to \gamma p$ cross section as a function of W

$$\sigma \sim W^{\delta(Q^2)}$$

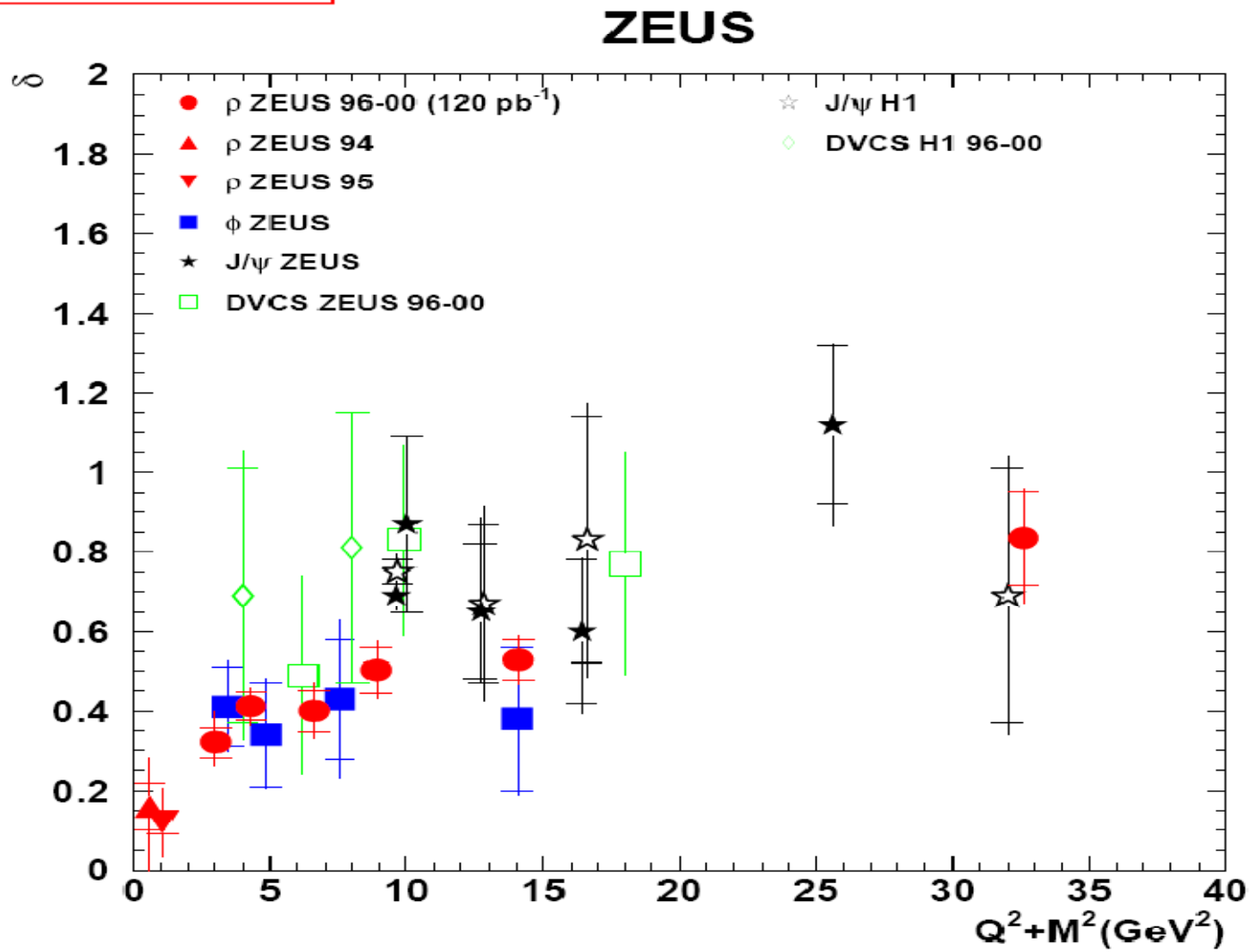
DVCS $\gamma^* p \to \gamma p$



$$\sigma \sim W^{\delta(Q^2)}$$

- fit to H1 data: $\delta = 1.00 \pm 0.16 \pm 0.22$

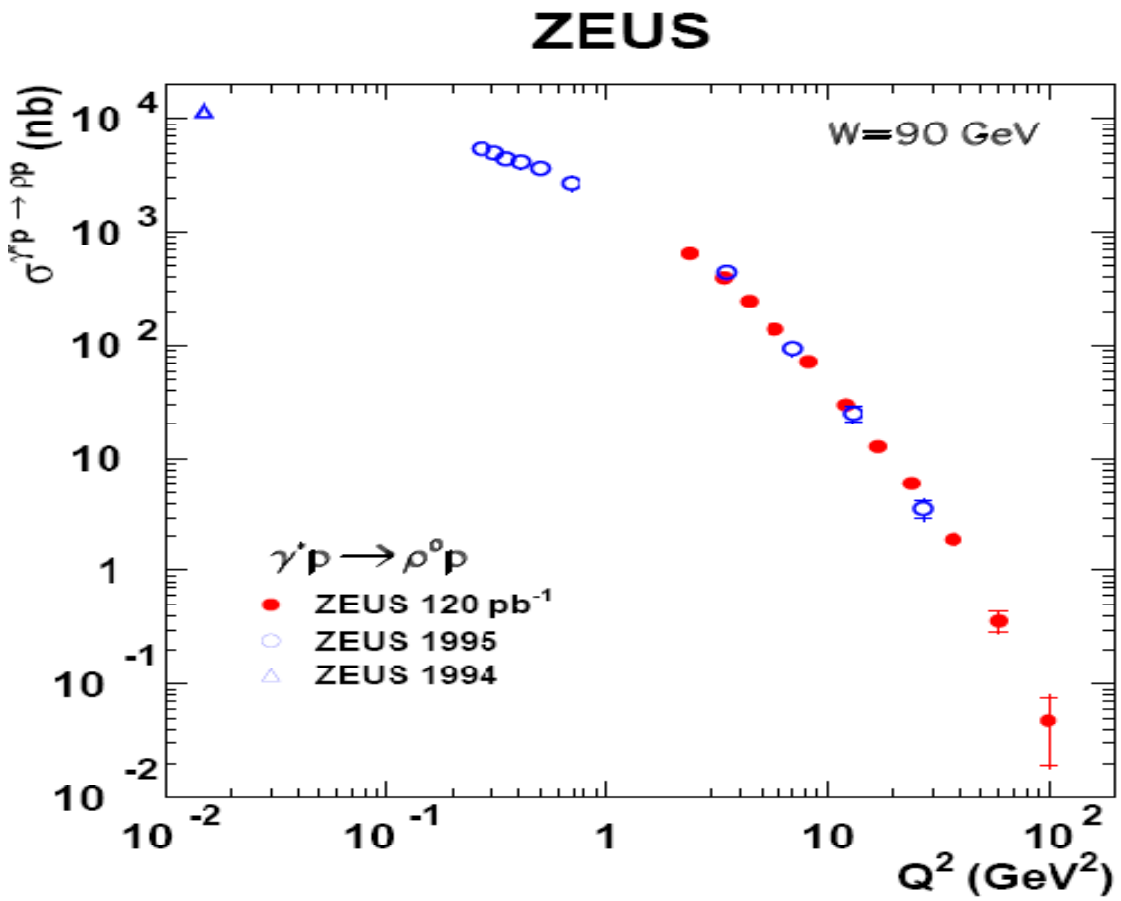
Vector mesons + DVCS



• A compilation of the value of δ for exclusive VM electroproduction and DVCS

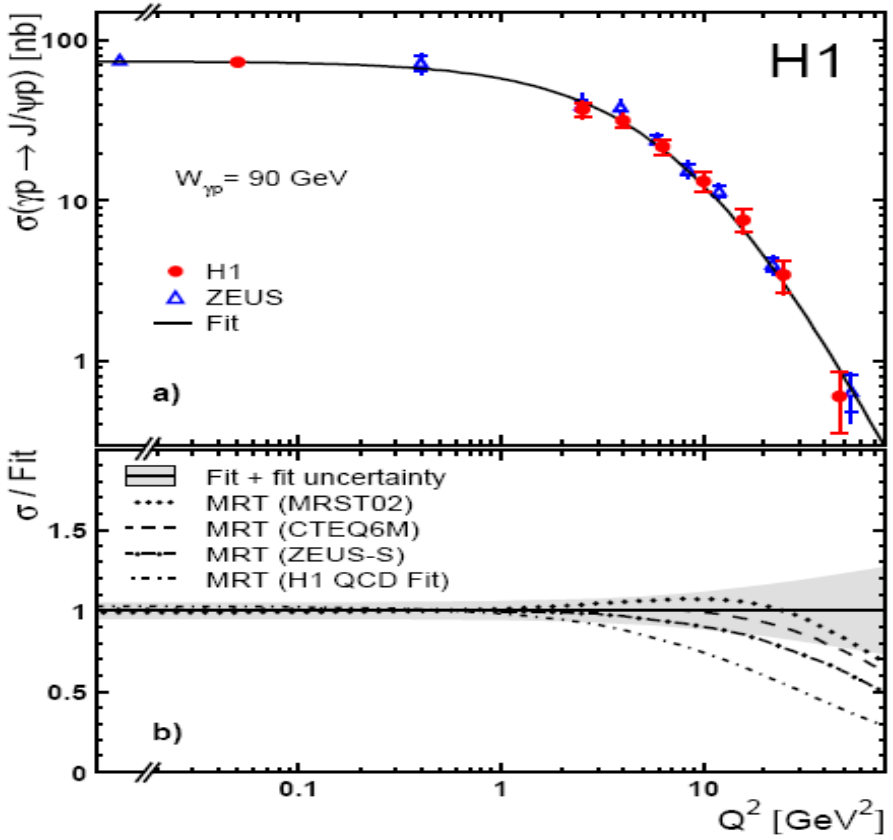
$$\sigma \sim W^{\delta(Q^2)}$$

Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$



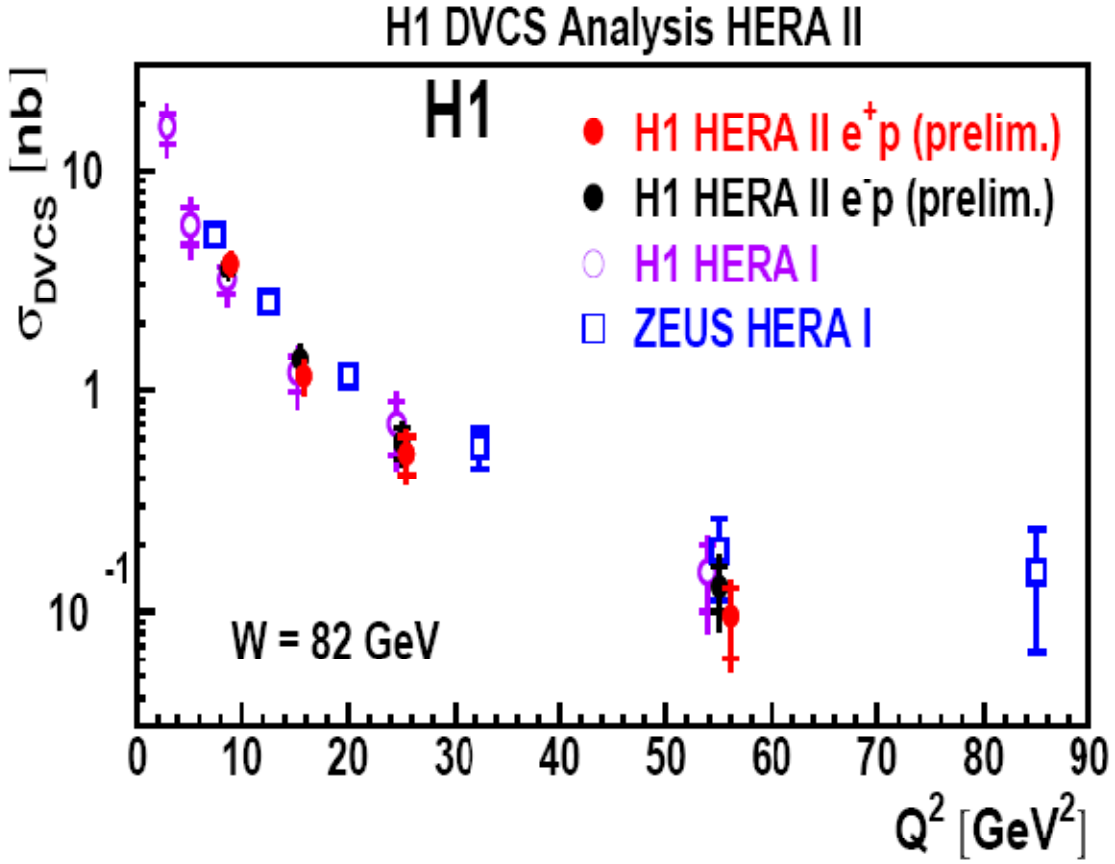
- $\sigma \propto (Q^2 + M^2)^{-n}$
- $Q^2 \geq 0$ GeV^2, n=2.00 $\pm$ 0.005, χ^2/ndf $\sim$ 30
- $Q^2 \geq 10$ GeV^2, n=2.5$\pm$0.02, χ^2/ndf $\sim$ 2

Elastic Electroproduction $\gamma^* p \to J/\Psi p$



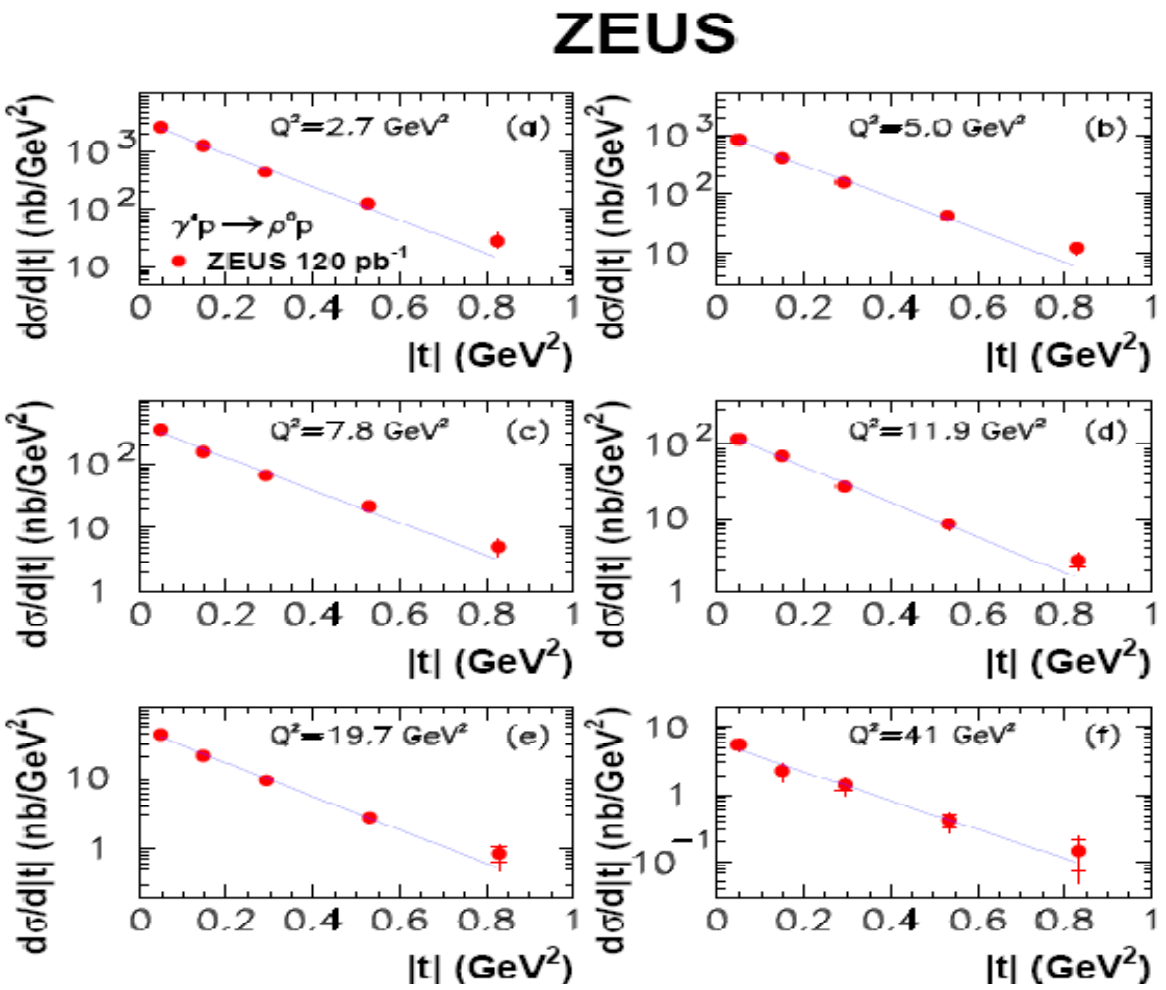
- Total cross section for elastic J/Ψ production as a function of Q^2.
- $\sigma \propto (Q^2 + M^2)^{-n}$
- $Q^2 \geq 0$ GeV^2, n=2.486$\pm$0.08$\pm$0.068

DVCS $\gamma^* p \to \gamma p$



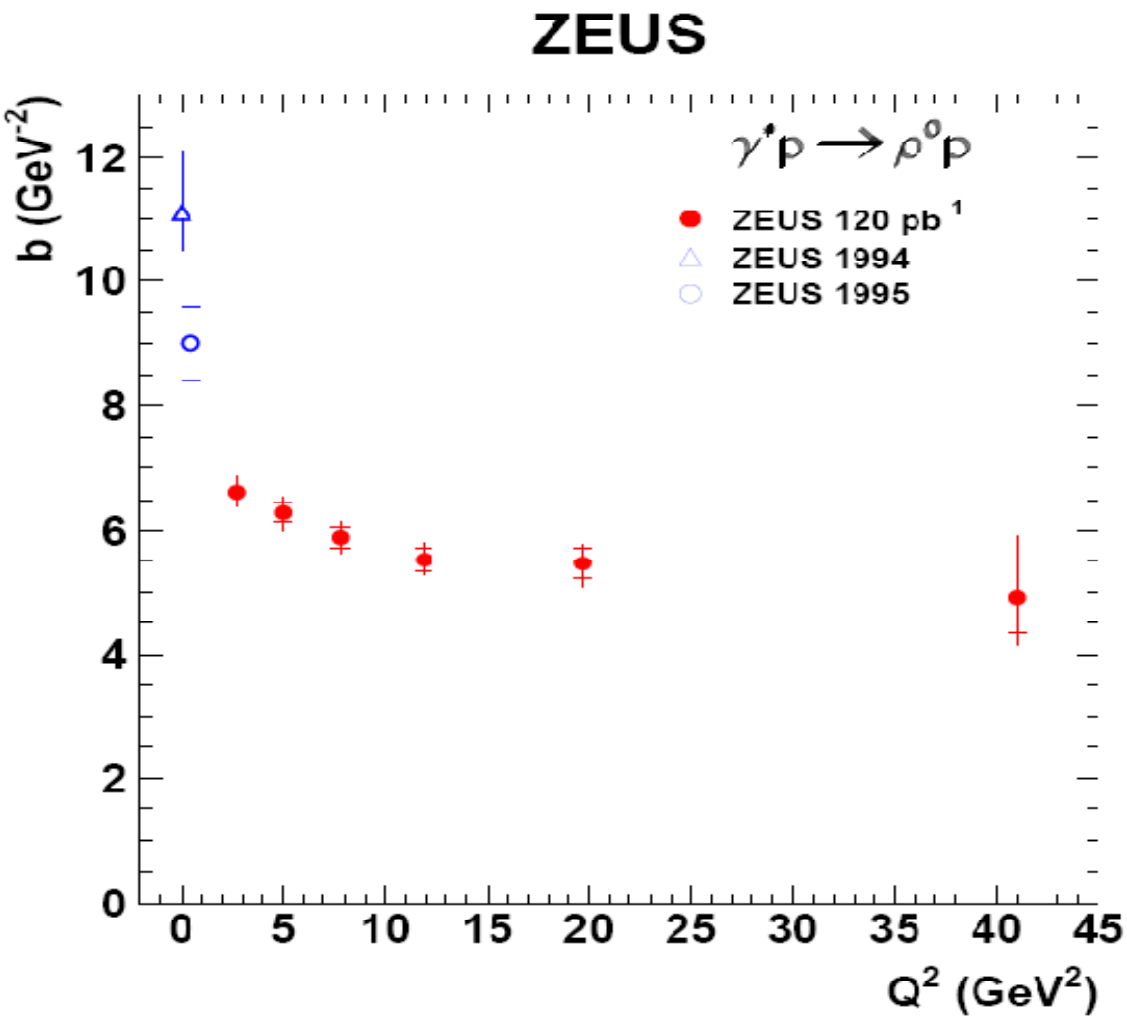
- The $\gamma^* p \to \gamma p$ cross section as a function of Q^2
- $\sigma \propto 1/(Q^2)^n$
- n=1.54$\pm$0.09$\pm$0.04

Elastic Electroproduction $\gamma^* p \to \rho p$



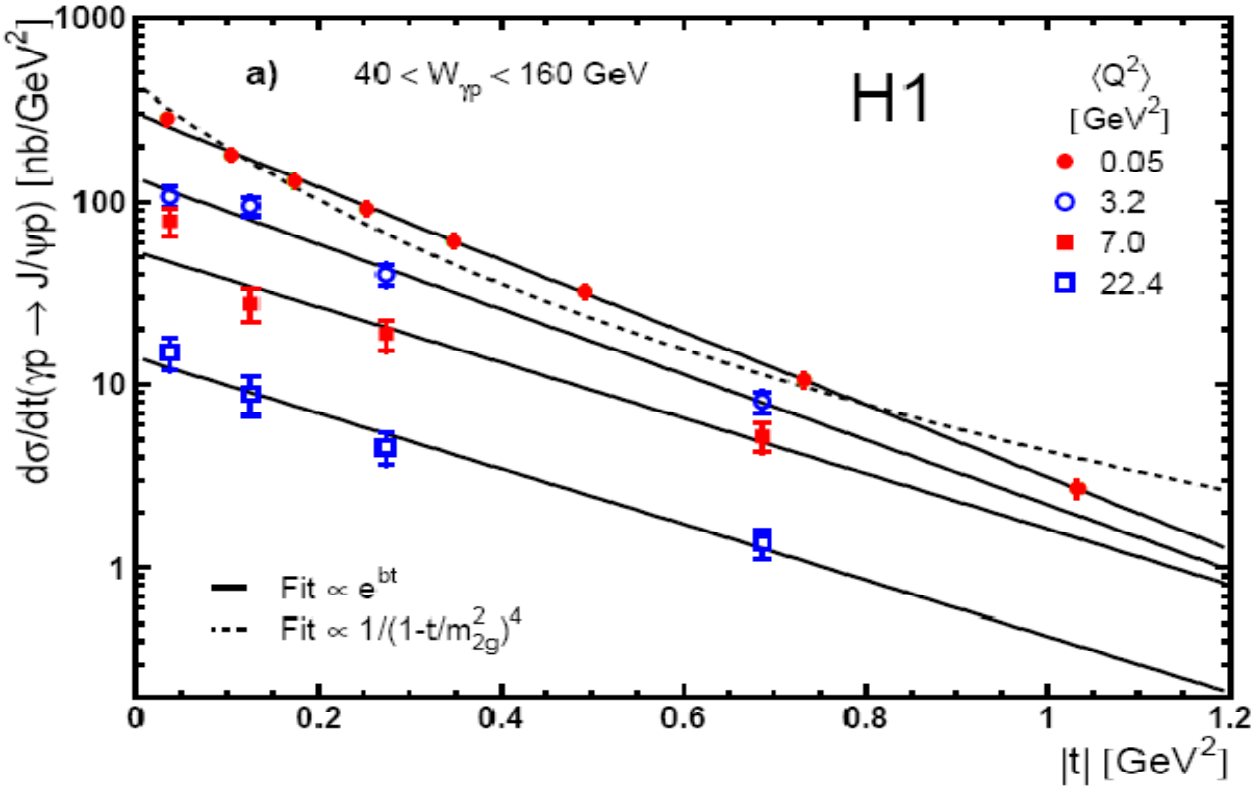
- Differential cross section $d\sigma/d|t|$ as a function of $|t|$ for different bins of Q^2

Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$



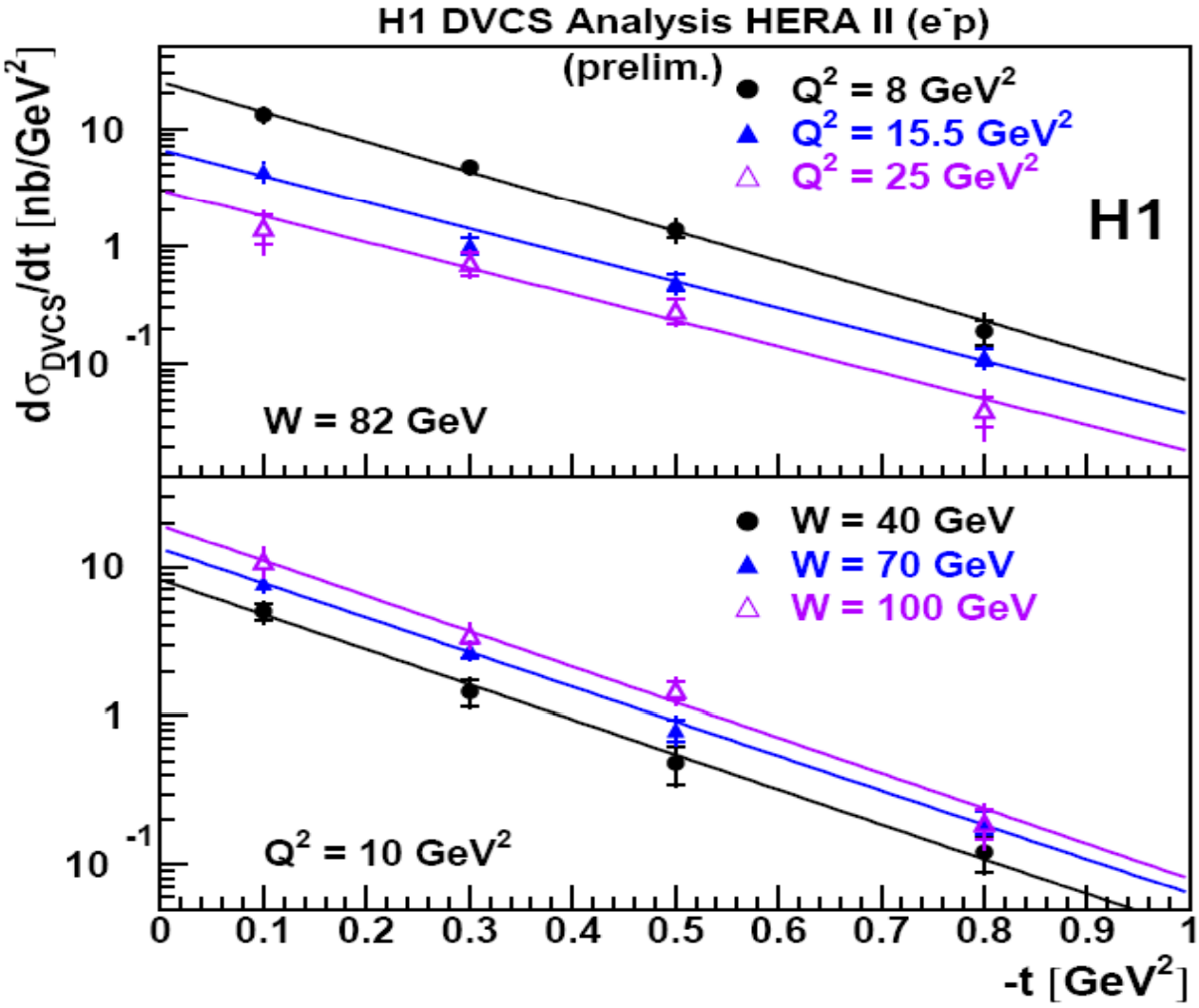
- The value of the b slope from a fit of the form $d\sigma/d|t| \sim exp(b|t|)$ as a function of Q^2.

Elastic Electroproduction $\gamma^* p \longrightarrow J/\Psi p$



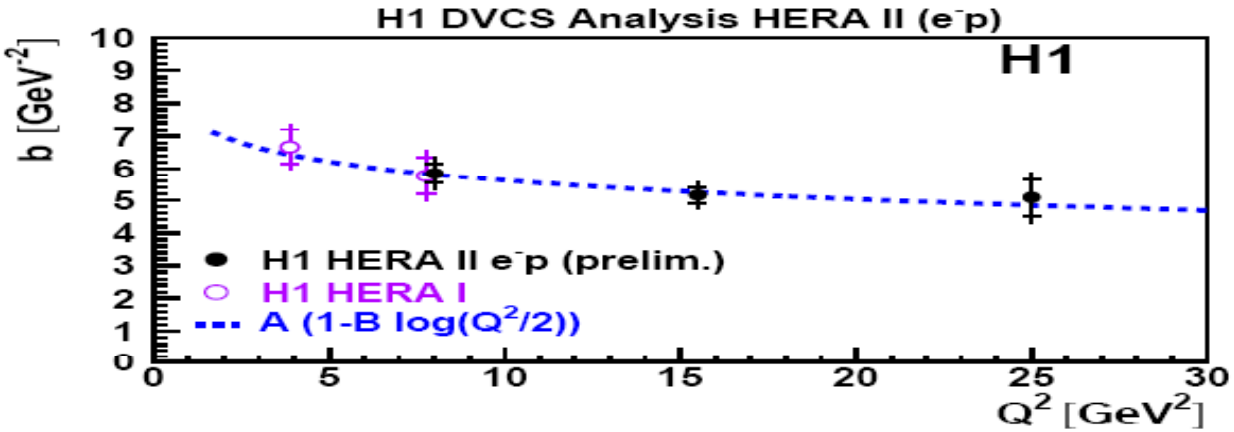
• **Differential cross section $d\sigma/d|t|$ for elastic J/Ψ production as a function of $|t|$ for different bins of Q^2**

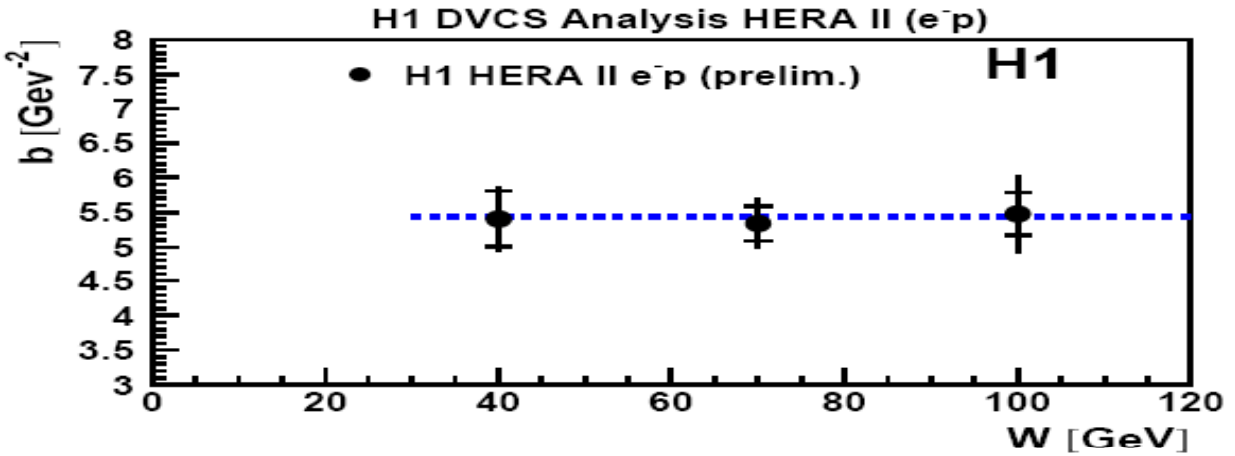
DVCS $\gamma^* p \to \gamma p$



• Differential cross section $d\sigma/d|t|$ for $\gamma^* p \to \gamma p$ reaction as a function of $|t|$ in bins of Q^2 and in bins of W

DVCS $\gamma^* p \longrightarrow \gamma p$





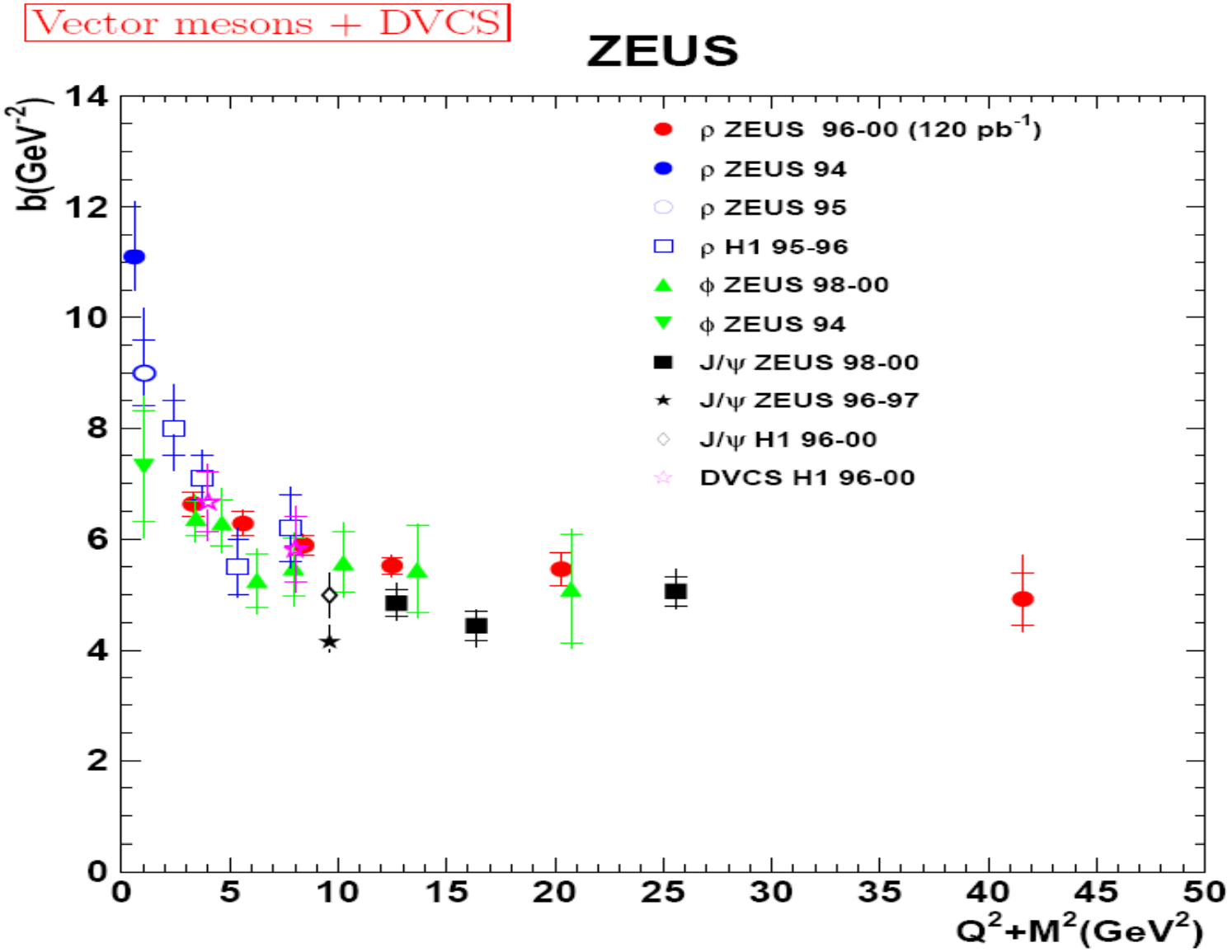
- b slope as a function of Q^2

$b(Q^2) = A(1 - B \cdot log(Q^2/2))$

A=$6.98 \pm 0.98 \mathrm{GeV}^{-2}$ and B=0.12 ± 0.03

- b slope as a function of $W \Longrightarrow$ no W dependence
- Global value: b=$5.45 \pm 0.19 \pm 0.34$ GeV^{-2}

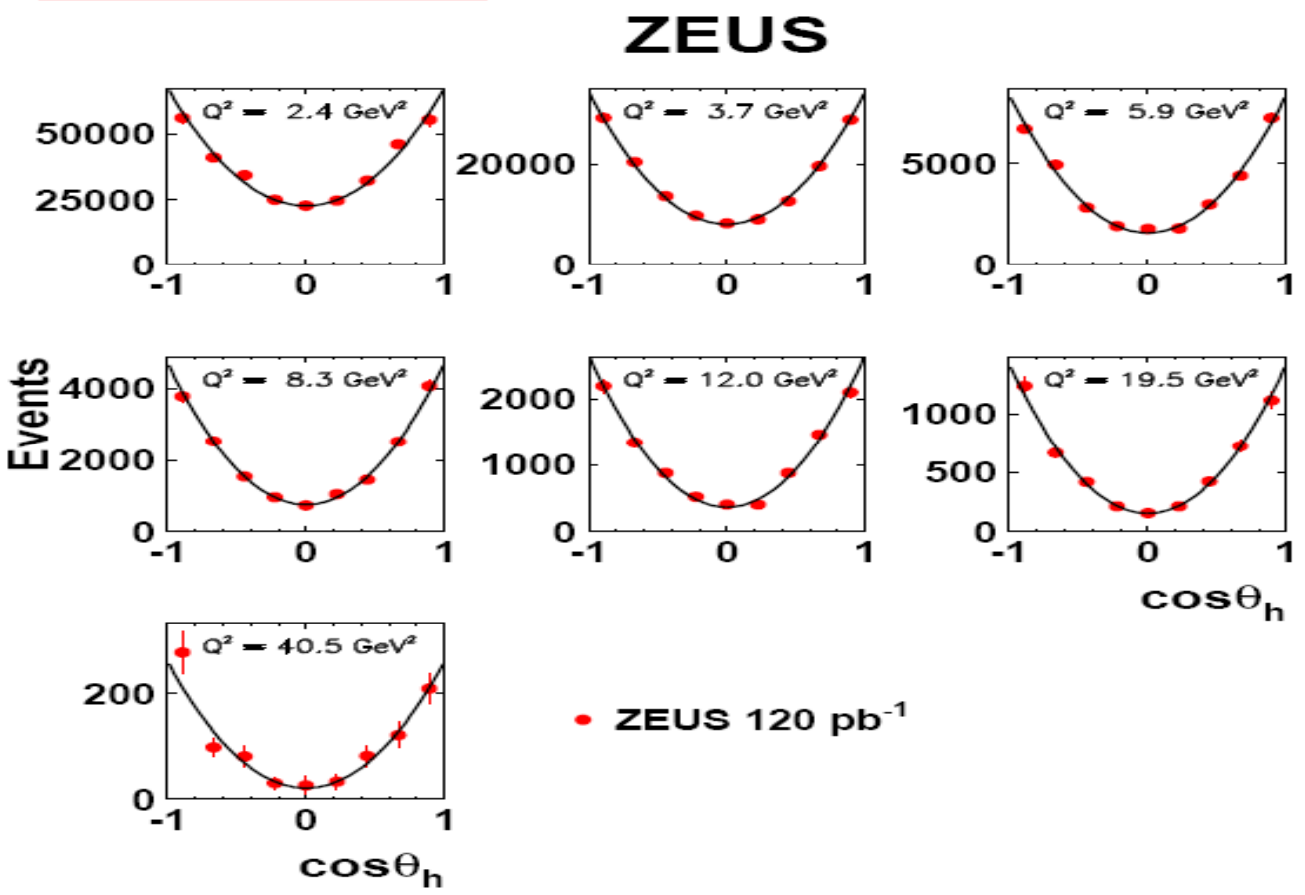
Vector mesons + DVCS



- Value of b decreases from soft ($\sim$ 10 GeV^{-2}) to hard ($\sim$ 4-5 GeV^{-2})

$$d\sigma/dt \sim exp(-bt)$$

Helicity Studies



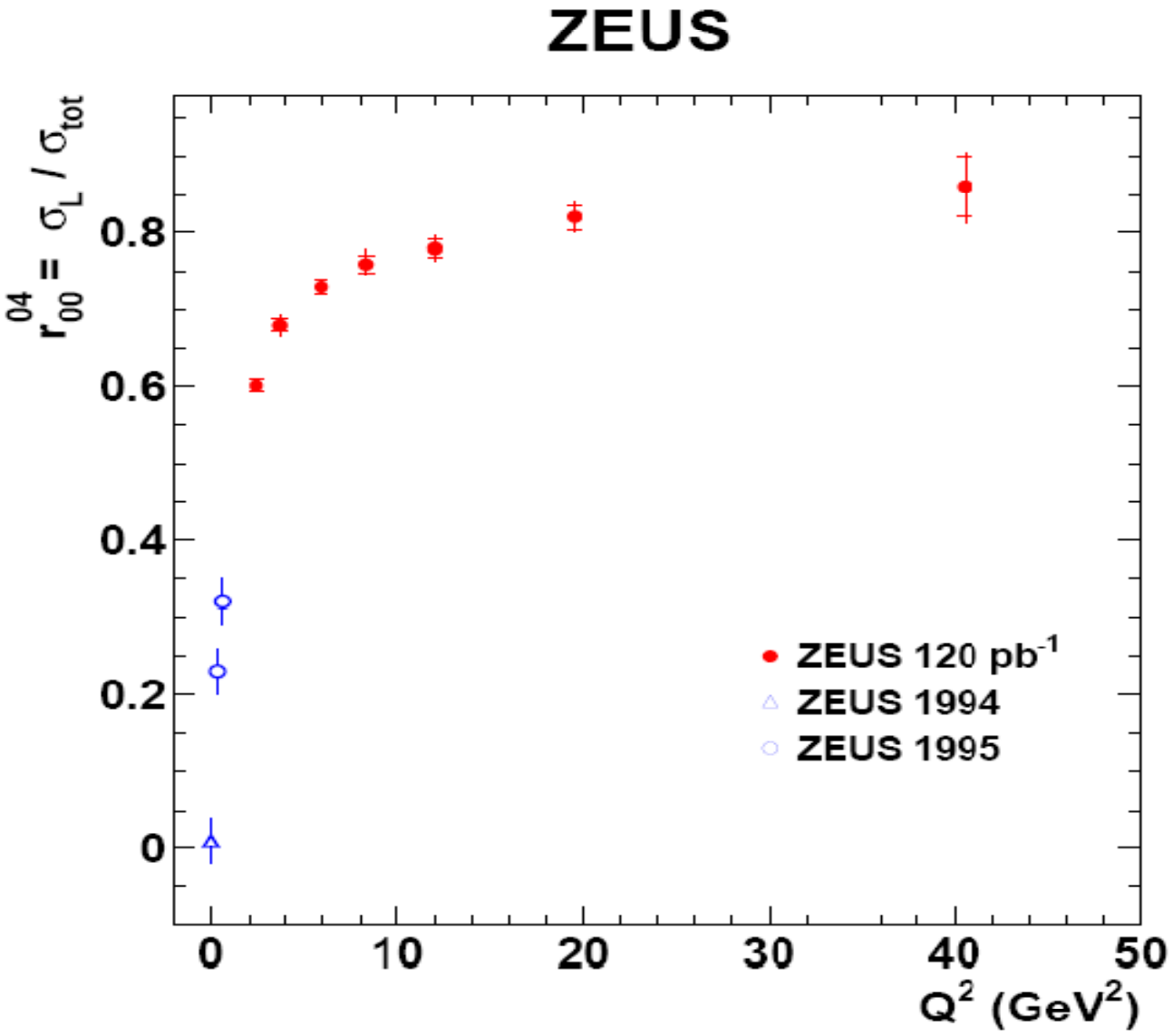
s-channel helicity conservation (SCHC)

- the VM retains the γ^* helicity
- if SCHC holds $\Longrightarrow$ $R = \sigma_L/\sigma_T = r_{00}^{04}/\epsilon(1 - r_{00}^{04})$

(at HERA kinematics $\epsilon \approx 1$)

- $d\sigma/dcos\theta_h \propto 1 - r_{00}^{04} + (3r_{00}^{04} - 1)cos^2\theta_h$
- $r_{00}^{04} = \sigma_L/\sigma_{tot}$

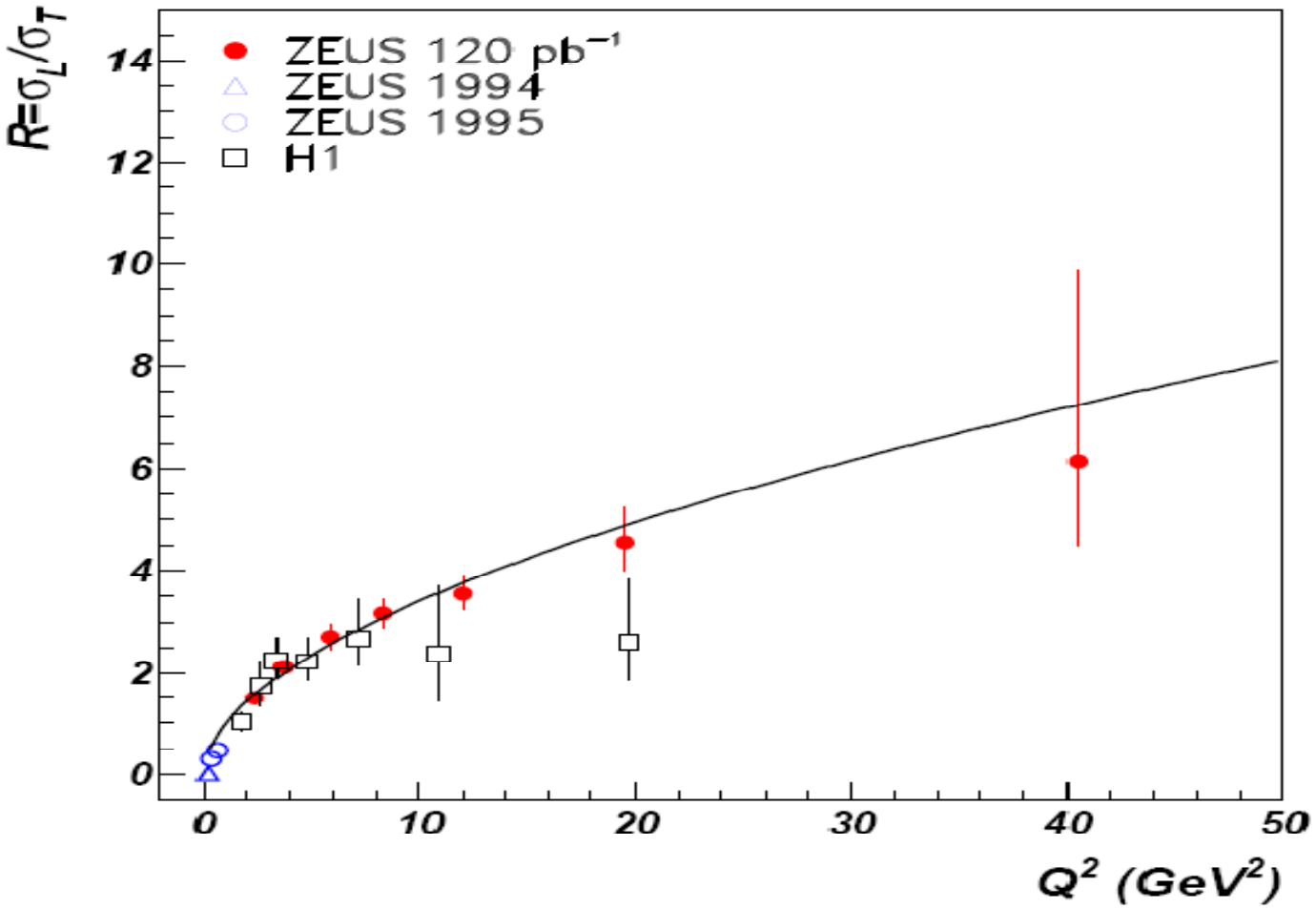
σ_L/σ_{tot}



- Longitudinal cross section increases with Q^2

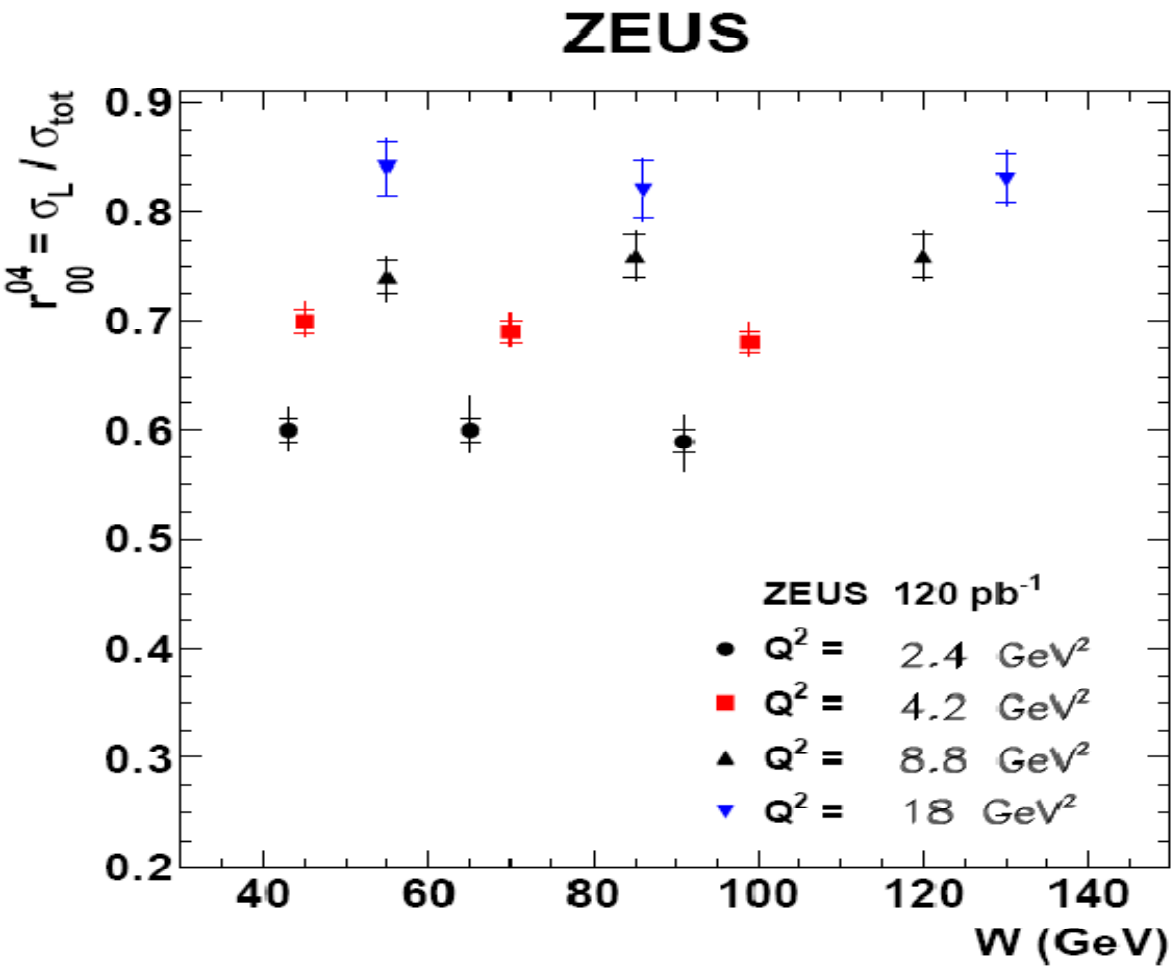
σ_L/σ_T

ZEUS



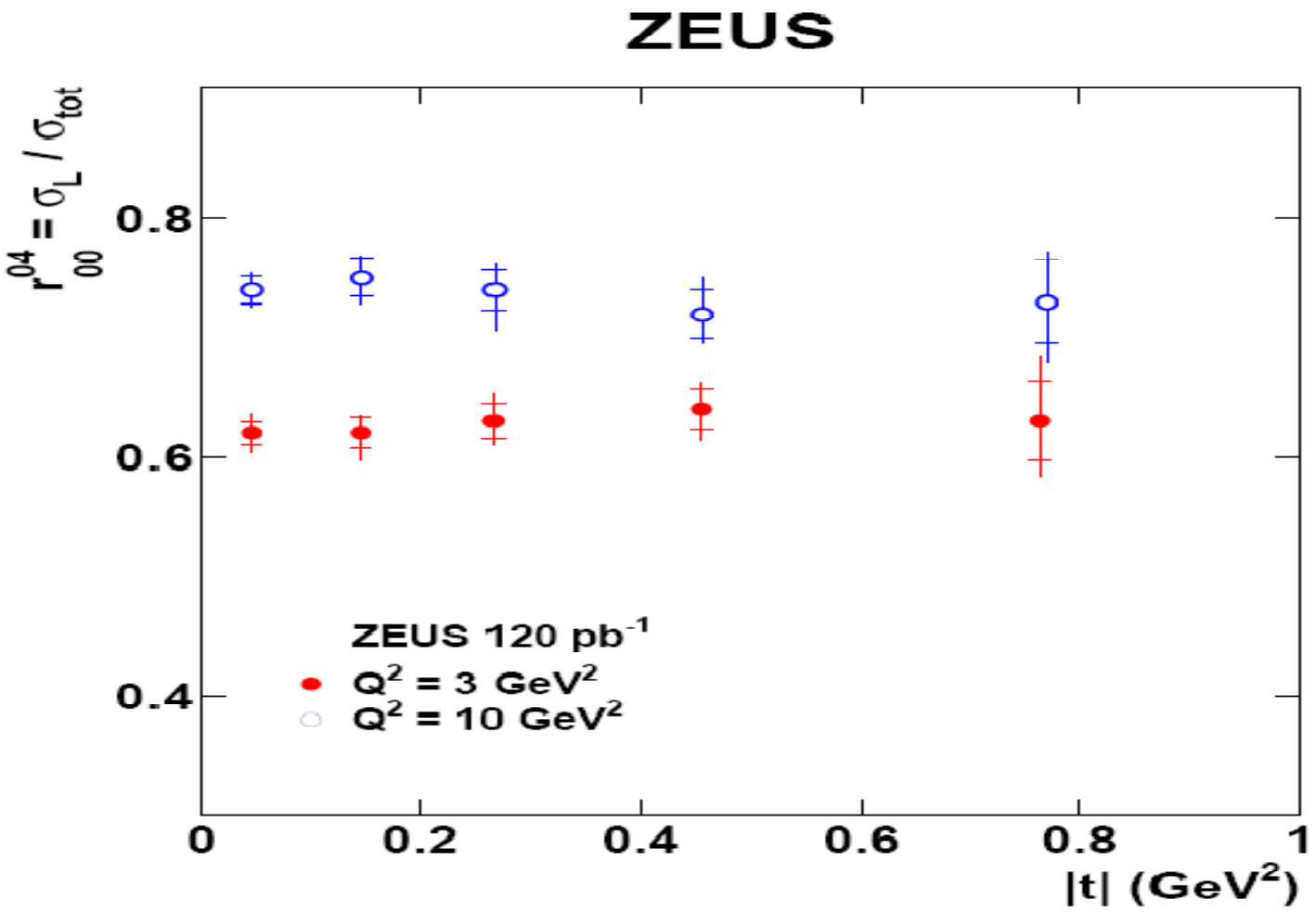
- fit to ZEUS data: $R = \sigma_L/\sigma_T = \xi(Q^2/M^2)^\kappa$
- $\xi = 0.74 \pm 0.04$ and $\kappa = 0.56 \pm 0.03$
- R increases with Q^2

σ_L/σ_{tot}



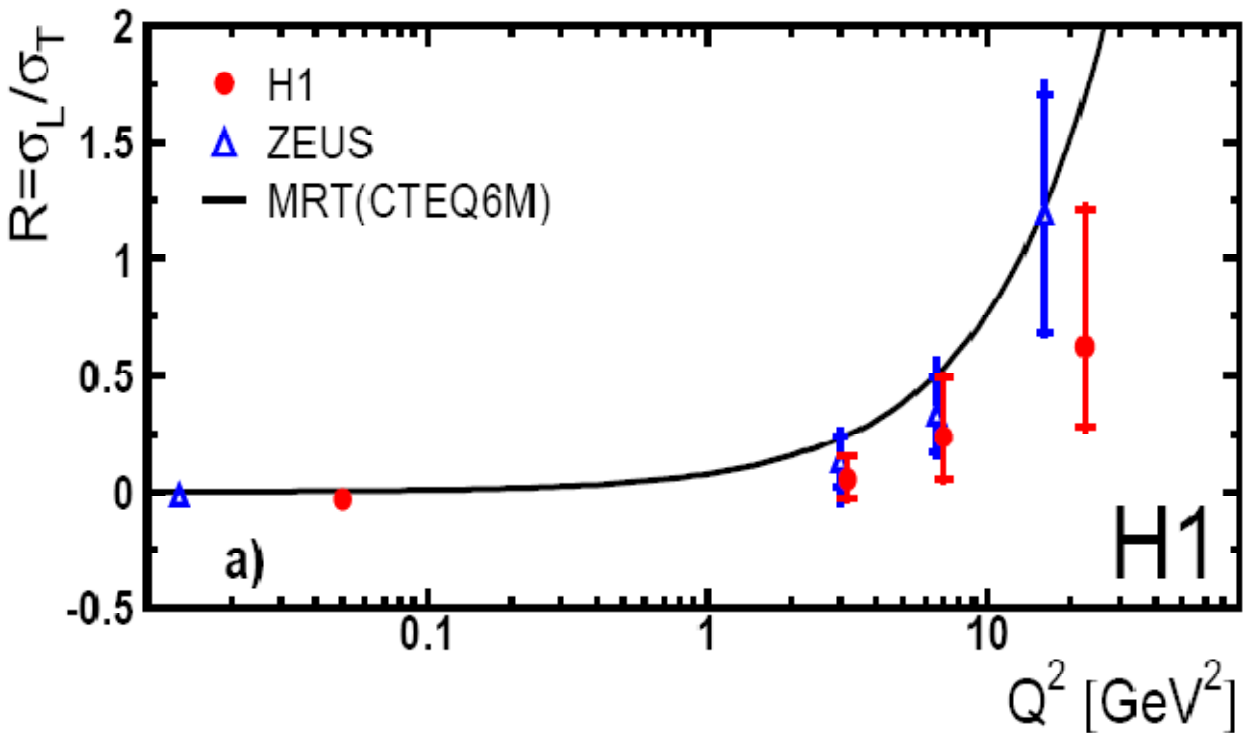
- σ_L/σ_{tot} is W independent
- σ_L and σ_T have the same W dependence
- the typical dipole size contributing to ρ production
- independent of the photon polarization
- large $q\bar{q}$ configuration is suppressed

σ_L/σ_{tot}



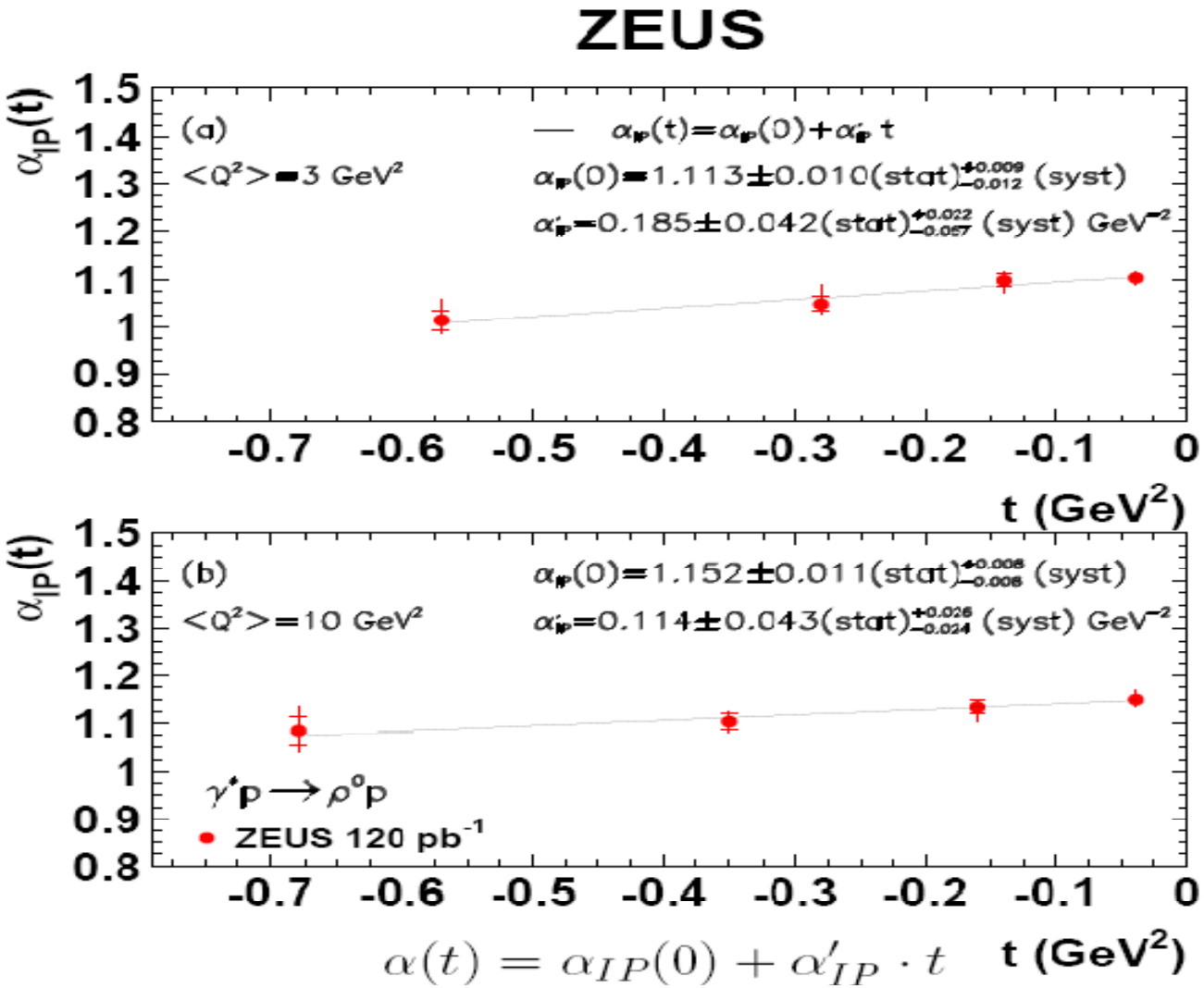
- σ_L/σ_{tot} **is** $|t|$ **independent**
- σ_L **and** σ_T **have the same** $|t|$ **dependence**
- $b_L \approx b_T$

σ_L/σ_T



- Ratio $R = \sigma_L/\sigma_T$ for J/Ψ elastic production as function of Q^2.
- σ_L/σ_T increases with Q^2

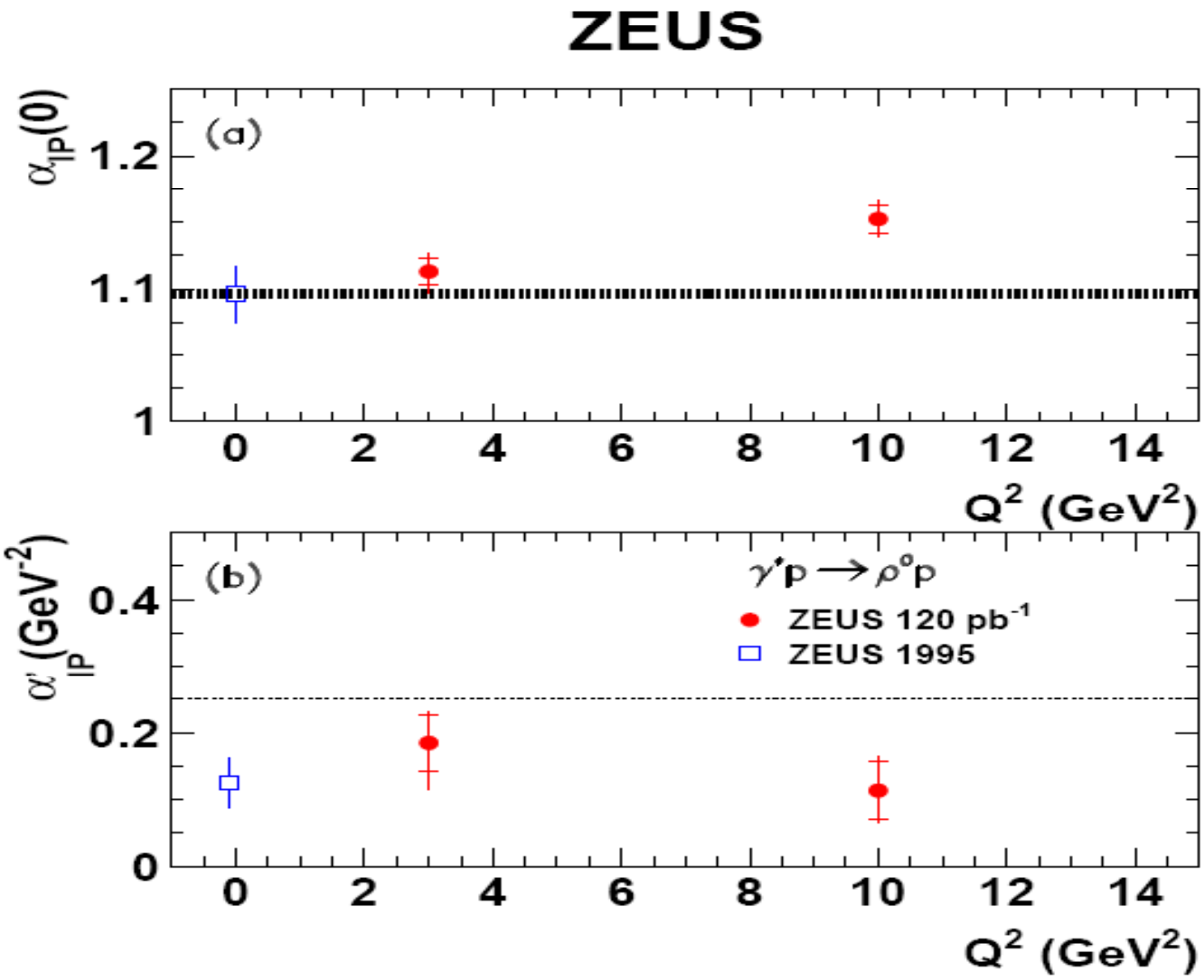
Effective Pomeron trajectory



$$\alpha(t) = \alpha_{IP}(0) + \alpha'_{IP} \cdot t$$

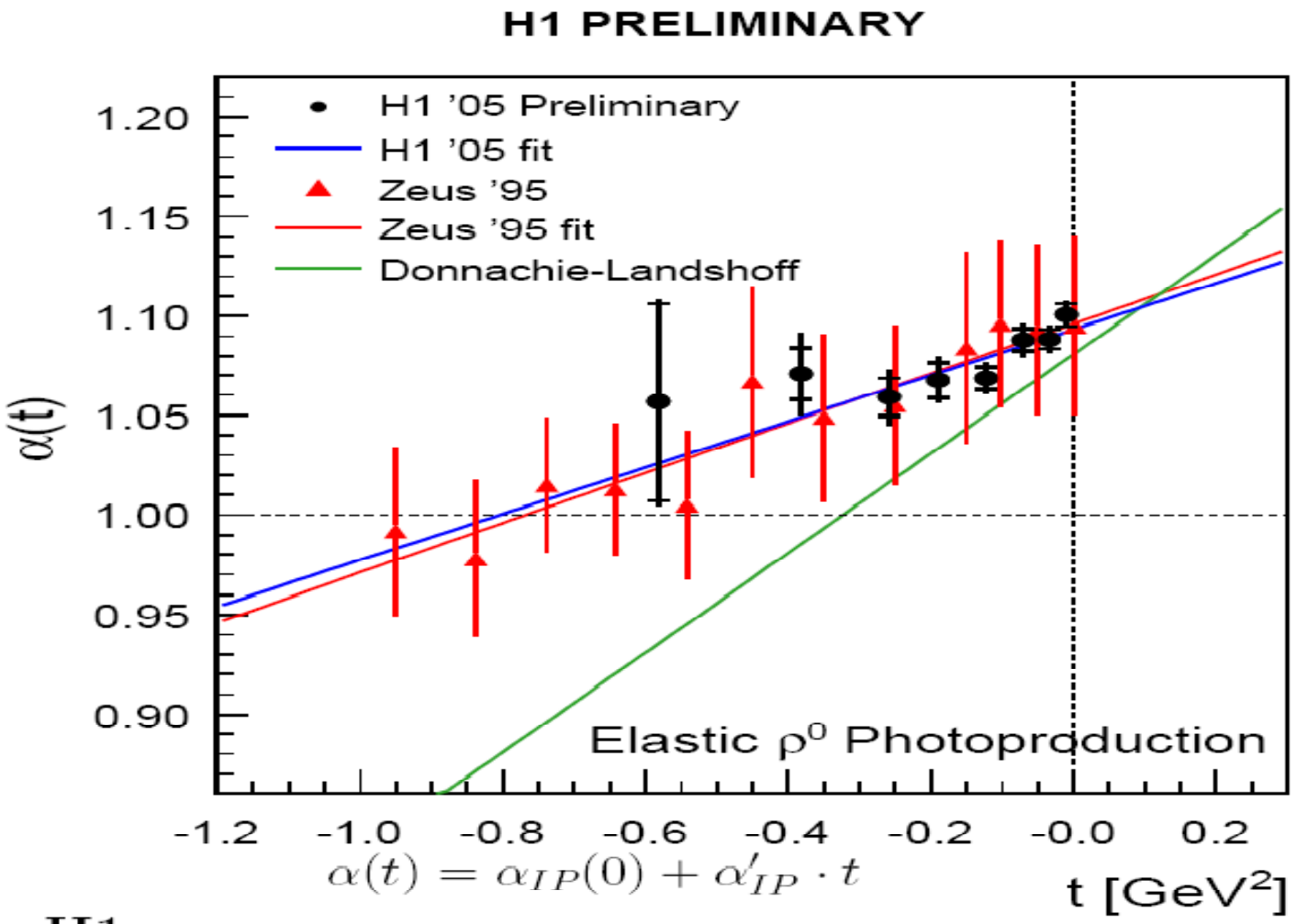
Q^2	3 GeV^2	10 GeV^2
$\alpha(0)$	1.113 ± 0.010	1.152 ± 0.011
α'	0.185 ± 0.042	0.114 ± 0.043

Effective Pomeron trajectory



- $\alpha(0)$ and α' as a function of Q^2

Effective Pomeron trajectory



- **H1 :**

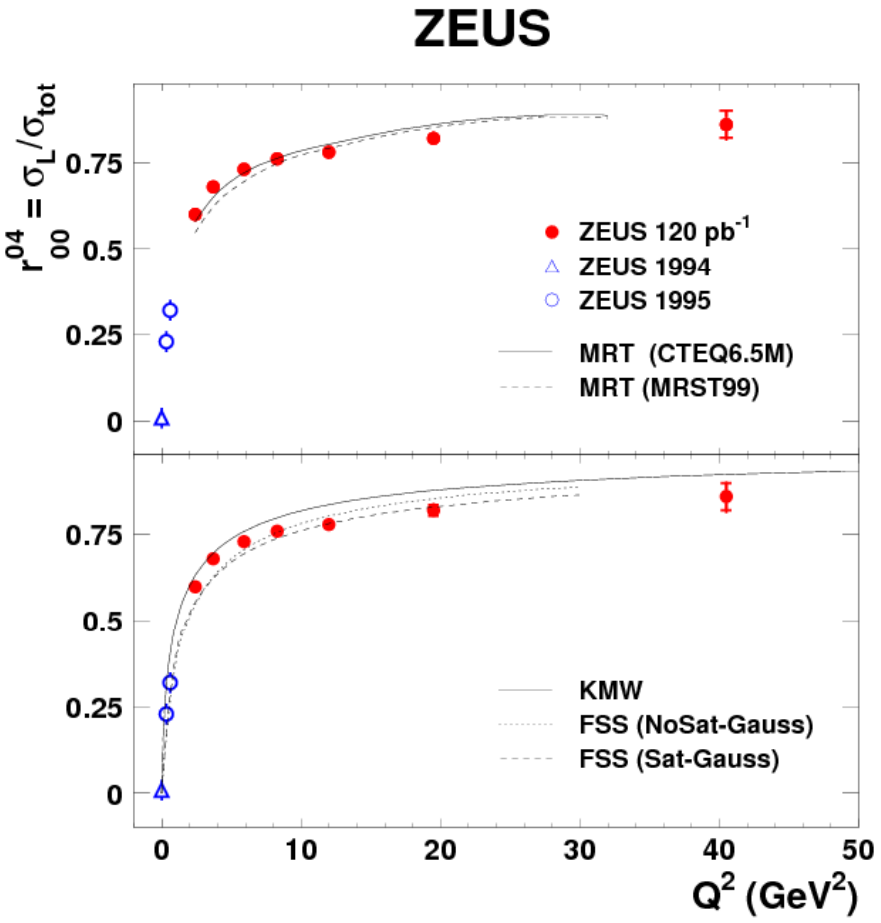
$\alpha(t) = (1.093 \pm 0.003^{+0.008}_{-0.007}) + (0.116 \pm 0.027^{+0.038}_{-0.046})\ GeV^2 \cdot t$

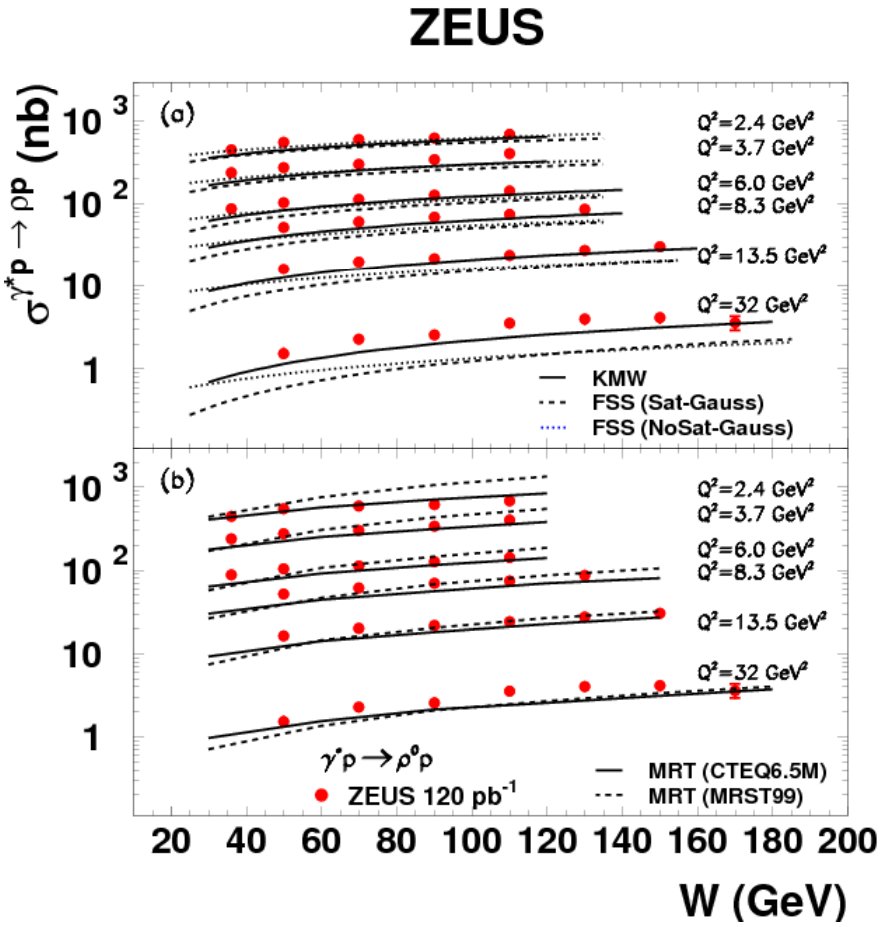
- **ZEUS :**

$\alpha(t) = (1.096 \pm 0.021) + (0.125 \pm 0.038)\ GeV^{-2} \cdot t$

Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$

- Martin-Ryskin-Teubner (MRT)
- Forshaw-Sandapen-Shaw (FSS)
- Kowalski-Motika-Watt (KMW)
- Dosh-Ferreira (DF)
- Frankfurt-Koepf-Strikman (FKS)





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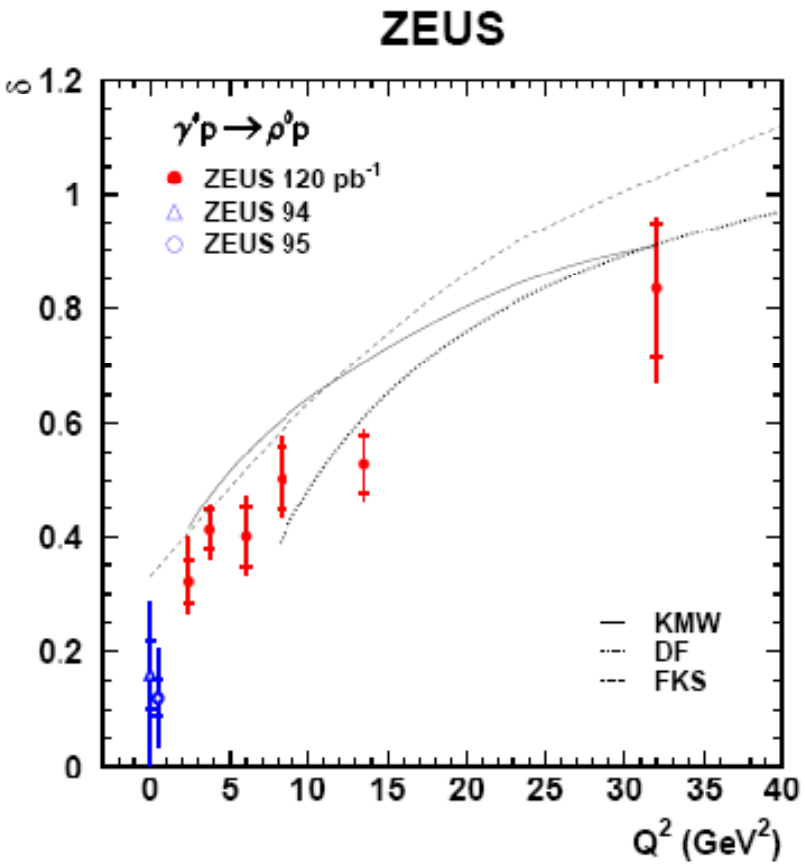

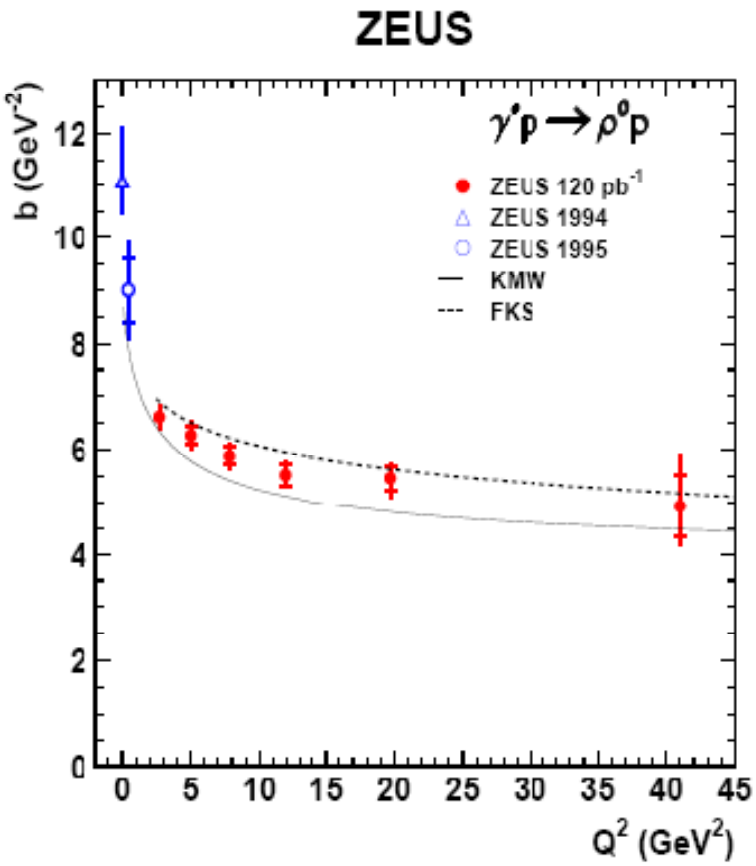

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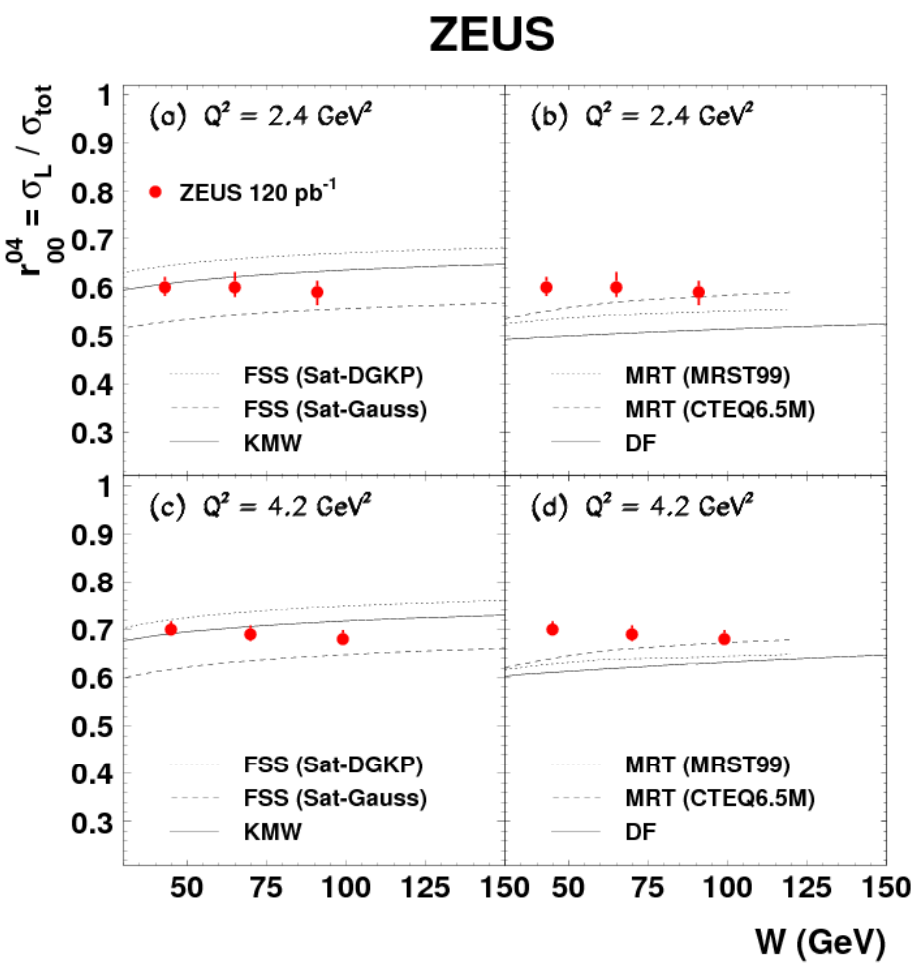

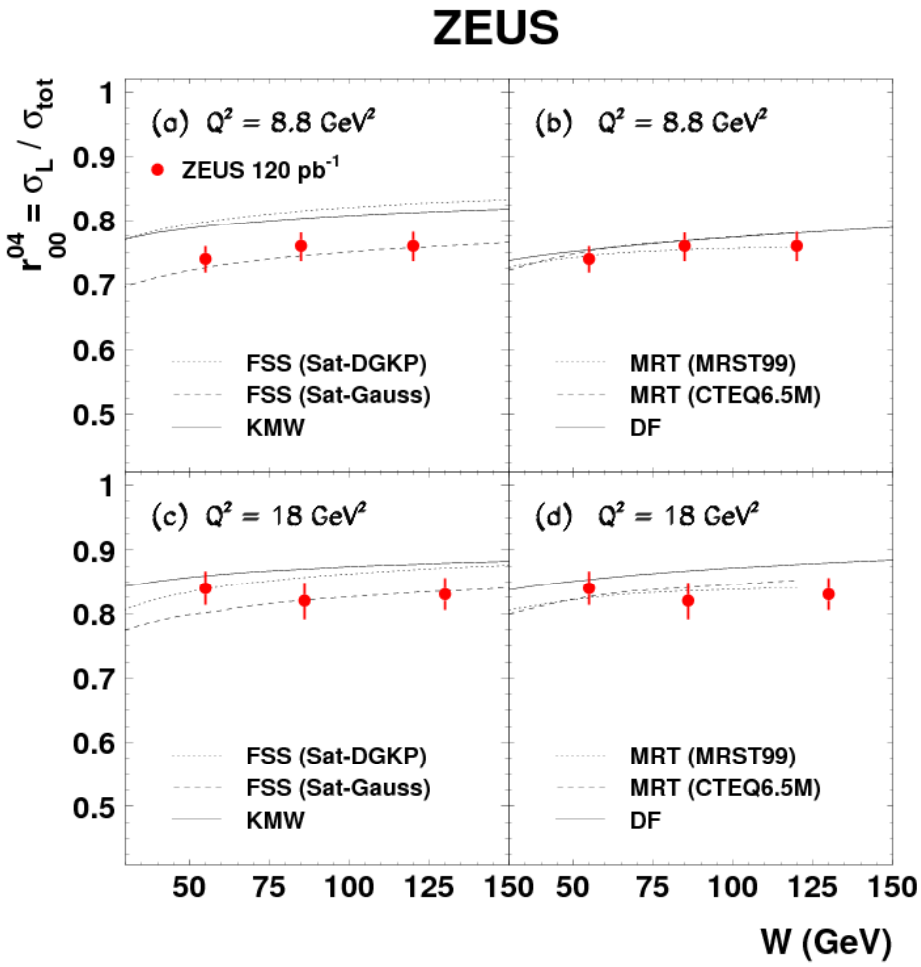

Summary and conclusions

- New high statistics measurements on ρ^0 electroproduction and on DVCS.
- Vector Meson production and DVCS cross sections rise with energy if a hard scale, Q^2 or M^2, is present.
- The Q^2 dependence of $\sigma(\gamma^* p \to \rho^0 p)$ cannot be described by a simple propagator term.
- The exponential slope of the t distribution decreases with Q^2 and levels off at $b \sim 5$ GeV^{-2}

Summary and conclusions

- The ratio of cross sections induced by longitudinally and tarnsversely polarised virtual photons increases with Q^2, but is independent of W and of t.
- The effective Pomeron trajectory has a larger intercept and smaller slope than those extracted from soft interactions.
- The first analyses of the interference BH/DVCS has been presented.
- **All these features are compatible with expectations of hard diffraction $\rightarrow$ pQCD**
- None of the models which have been compared to the ρ^0 measurements are able to reproduce all the features of the data.