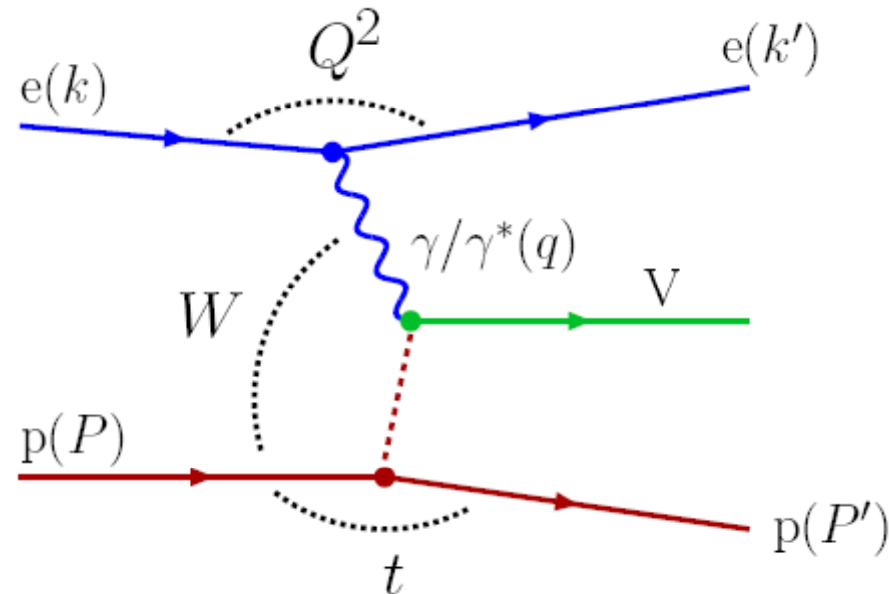# *Upsilon production and DVCS*

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On behalf of the ZEUS Collaboration

Diffractive vector mesons at HERA

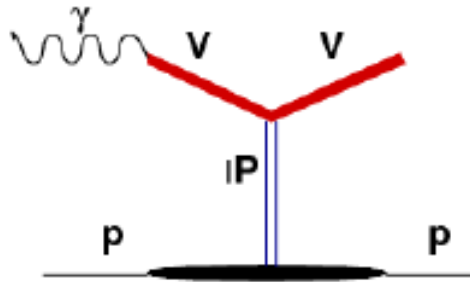**Diffraction - no quantum numbers are exchanged in the interaction.**
The proton can stay intact or dissociate.

V	- *Vector Meson*	$\rho, \omega, \phi, J/\psi, \psi', \Upsilon$
Q²	- *photon virtuality*	*Q²=-q²=-(k-k')²*
W	- *c.m. energy of γp system*	*W=(q+p)²*
t	- *(4-mom. transfer)² at p-vertex*	*t = (P - P')²*

Soft *and hard* production mechanism

Non- perturbative description based on Regge theory and Vector Dominance Model

• *Photon fluctuates into a Vector Meson*

•*Vector Meson interacts with the proton by soft Pomeron exchange.*

Slow increase of γp cross section with energy:

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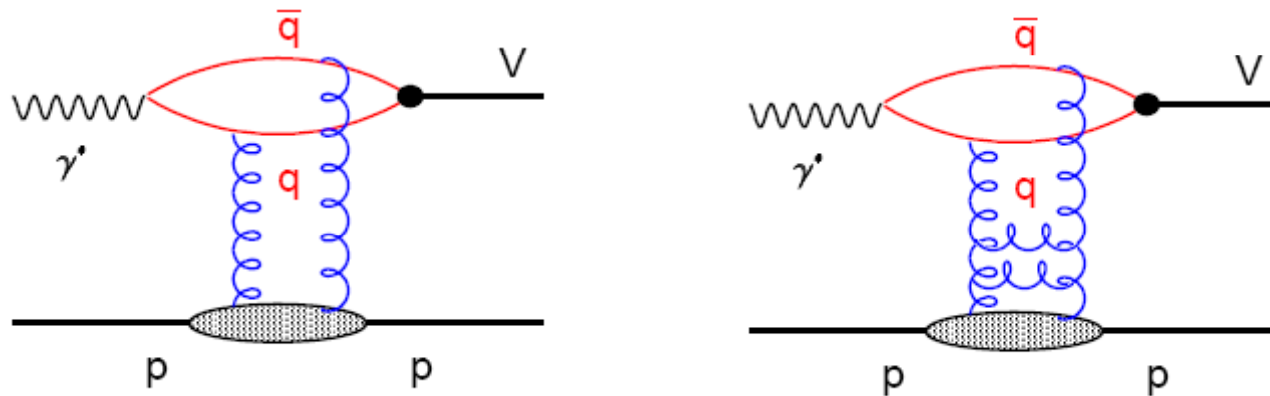
Experimental determination:

$$\alpha(t) = \alpha(0) + \alpha't = 1.08 + 0.25t$$

$$b(W) \propto b_0 + 2\alpha'\ln\left(W^2/W_0^2\right) \qquad b_0 \sim 10 GeV^{-2}$$

~~Soft and~~ *hard production mechanism*

Perturbative QCD applicable.

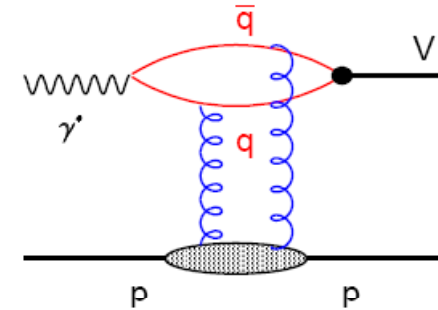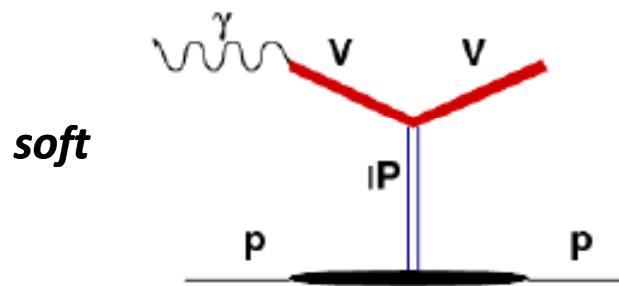- ***Photon fluctuates into a*** $q\bar{q}$ ***pair***
- $q\bar{q}$ ***pair interacts with the proton by at least two gluon exchange***

                                             (color singlet –QCD pomeron)

- $q\bar{q}$ ***pair forms a vector meson***

Fast increase of the cross-section with Wγp - related to gluon density in the proton:

$$\sigma(W) \propto [\alpha_s(\mu^2)\overline{x}g(\overline{x}, \mu^2)]^2 \quad \mu\text{ - hard scale} \qquad \overline{x} \propto \frac{Q^2 + M_V^2}{W_{\gamma p}}$$

Transition from soft to hard at HERA

soft

$$\sigma \propto W^\delta \qquad \delta \approx 0.2$$

$$\frac{d\sigma}{d|t|} \propto e^{-b|t|} \qquad b \approx 10\,\text{GeV}^{-2}$$

$$\alpha(t),\, b(W) \qquad \alpha' \approx 0.25\,\text{GeV}^{-2}$$
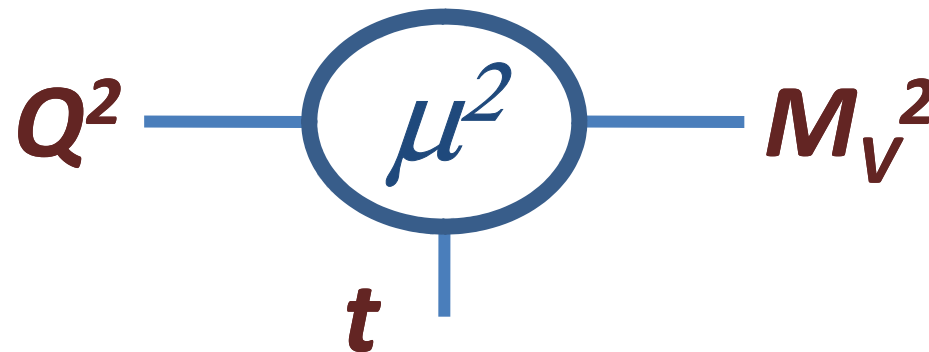
hard

$$\sigma \propto W^\delta \qquad \delta \approx 0.8\,(J/\psi),\ 1.1(\psi')$$
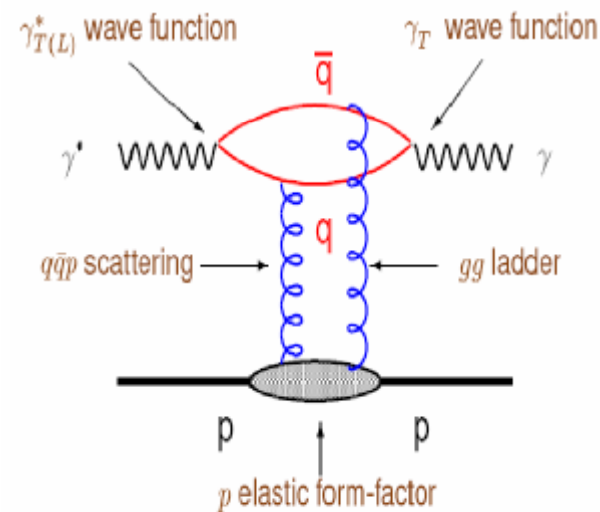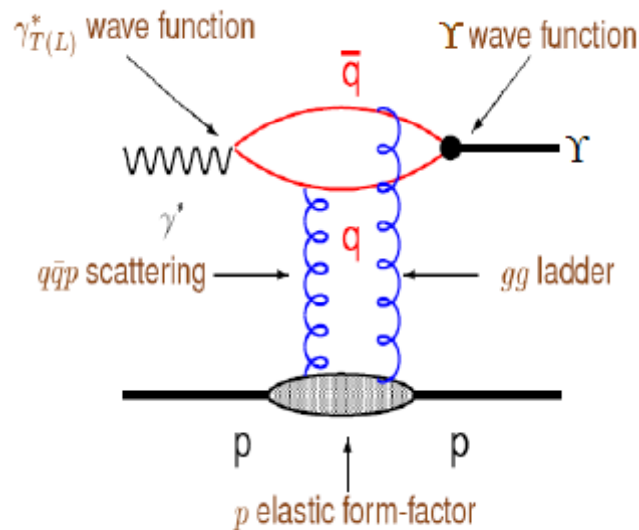
$$\frac{d\sigma}{d|t|} \propto e^{-b|t|} \qquad b \approx 4\text{-}5\,\text{GeV}^{-2}$$

$$\alpha(t),\, b(W) \qquad \alpha' \approx 0$$

$$Q^2 \quad \mu^2 \quad M_V^2$$

$$t$$

Upsilon and Deeply Virtual Compton Scattering (DVCS) production

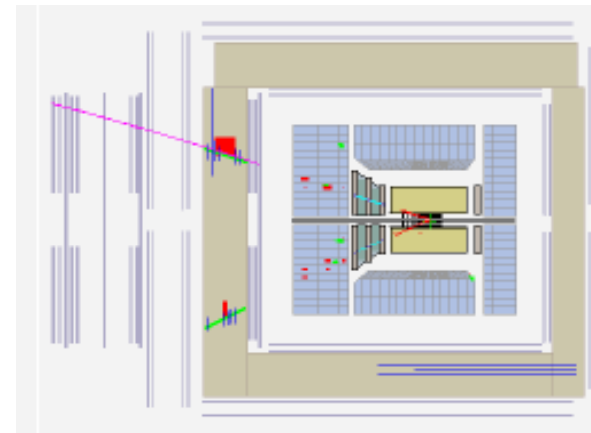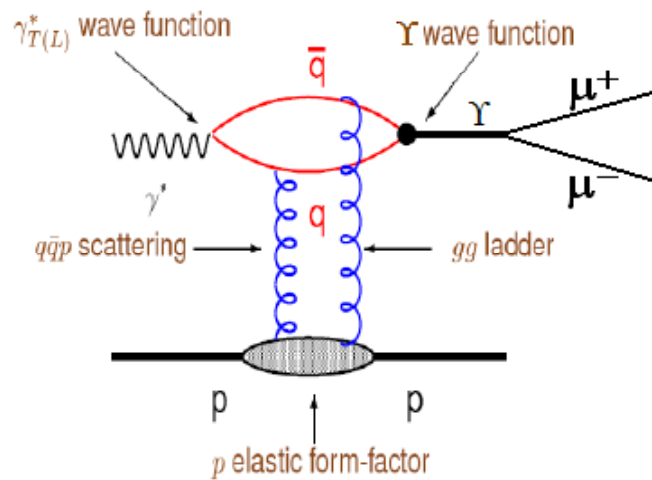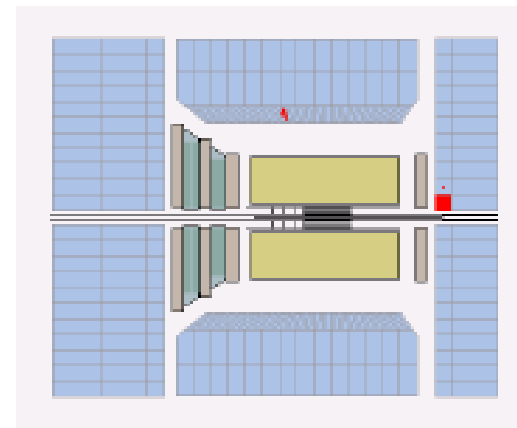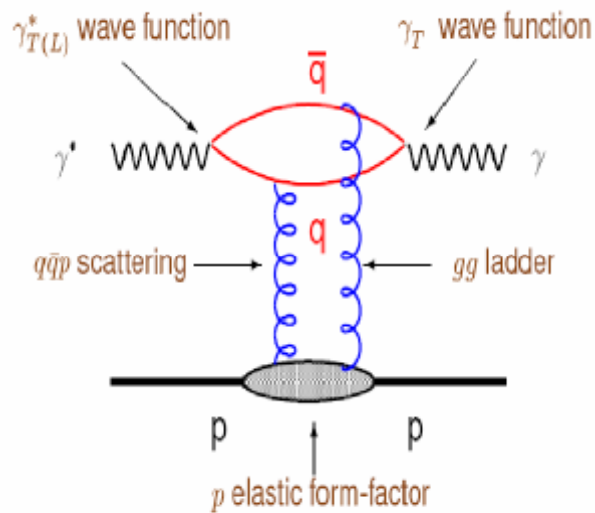
Use QED for photon wave function.

Study properties of VM wave function and the gluon density in the proton.

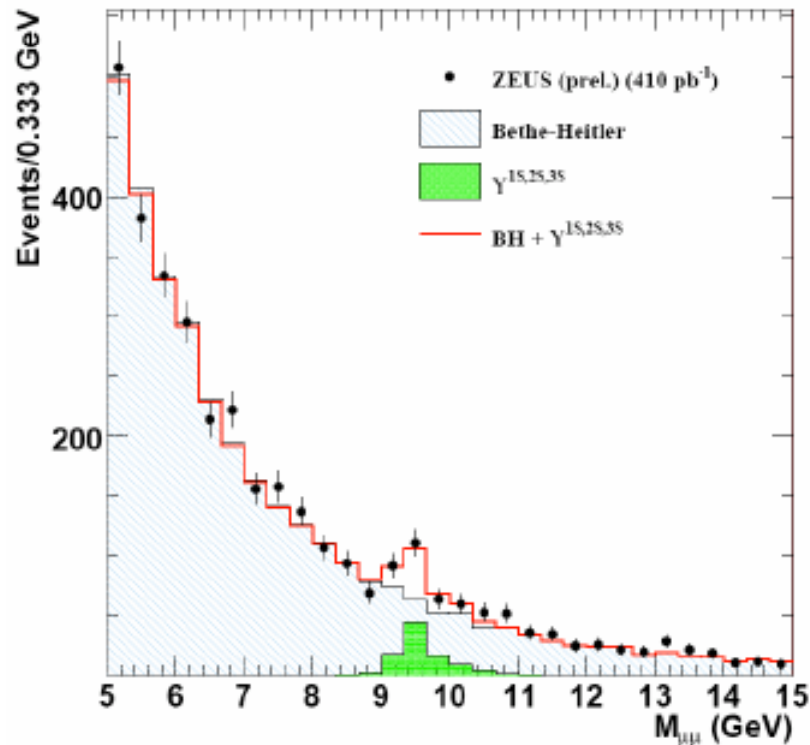# Upsilon and Deeply Virtual Compton Scattering (DVCS) production

Janusz T. Malka: Upsilon production and DVCS, DIS2008

Exclusive Upsilon photoproduction

1998-2007 ZEUS data with Ep=920GeV integrated luminosity 410pb⁻¹

5 sigma signal from Υ(1S), Υ(2S), Υ(3S)

Signal extraction method:
$\mu^+\mu^-$**mass spectrum fitted simultaneouly with two distributions in the range 5 < M$_{\mu^+\mu^-}$ < 15GeV : generated BH and signal distribution.**

Number of Upsilon candidates 104 ± 21

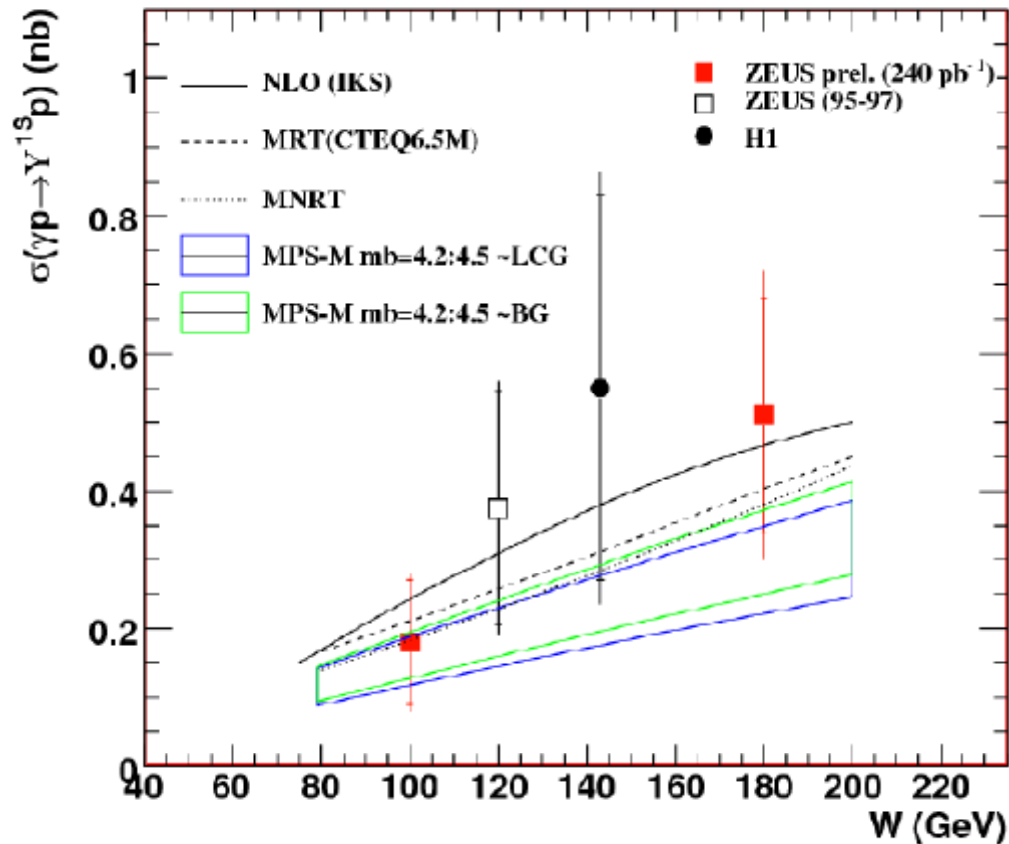**For cross section measurement we use:**

1998-2005 data only (240pb⁻¹) proton dissociative fraction 34%

Upsilon cross section measurement

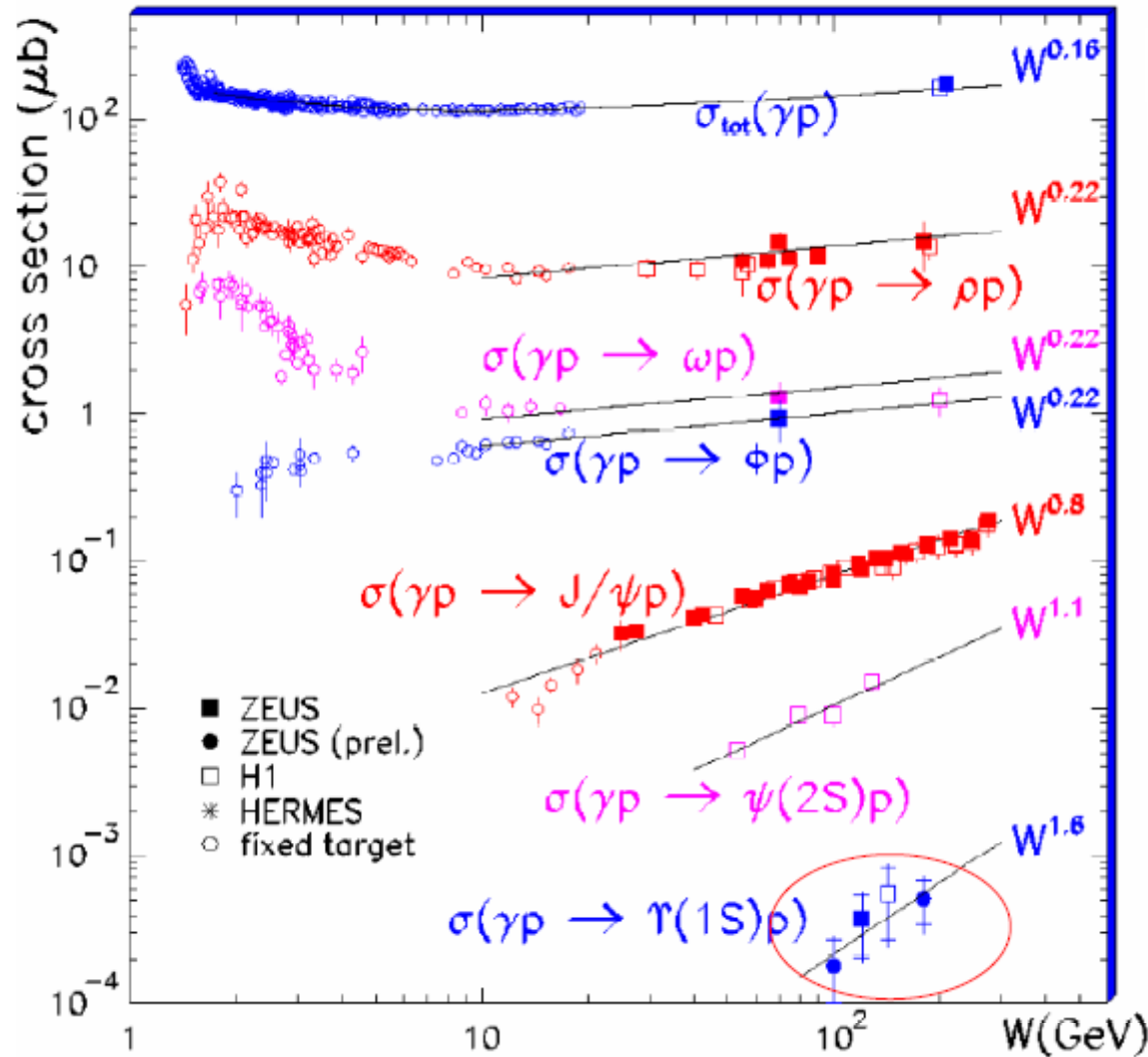Two red points – our preliminary cross section measurement with 98-05 only

NLO – Ivanov , Krasnikov , Szymanowski – hep-ph/0412235

MRT – Martin, Ryskin, Teubner, (based on CTEQ6.5M gluon)

MNRT – Martin, Nockles, Ryskin, Teubner (based on diffractive J/ψ data alone)

MPS – color dipole approach calculation by Magno Machado (private com.)
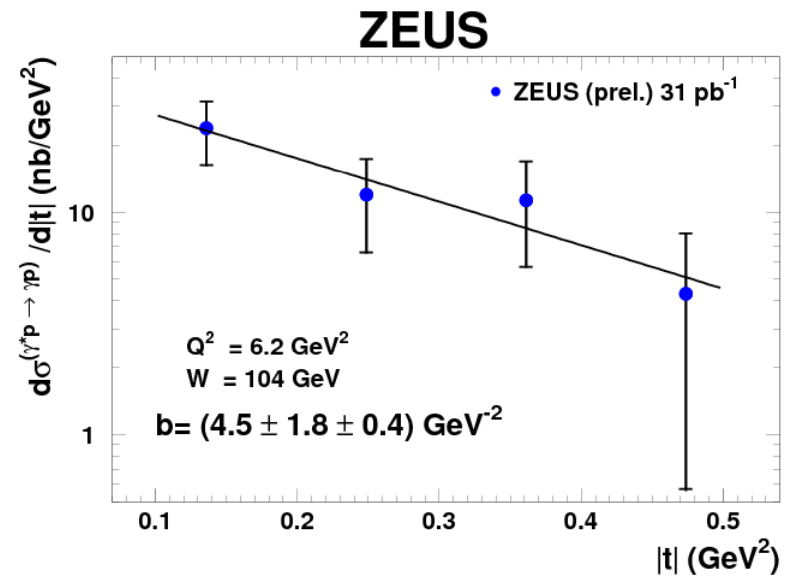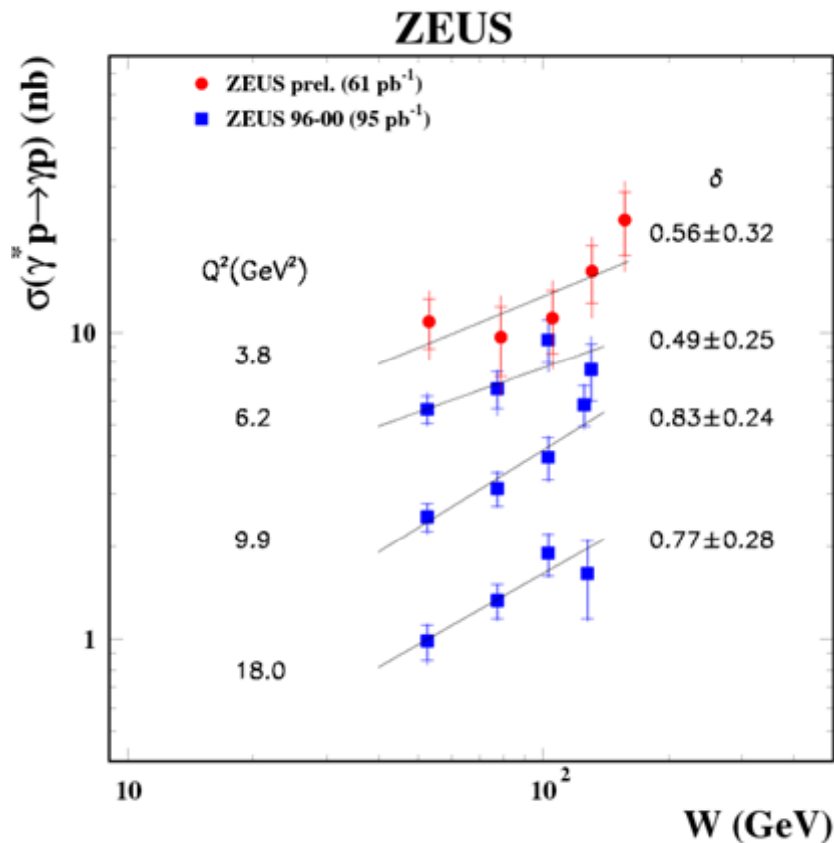
Compilation γp cross sections

$$\sigma \propto W^{\delta} \quad \delta = f(M_V)$$

Process becomes hard as scale (mass) becomes larger.

δ = 1.6 ± 0.8 comes from the fit to 4 (ZEUS +H1) points.
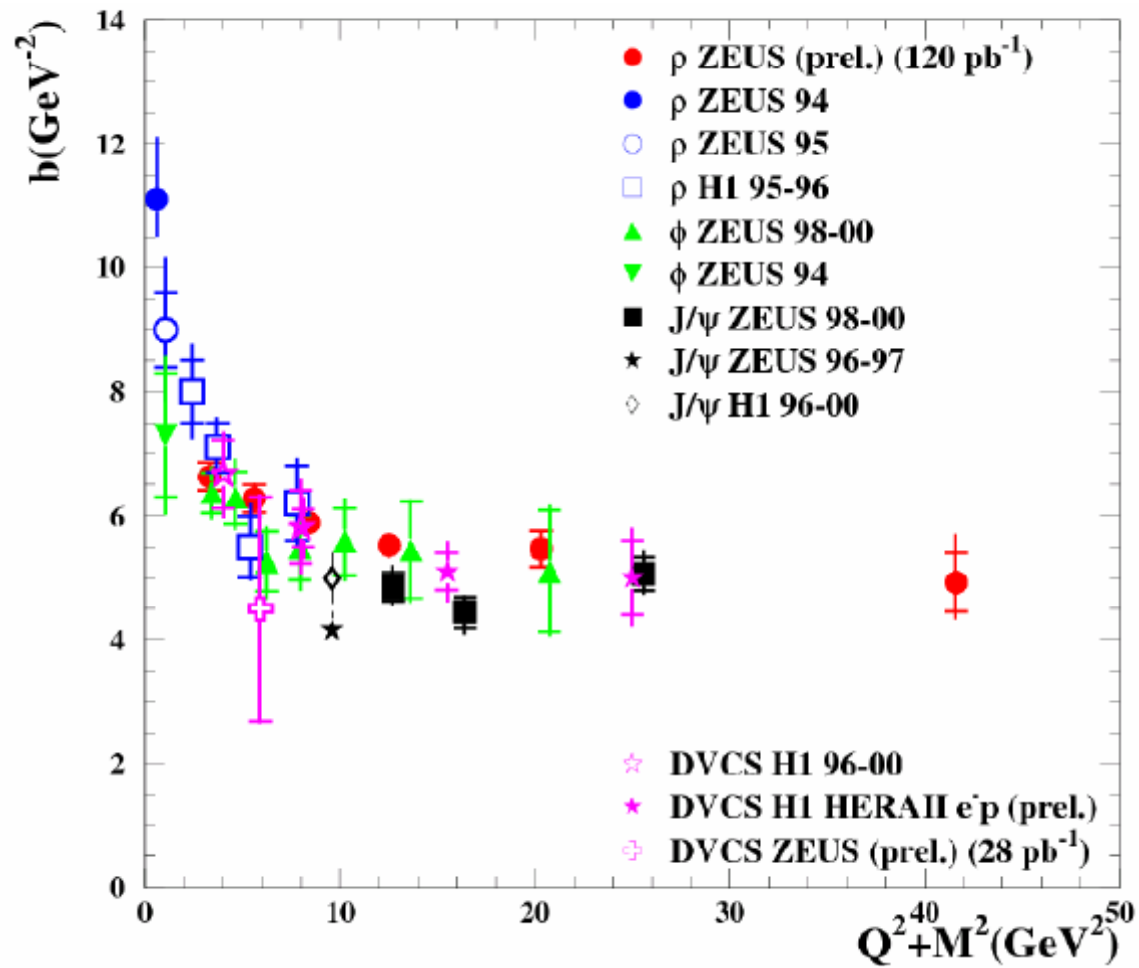
Cross section $\gamma^* p \to \gamma p$

First _direct measurement_ of differential cross section as a function of t using LPS

Steep rise for large Q^2 observed in ZEUS
- *Similar behaviour to heavy Vector Mesons*
- *DVCS shows hard behaviour even at low Q^2*
- *May suggest that the most sensitive part to soft scale is the wave function.*

Comparison to other Vector Mesons

Compilation b (Q² + M²)

Summary

- *Measurement of the Upsilon photoproduction has been presented and compared with theoretical models*

- $\delta = 1.6$ *form Upsilon, bigger than for other heavy Vector Mesons*

- *W dependence of DVCS cross section shows similar behaviour to heavy Vector Mesons even at low Q^2*

- *Measurement of "DVCS" b-slope is consistent with other Vector Mesons*

- *The cross section rises with W and the rate of increase grows with the hard scale (Q^2+M^2)*