

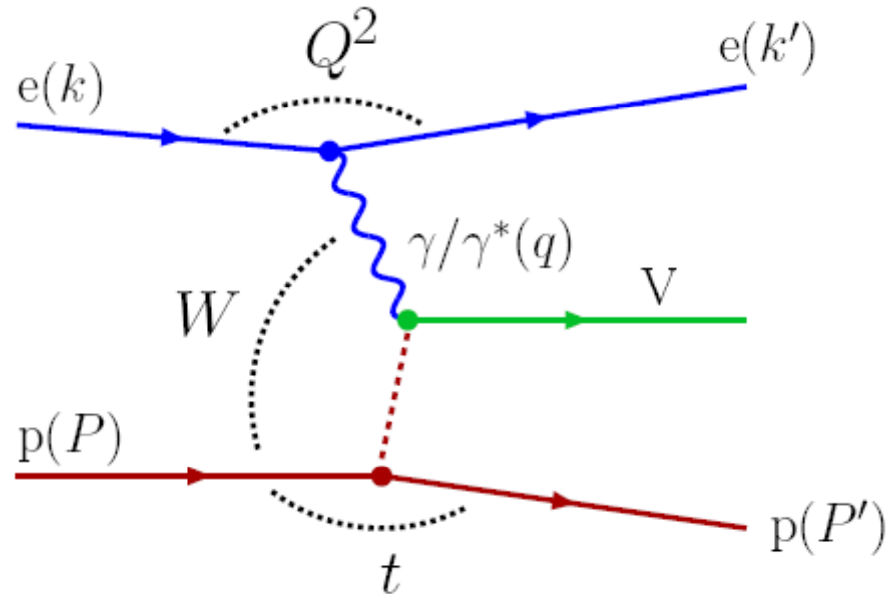
# ***Upsilon production and DVCS***

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***On behalf of the ZEUS Collaboration***

# ***Diffractive vector mesons at HERA***

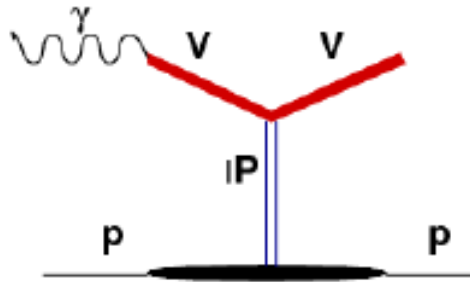


***Diffraction - no quantum numbers are exchanged in the interaction.  
The proton can stay intact or dissociate.***

$V$	- Vector Meson	$\rho, \omega, \phi, J/\psi, \psi', \Upsilon$
$Q^2$	- photon virtuality	$Q^2 = -q^2 = -(k-k')^2$
$W$	- c.m. energy of $\gamma p$ system	$W = (q+p)^2$
$t$	- (4-mom. transfer) <sup>2</sup> 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  $\gamma p$  cross section with energy:*

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

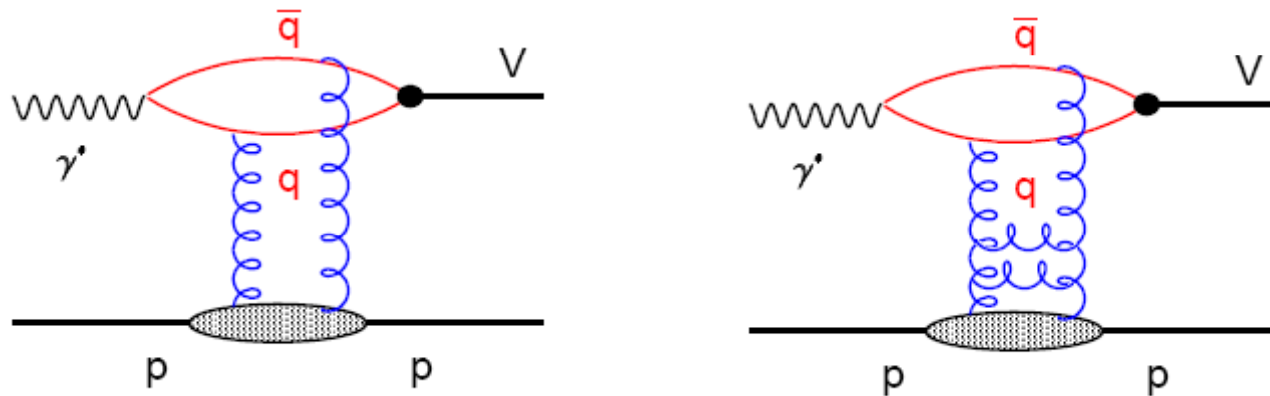
*Experimental determination:*

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

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

# Soft and hard production mechanism

*Perturbative QCD applicable.*

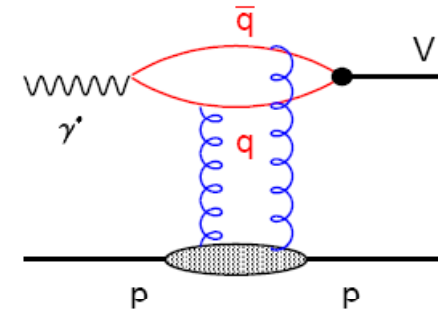
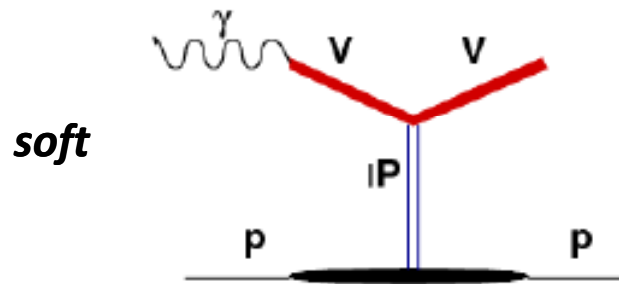


- *Photon fluctuates into a  $q\bar{q}$  pair*
- *$q\bar{q}$  pair interacts with the proton by at least two gluon exchange  
(color singlet –QCD pomeron)*
- *$q\bar{q}$  pair forms a vector meson*

*Fast increase of the cross-section with  $W_{\gamma p}$  - related to gluon density in the proton:*

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

# Transition from soft to hard at HERA



$$\sigma \propto W^\delta$$

$$\delta \approx 0.2$$

$$\frac{d\sigma}{d|t|} \propto e^{-b|t|}$$

$$b \approx 10 \text{ GeV}^{-2}$$

$$\alpha(t), b(W)$$

$$\alpha' \approx 0.25 \text{ GeV}^{-2}$$

$$\sigma \propto W^\delta$$

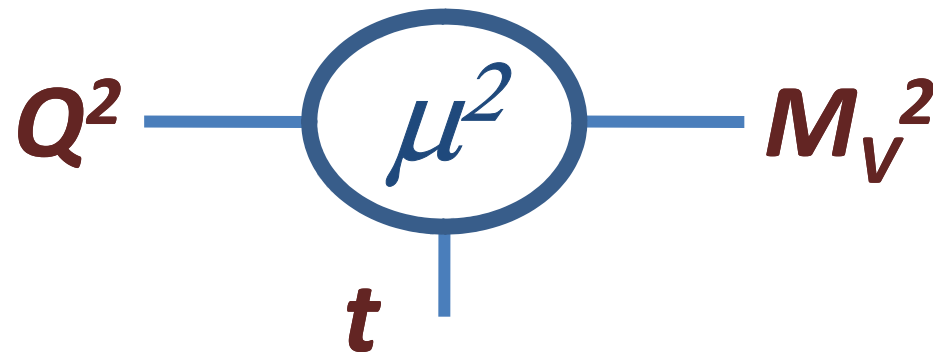
$$\delta \approx 0.8 (J/\psi), 1.1 (\psi')$$

$$\frac{d\sigma}{d|t|} \propto e^{-b|t|}$$

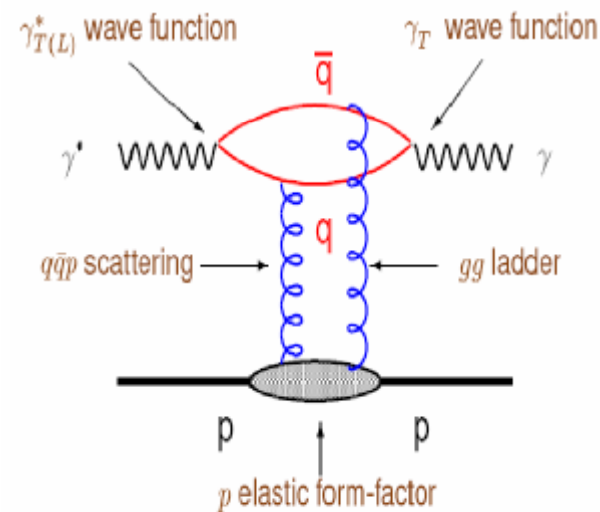
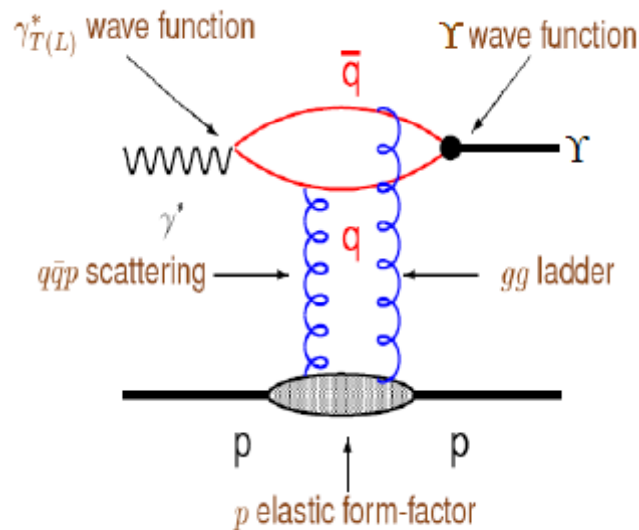
$$b \approx 4-5 \text{ GeV}^{-2}$$

$$\alpha(t), b(W)$$

$$\alpha' \approx 0$$



# ***Upsilon and Deeply Virtual Compton Scattering (DVCS) production***

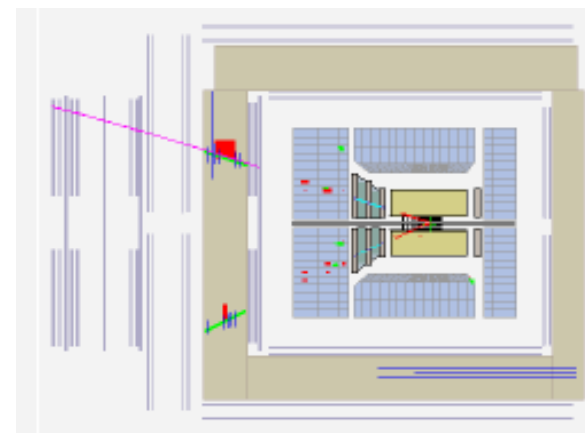
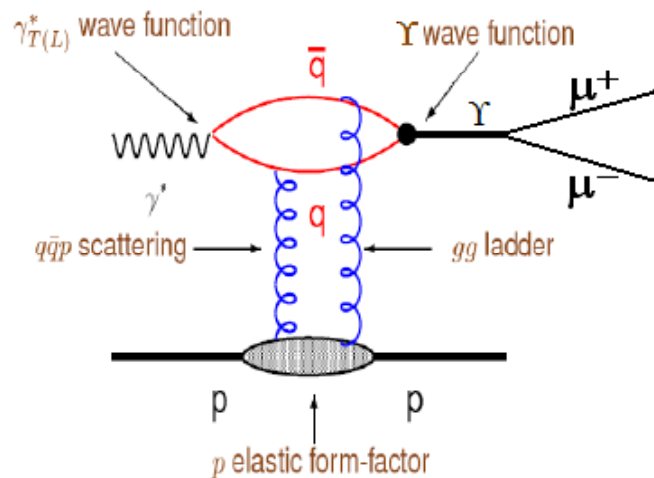


***Use QED for photon wave function.***

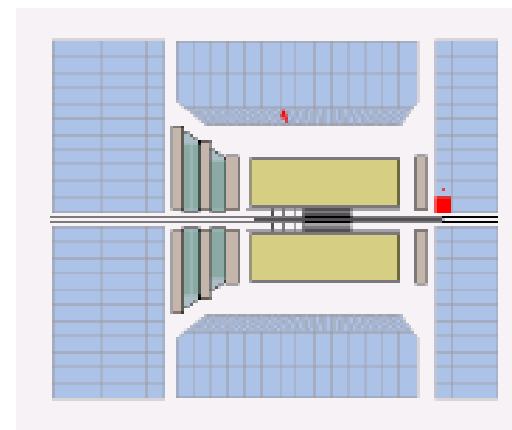
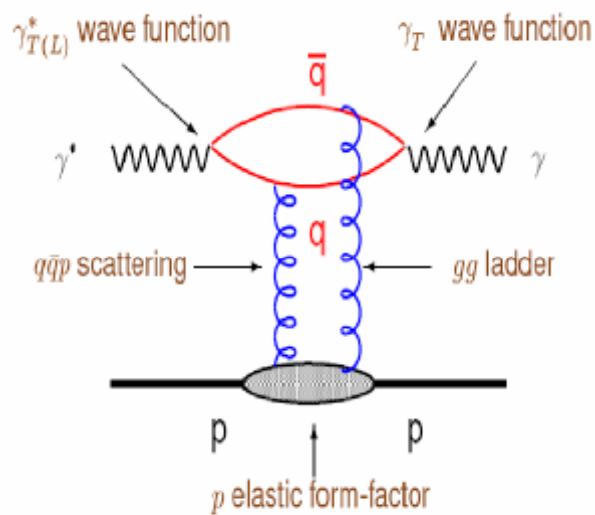
***Study properties of VM wave function and the gluon density in the proton.***

# Upsilon and Deeply Virtual Compton Scattering (DVCS) production

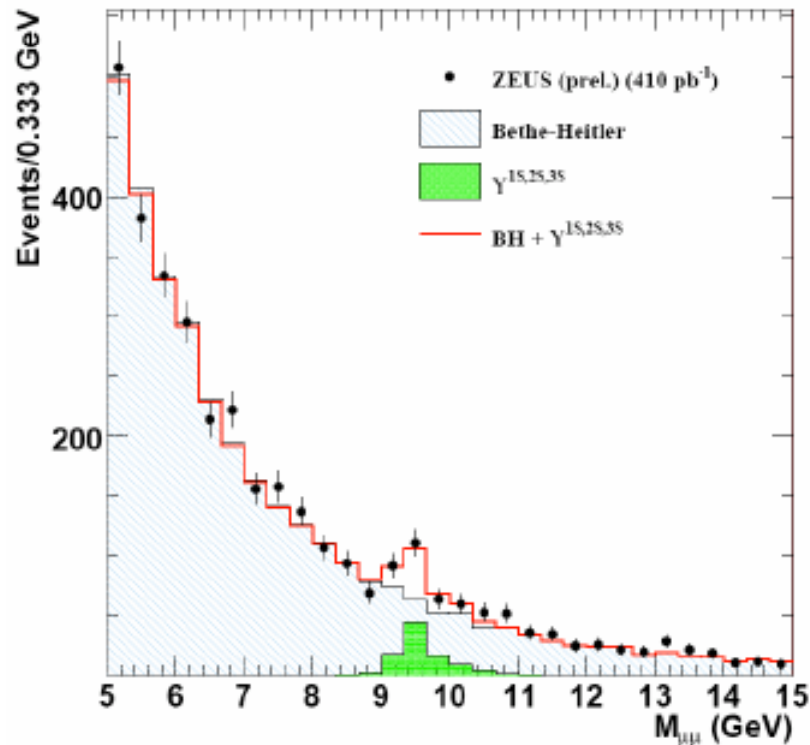
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# Exclusive Upsilon photoproduction



**1998-2007 ZEUS data with  $E_p=920\text{GeV}$   
integrated luminosity  $410\text{pb}^{-1}$**

**5 sigma signal from  $\Upsilon(1S)$ ,  $\Upsilon(2S)$ ,  $\Upsilon(3S)$**

**Signal extraction method:**

**$\mu^+\mu^-$  mass spectrum fitted simultaneously  
with two distributions in the range**

**$5 < M_{\mu^+\mu^-} < 15\text{GeV}$  : generated BH and signal  
distribution.**

**Number of Upsilon candidates  $104 \pm 21$**

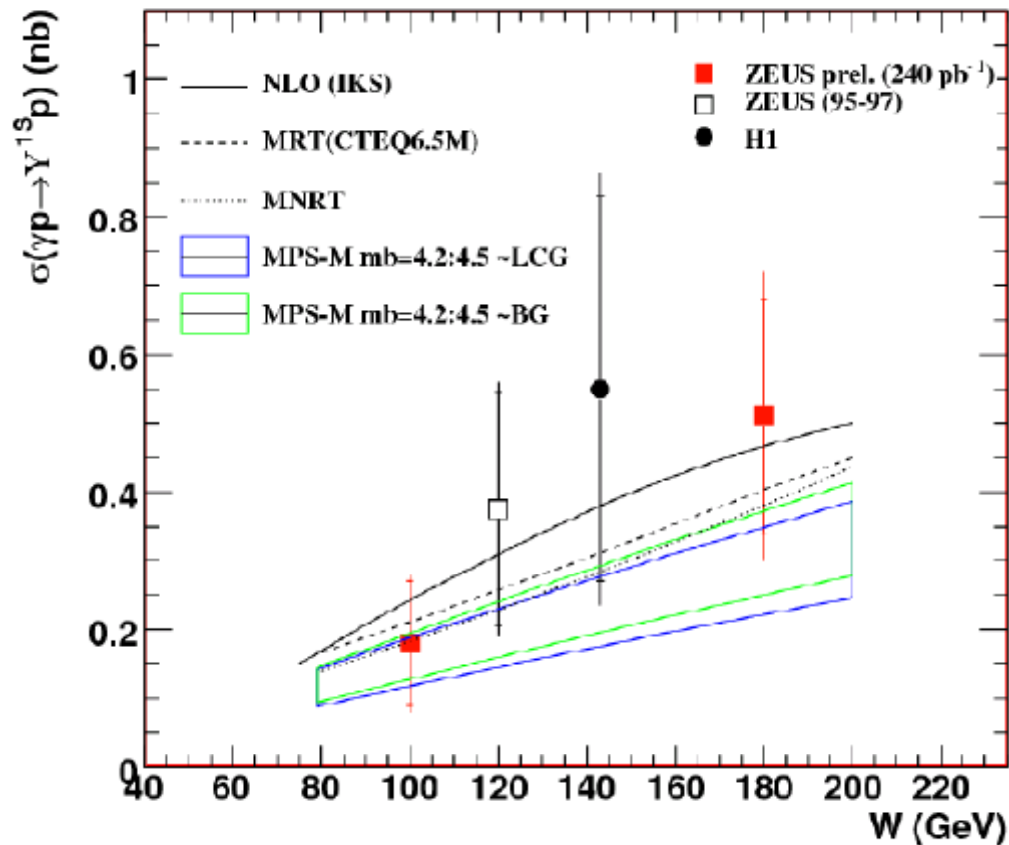
**For cross section measurement we use:**

**1998-2005 data only ( $240\text{pb}^{-1}$ )**

**proton dissociative fraction 34%**



# *Upsilon cross section measurement*



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

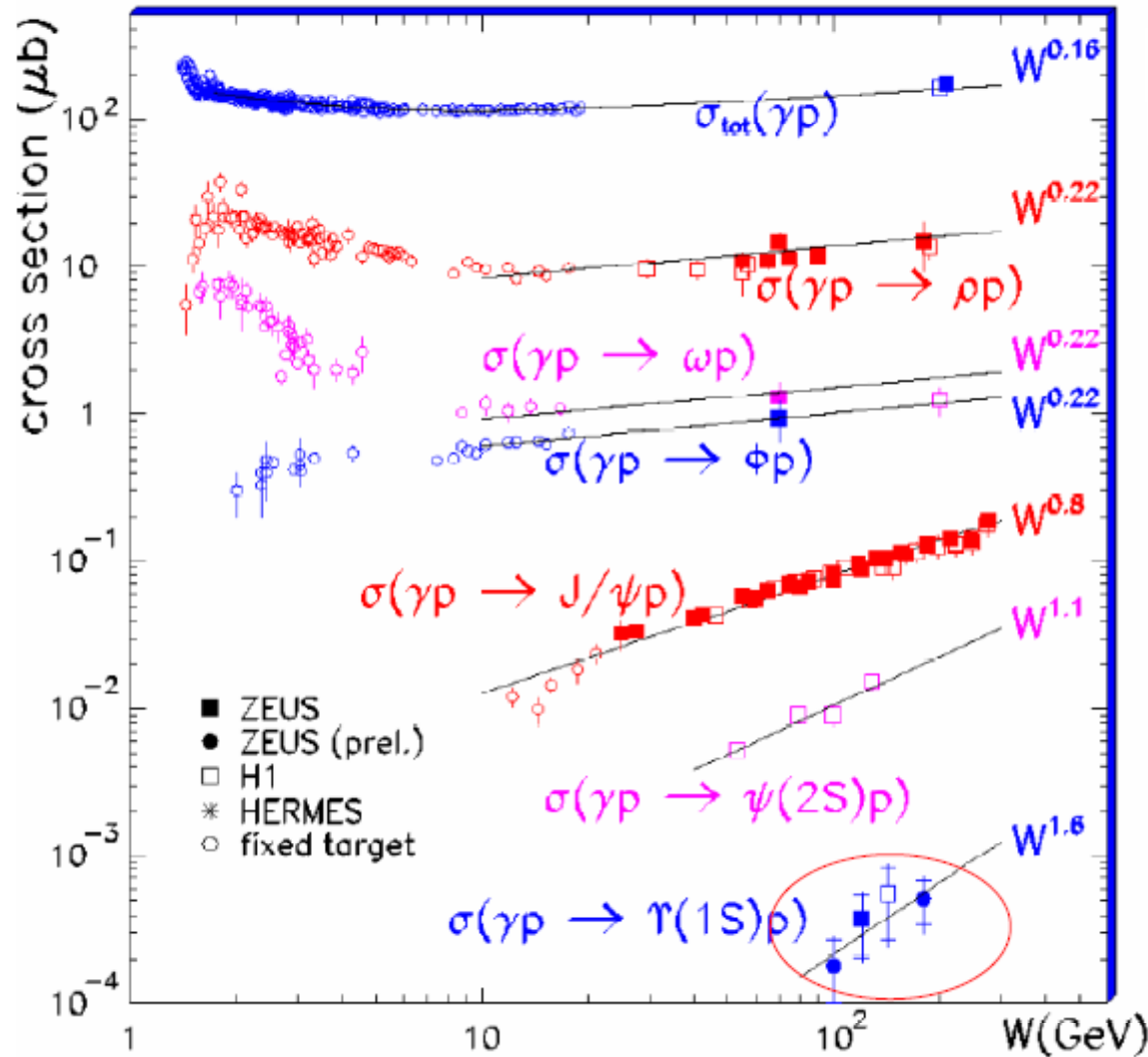
*NLO – Ivanov , Krasnikov , Szymanowski – hep-ph/0412235*

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

*MNRT – Martin, Nockles, Ryskin, Teubner (based on diffractive  $J/\psi$  data alone)*

*MPS – color dipole approach calculation by Magno Machado (private com.)*

# Compilation $\gamma p$ cross sections

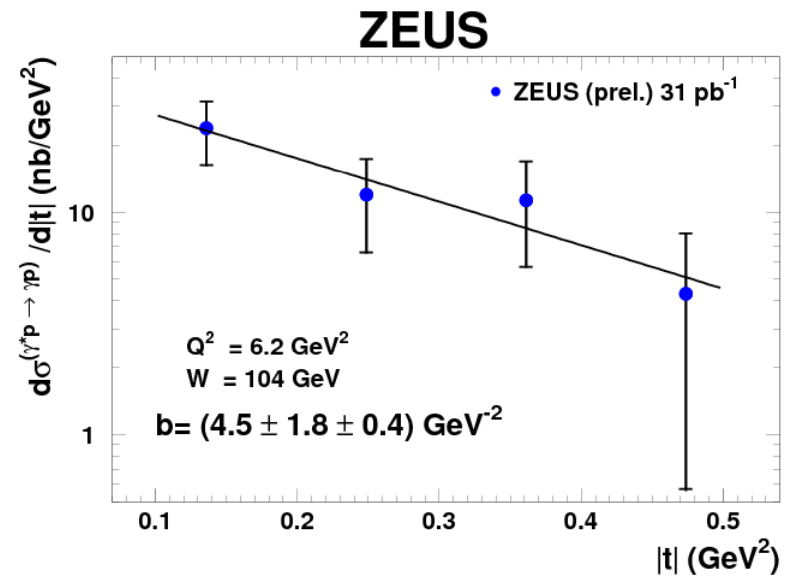
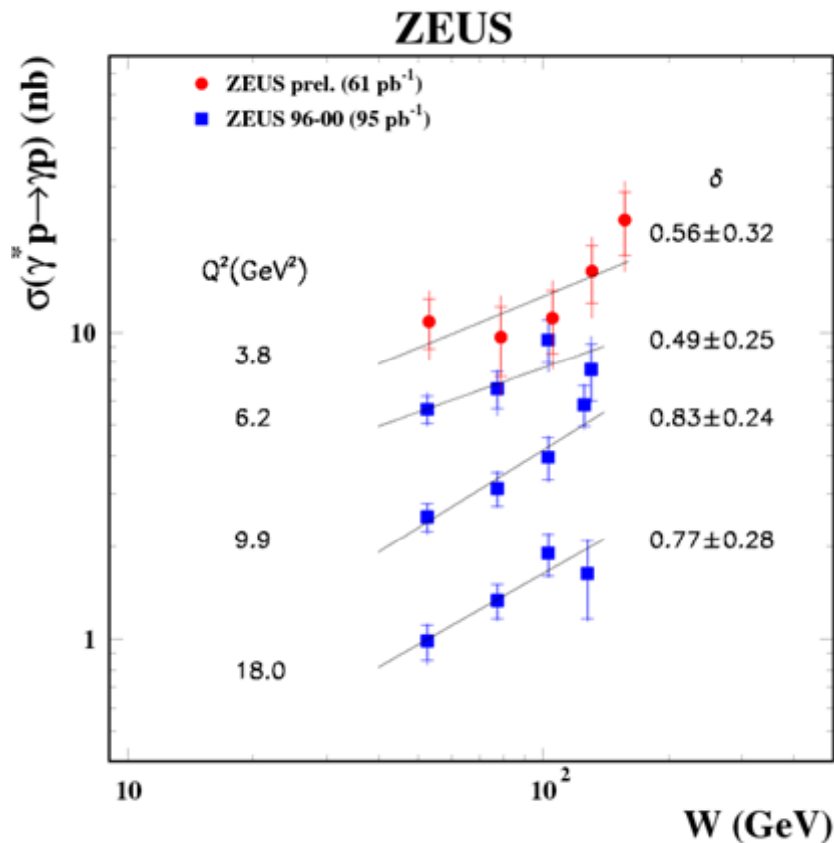


$$\sigma \propto W^\delta \quad \delta = f(M_V)$$

*Process becomes hard as scale (mass) becomes larger.*

*$\delta = 1.6 \pm 0.8$  comes from the fit to 4 (ZEUS + H1) points.*

# Cross section $\gamma^*p \rightarrow \gamma p$

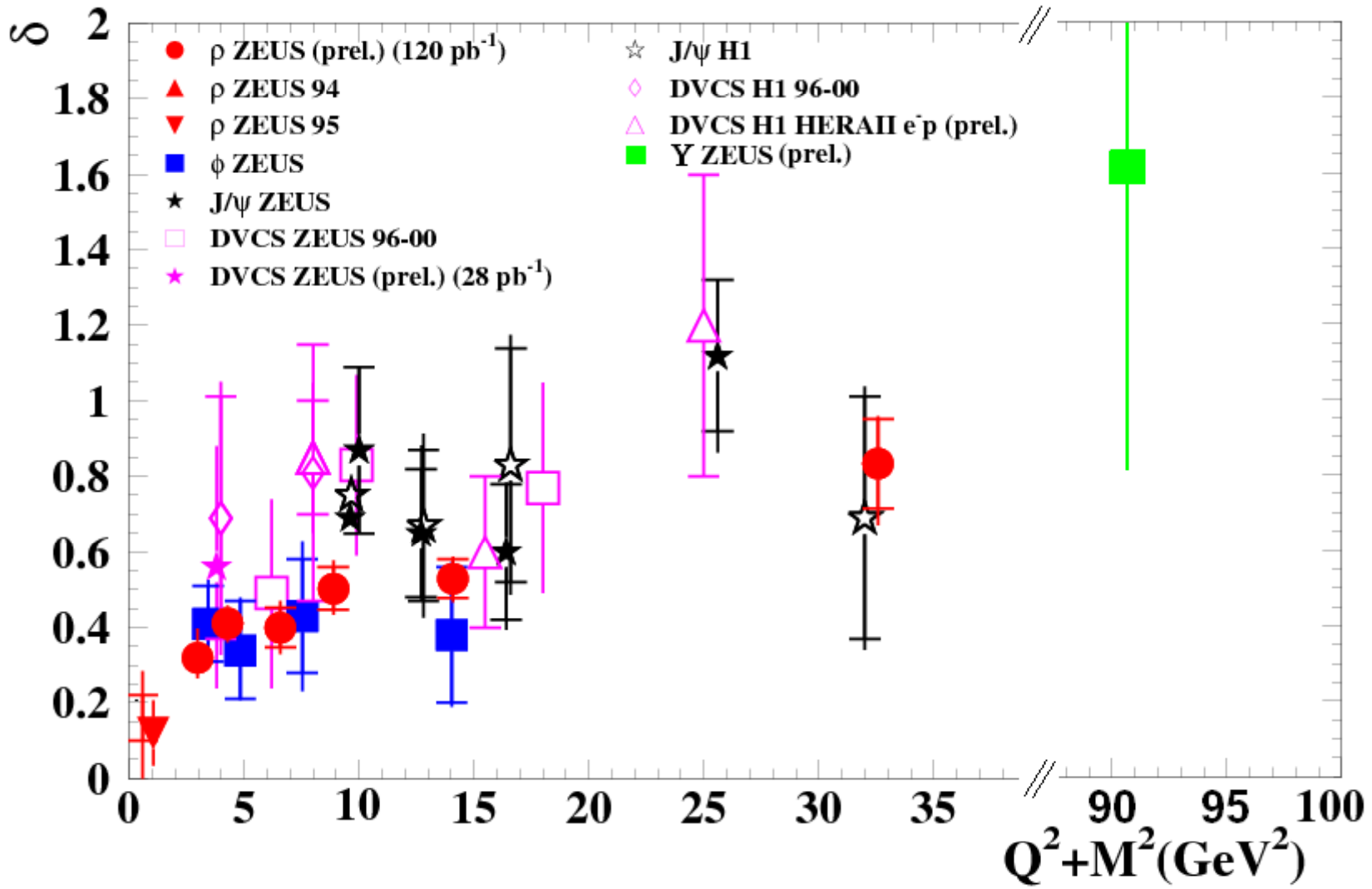


*First direct measurement of differential cross section as a function of  $t$  using LPS*

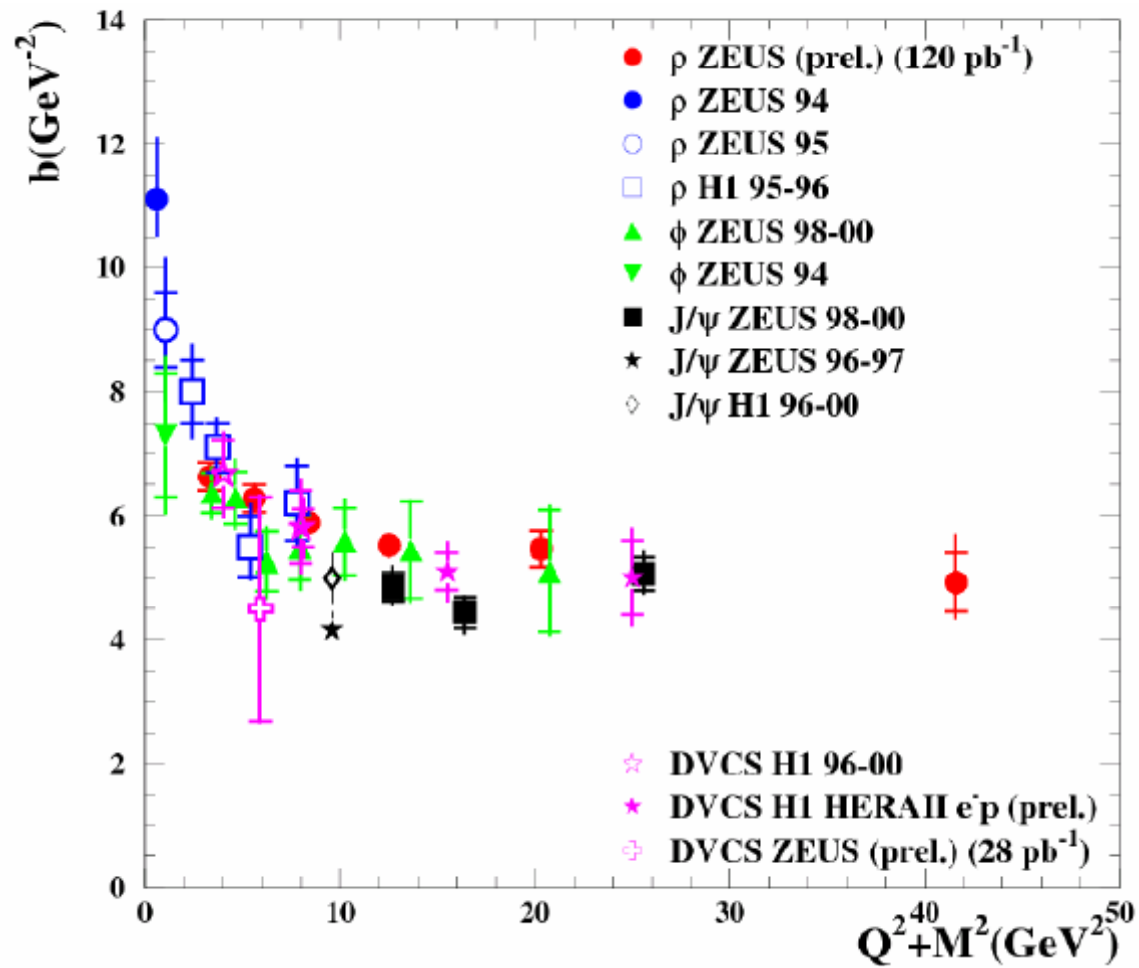
*Steep rise for large  $Q^2$  observed in ZEUS*

- *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 $b(Q^2 + M^2)$



# 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 ( $Q^2+M^2$ )*