Diffractive exclusive final states in ep collisions

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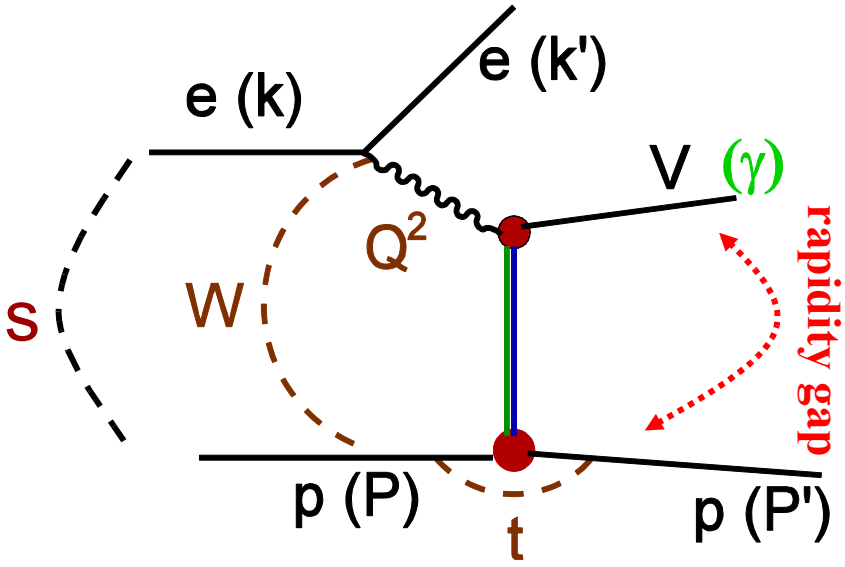
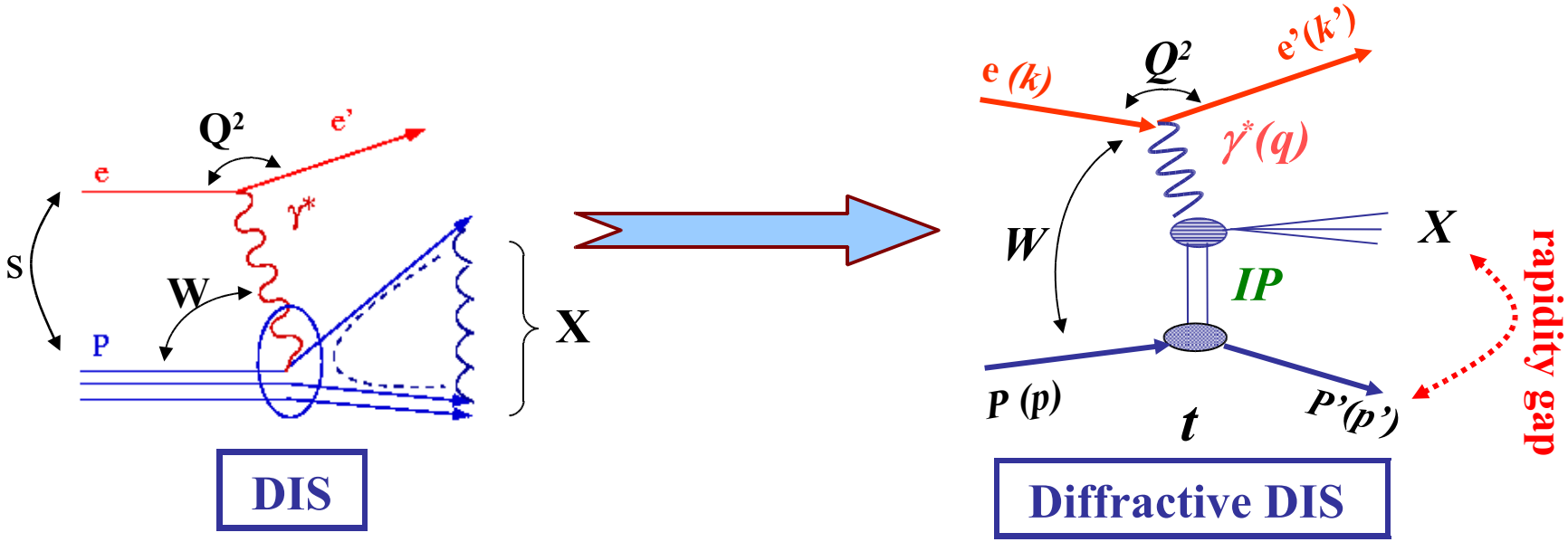
on behalf of the ZEUS and H1 Collaborations



Lake Louise Winter Institute 2008
Lake Louise (Canada), *17 – 23 Feb. 2008*

Diffraction at HERA



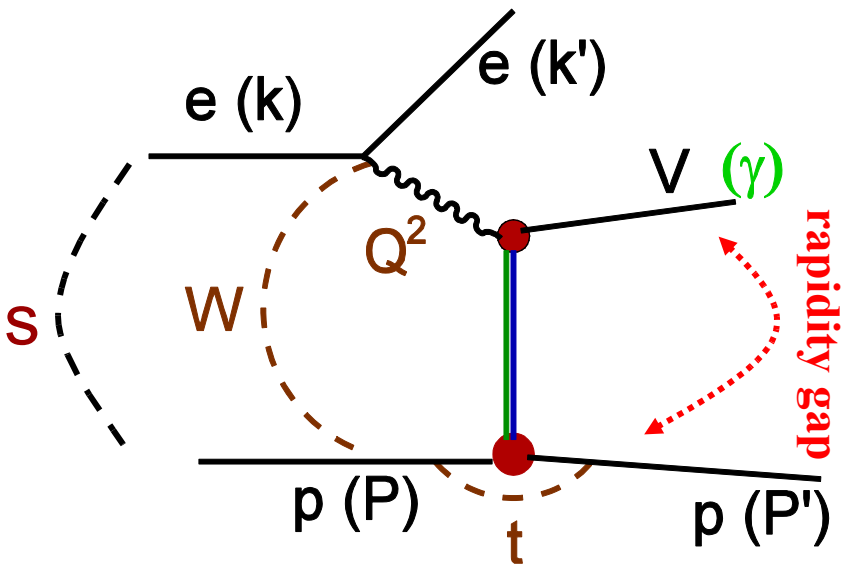
HERA was designed to study

Deep Inelastic Scattering

- **p stays intact** and escapes in the beam pipe
- no quantum numbers exchanged btw γ* and ***p***

  ↦ **no colour flux** ↦ **large rapidity gap**
- Providing a perturbative QCD motivated description of strong interactions

Exclusive diffraction



Main kinematic variables

electron-proton centre-of-mass energy:

$$s = (k+p)^2 \approx 4E_e E_p$$

photon virtuality:

$$Q^2 = -q^2 = -(k-k')^2 \approx 4E_e E'_e \sin^2\frac{\theta}{2}$$

photon-proton centre-of-mass energy:

$$W^2 = (q+p)^2, \text{ where: } m_p < W < \sqrt{s}$$

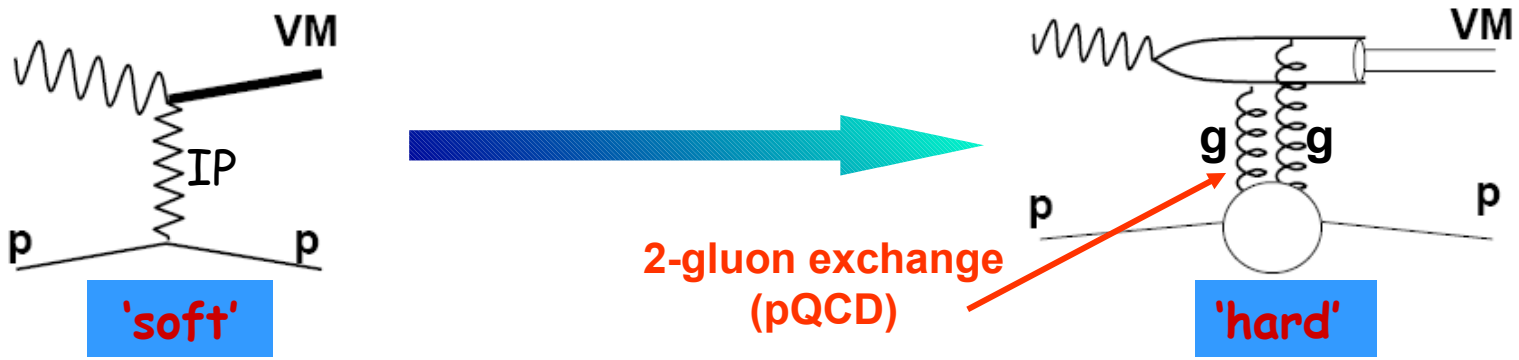
square 4-momentum at the *p* vertex:

$$t = (p'-p)^2$$

- **Vector Mesons production in diffraction**
- **Deeply Virtual Compton Scattering**
- ***W*, Q^2 ant *t* cross section dependence for exclusive processes**

Soft and hard diffraction

Vector Meson production (ρ, ϕ, J/ψ, Υ, γ)



Gluon density in the proton

Cross section proportional to probability of finding 2 gluons in the proton

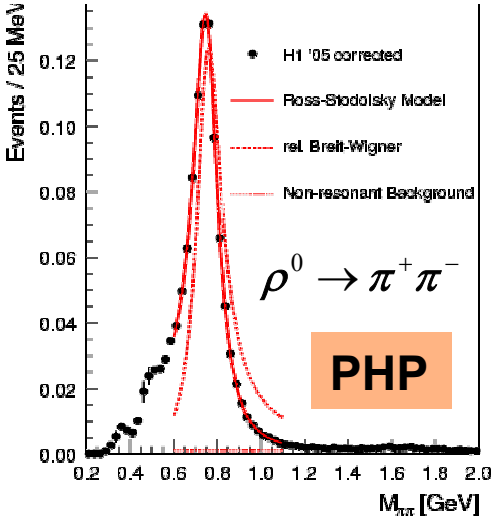
$$\begin{cases} \sigma \propto [x\,g(x,\mu^2)]^2 & \leftarrow\ ! \\ \mu^2 \propto (Q^2 + M_V^2) & \leftarrow\ ? \end{cases}$$

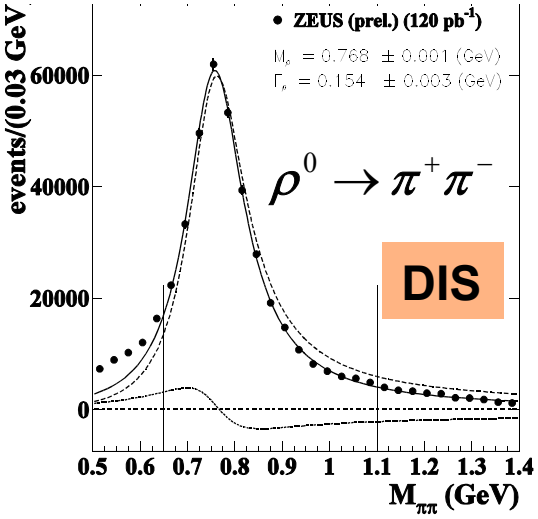
$\sigma(W) \propto W^{\delta}$ ➡ δ Expected to increase from soft (~0.2, "soft Pomeron") to hard (~0.8, "hard Pomeron")

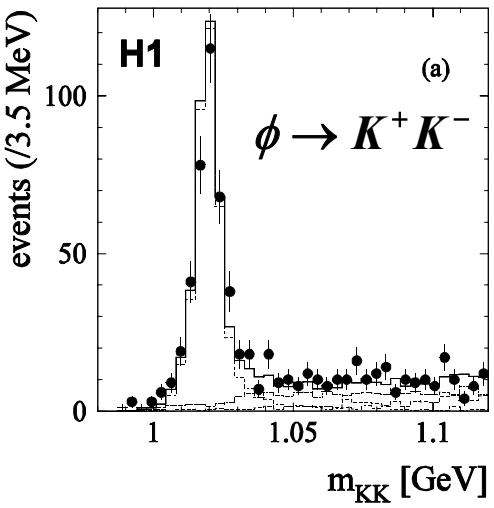
$\frac{d\sigma}{dt} \propto e^{-b|t|}$ ➡ *b* expected to decrease from soft (~10 GeV^{-2}) to hard (~4-5 GeV^{-2})

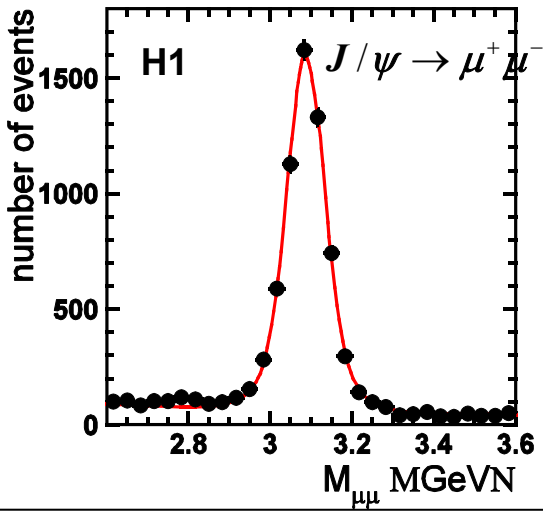
VM mass distributions

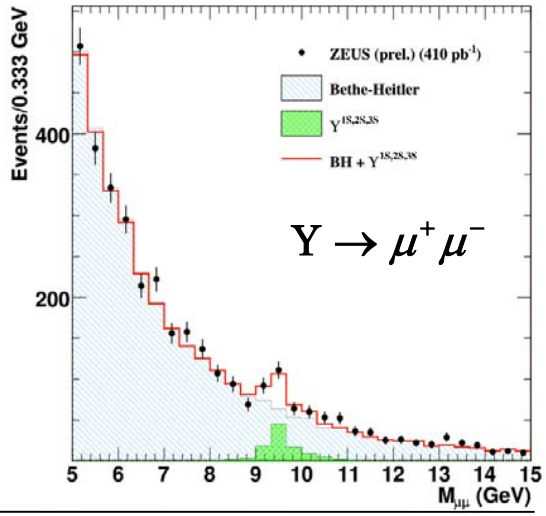
Large variety of processes to study dynamics versus scales: M_V^2, Q^2, t





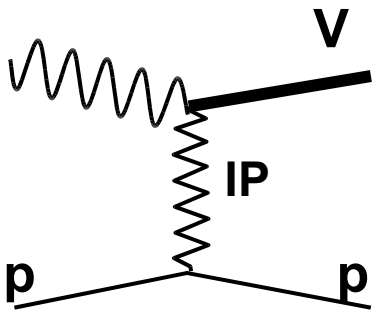




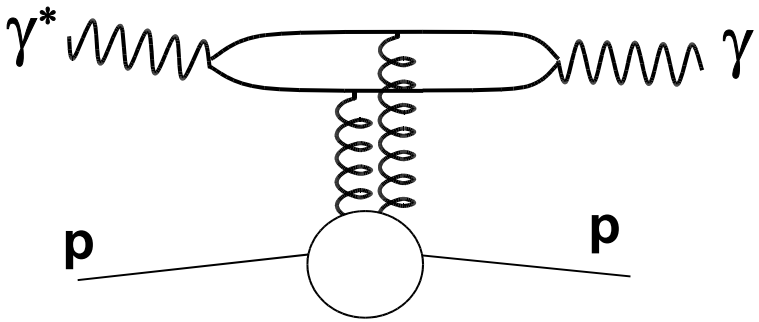


Deeply Virtual Compton Scattering

VM (ρ, ω , ϕ, ψ, Υ)



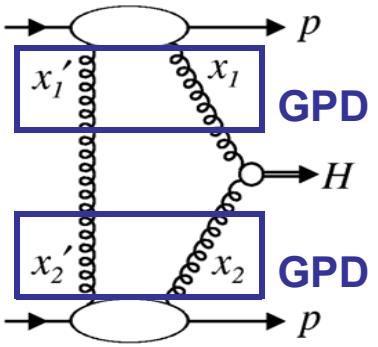
DVCS (γ)



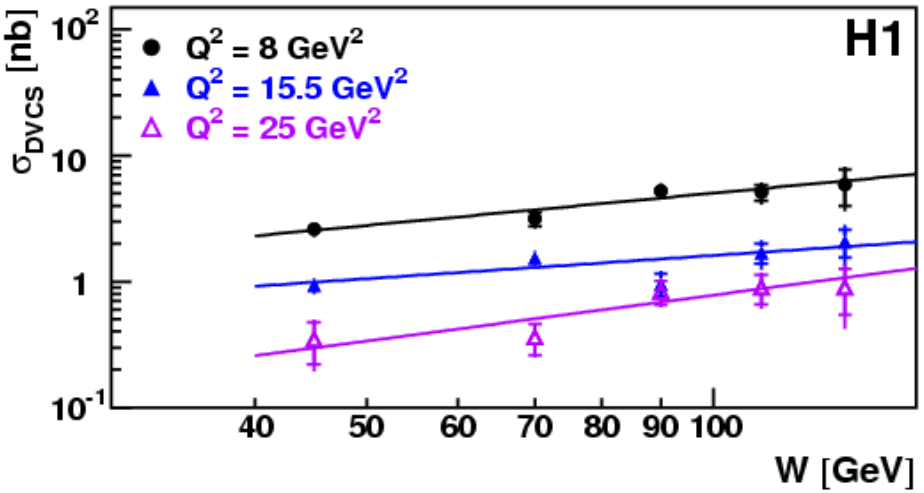
Scale: $Q^2 + M^2$ ⟷ **Q^2**

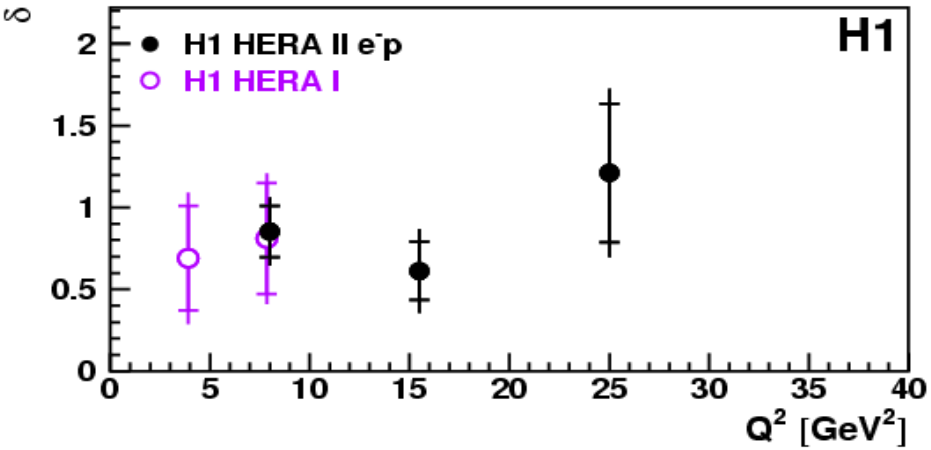
DVCS properties:

- **Similar to VM production, but γ instead of VM in the final state**
- **No VM wave-function involved**
- **Important to determine Generalized Parton Distributions sensible to the correlations in the proton**
- **GPD_s are an ingredient for estimating diffractive cross sections at LHC**

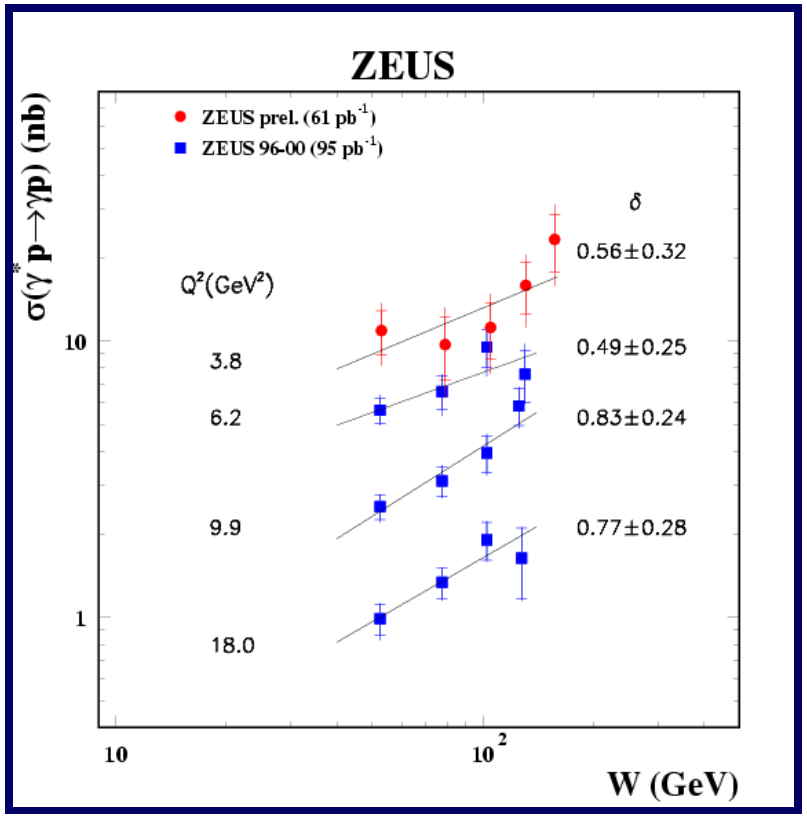


DVCS: *W*-dependence





Fit: $\sigma \sim W^{\delta}$



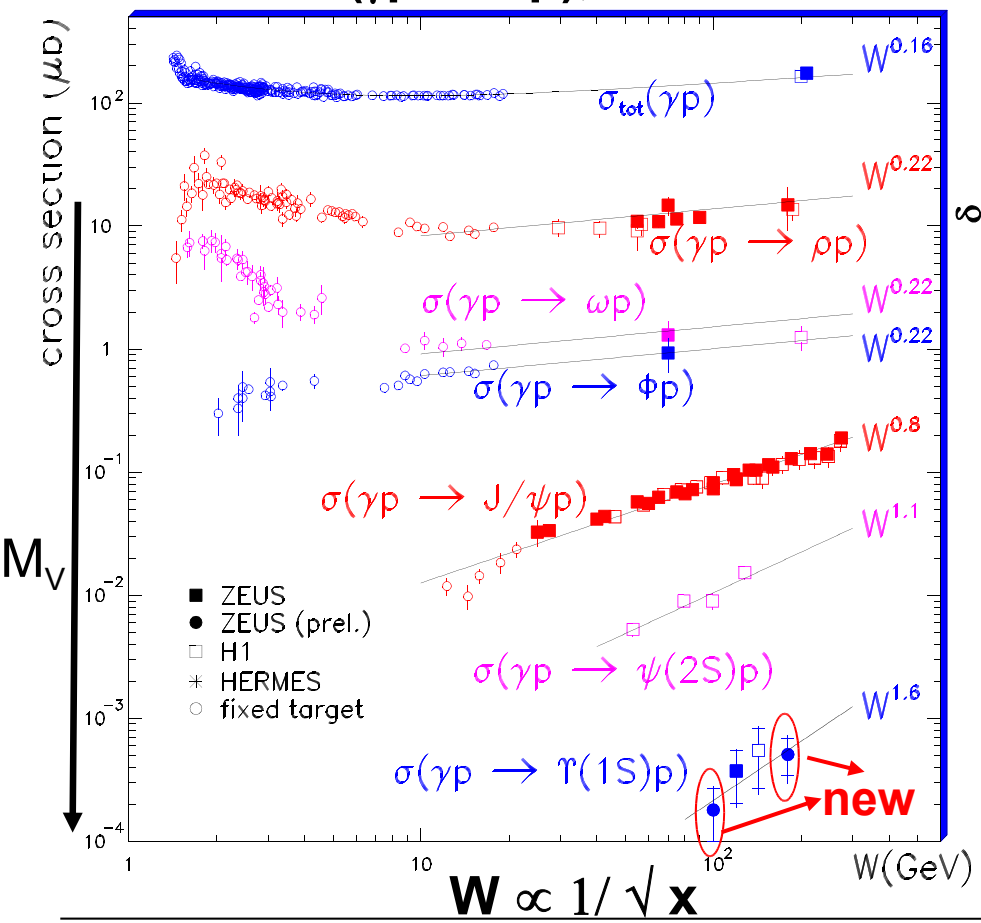
We can't say anything about the Q^2 dependence for the *W* slope within the uncertainties!

VM: W-dependence

Large M_V supplies a scale for hard processes → apply pQCD models

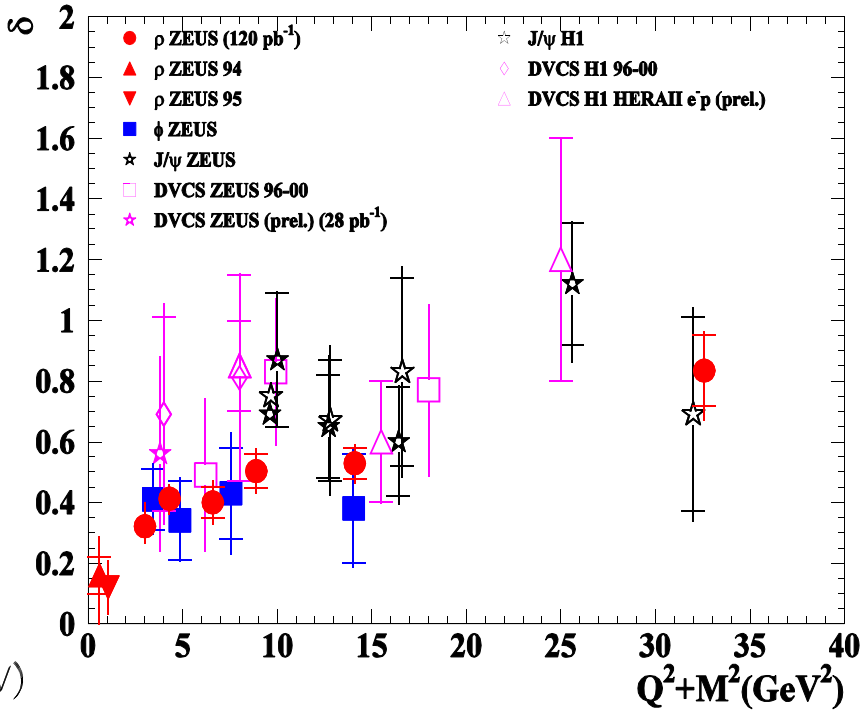
Fit: $\sigma \sim W^{\delta}$

$\sigma(\gamma p \rightarrow Vp)$, $Q^2=0$

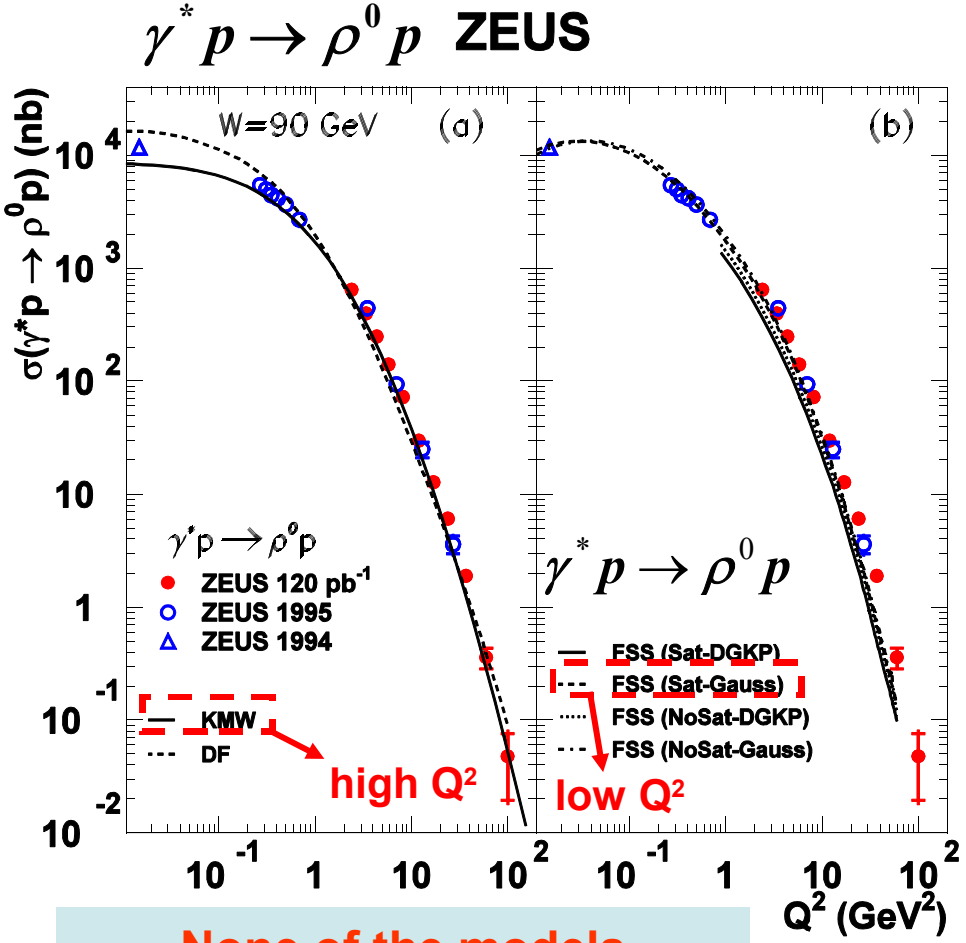


***W*-slope is ($Q^2 + M_V^2$) scale dependent**

$$\delta \propto \ln\left(Q^2 + M_V^2\right)$$



ρ^0: cross section

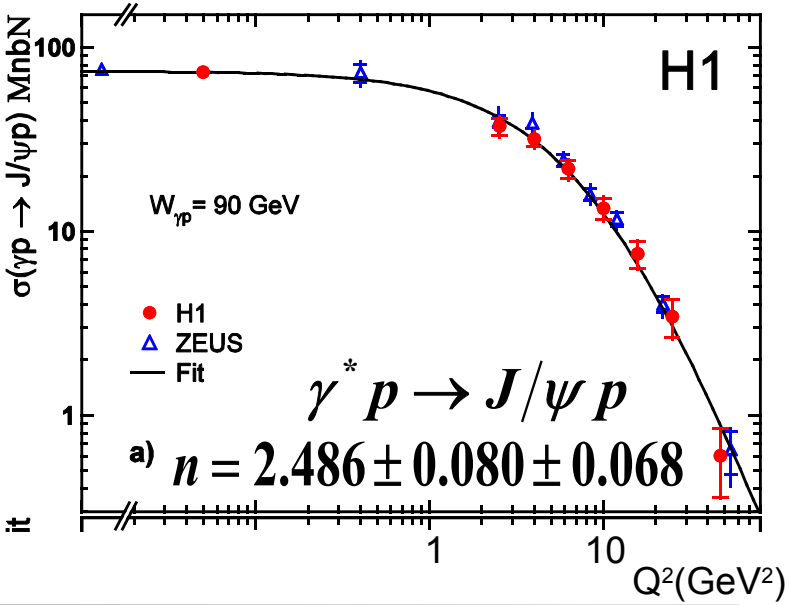


None of the models reproduces the data over the full kinematic range

$$\sigma \propto \left(Q^2 + M^2\right)^{-n}$$

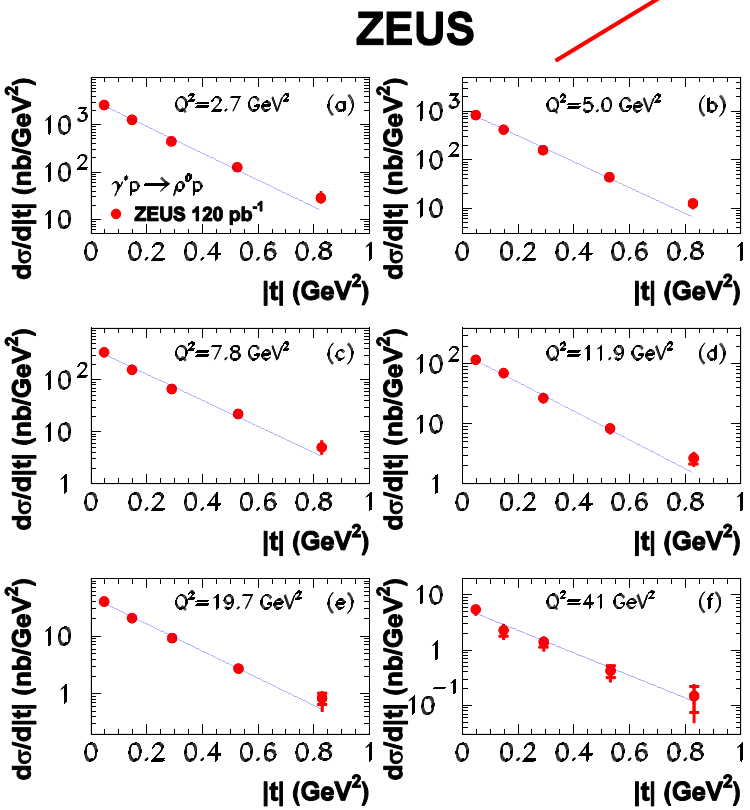
Fit to whole Q^2 range gives bad χ^2/df (~70)

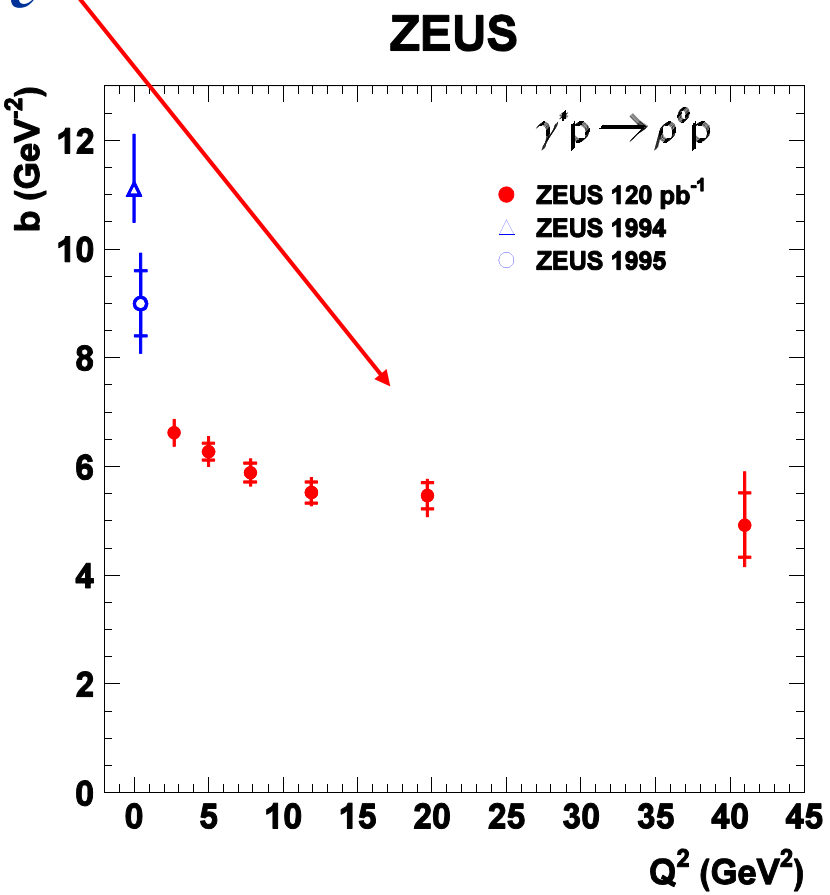
n increasing with Q^2 appears to be favored



ρ^0: t dependence

$\gamma^* p \to \rho^0 p$ $\quad$ *Fit :* $\quad \frac{d\sigma}{dt} \propto e^{-b|t|}$

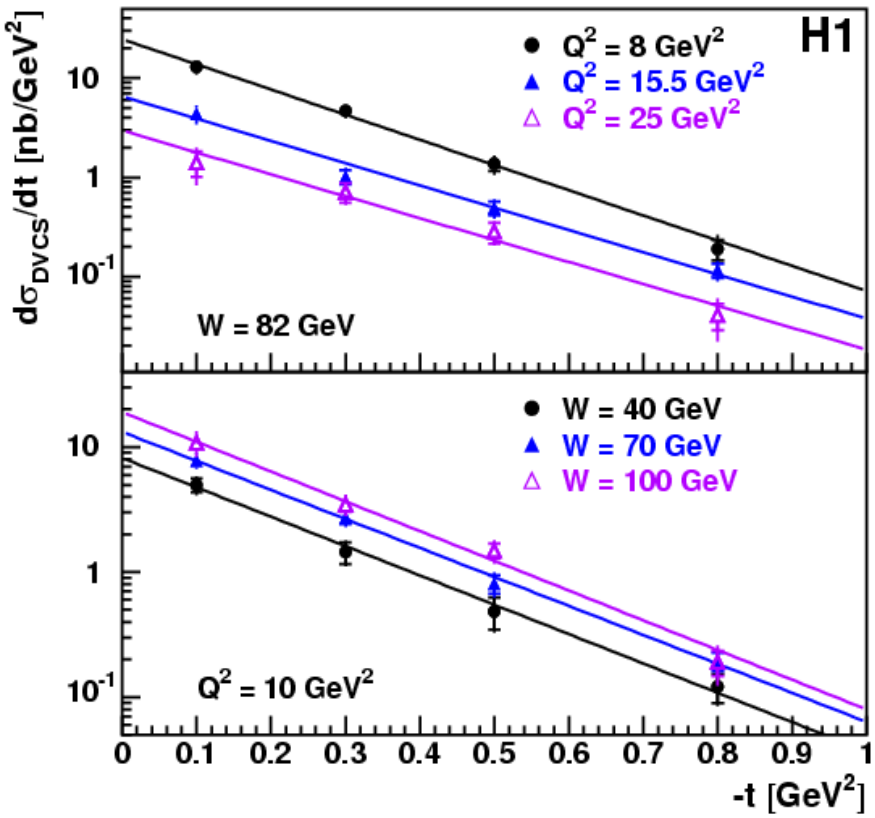


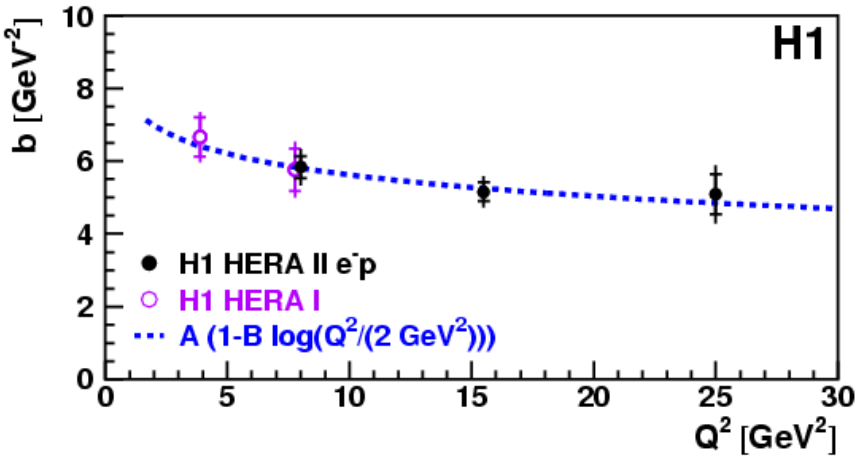


***b* decreases from soft values to pQCD expected values (~4-5 GeV^{-2})**

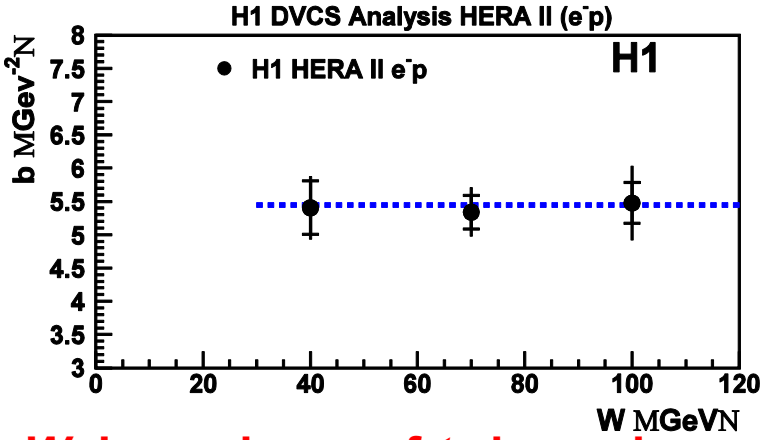
DVCS: *t* dependence

H1 DVCS





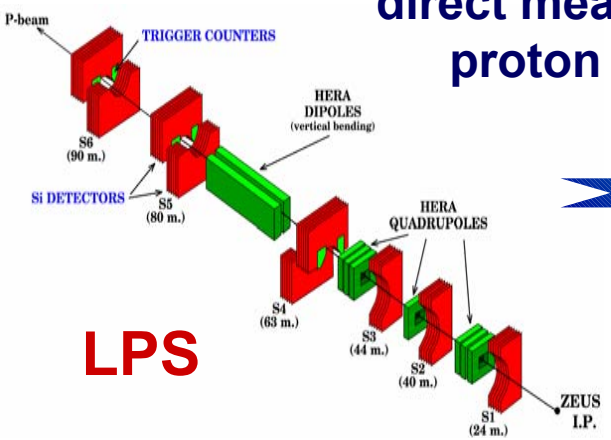
***b* decreases with increasing Q^2**



No *W* dependence of *t* slope observed

Flat Pomeron?!

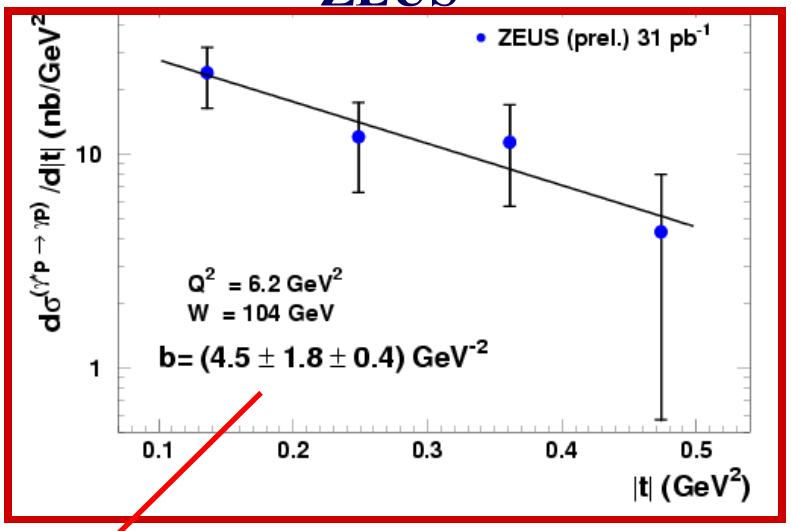
DVCS: *t* dependence



LPS

direct measurement of the proton 4-momentum

ZEUS



$$b = \left(4.5 \pm 1.8 \pm 0.4\right) GeV^{-2}$$

Compatible with the H1 measurements!

No p dissociation background → Clean measurement

Low detector acceptance → low statistics

VM: *t* dependence

Same slope for all VM vs (Q^2 + M^2)

Size of the gluons:

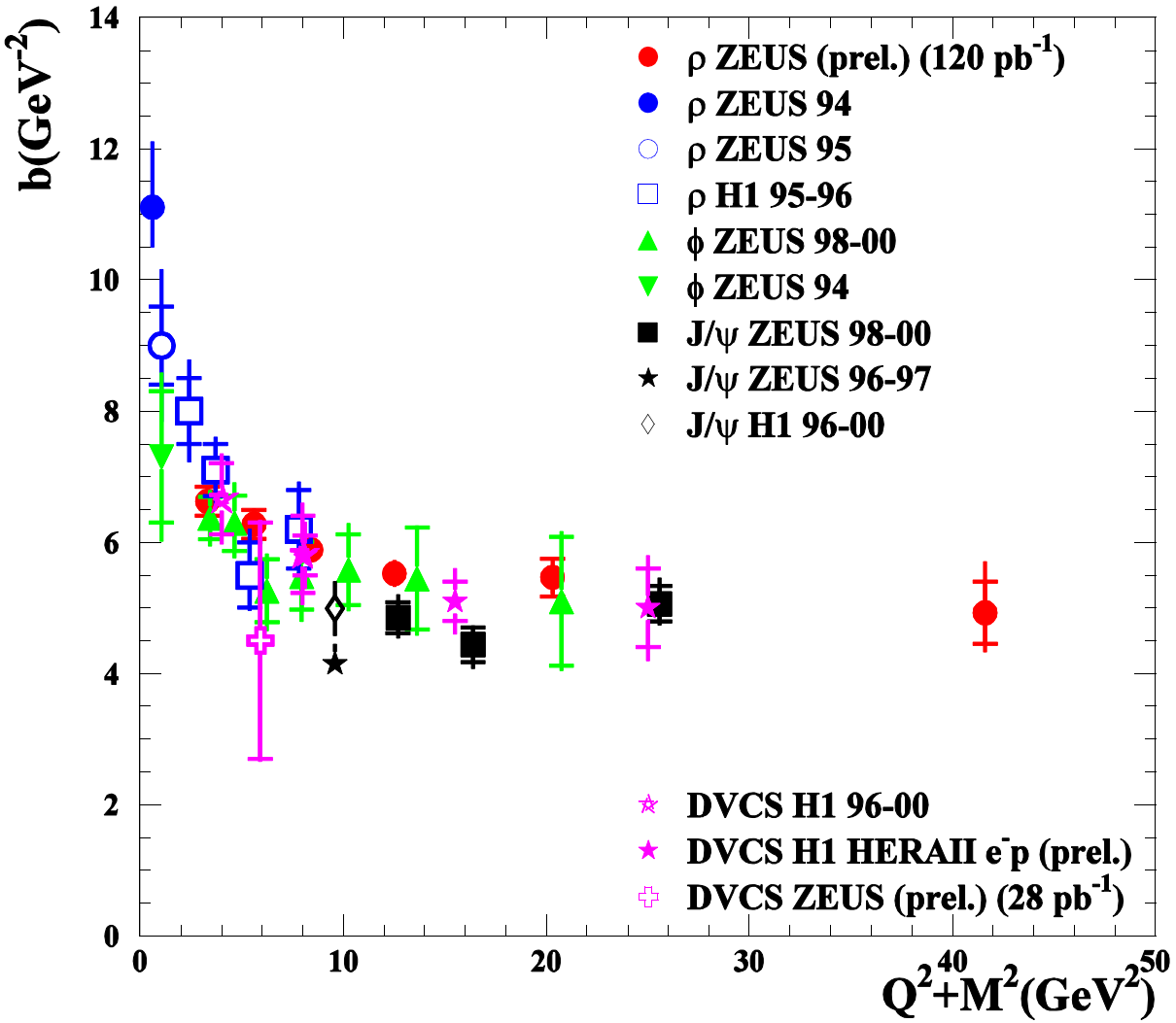
$$\left\langle r^2 \right\rangle = 2 \cdot b \cdot (\hbar c)^2$$

$$r_{glue} = 0.56 \text{ fm}$$

Proton radius:

$$r_{proton} = 0.8 \text{ fm}$$

Gluons confinement area is smaller than proton



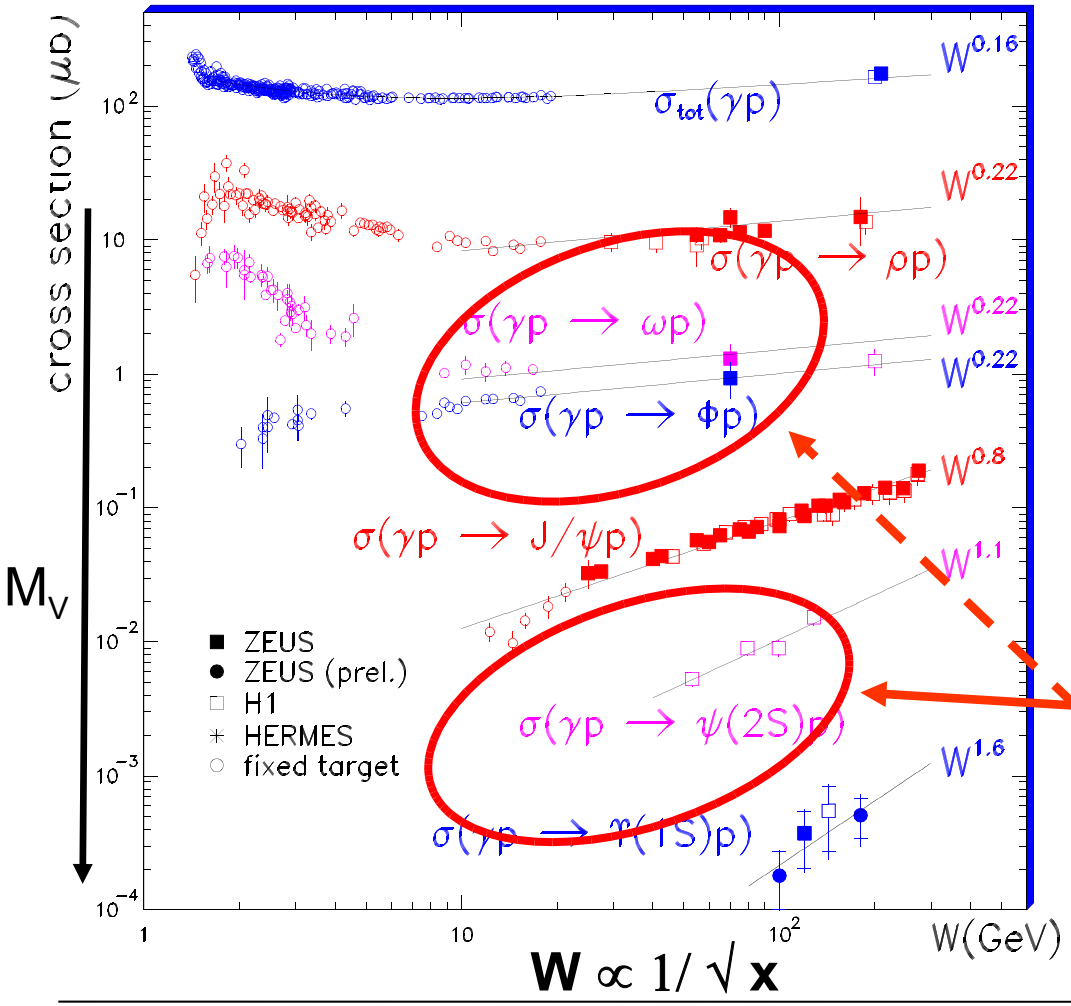
Summary

- New high statistics measurement of Υ (photoproduction) and ρ^0 have been published
- The Υ cross section rises as W^{δ} and δ grows with the universal hard scale Q^2+M^2
- None of the models compared to the ρ^0 cross section can reproduce all the features of the data in the full kinematic range
- DVCS high statistics measurements recently published show that the t slope seems to have a dependence from Q^2 but not from W
- t slope for all VM was found to fall following the universal hard scale Q^2+M^2

Back up

VM: sensitivity to gluons in proton

$\sigma(\gamma p \rightarrow Vp)$, $Q^2=0$



$W \propto 1/\sqrt{x}$

Fit: $\sigma \sim W^{\delta}$ **with** $\delta = 4(\alpha_P(0) - 1)$

***W*-dependence steeper with M_V^2:**

$\delta_\rho \sim 0.2 \longrightarrow \delta_{\Psi(2S)} \sim 1.0$

Large M_V supplies a scale for hard processes → apply pQCD models