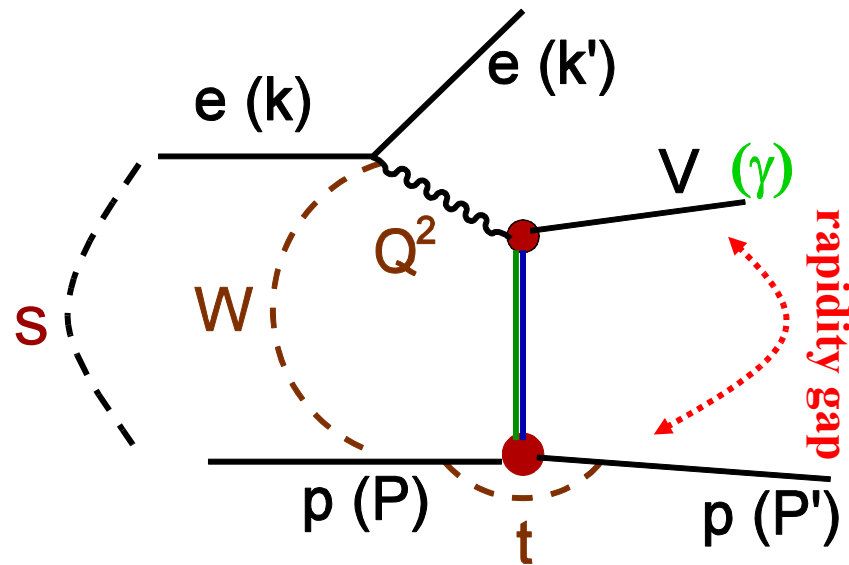


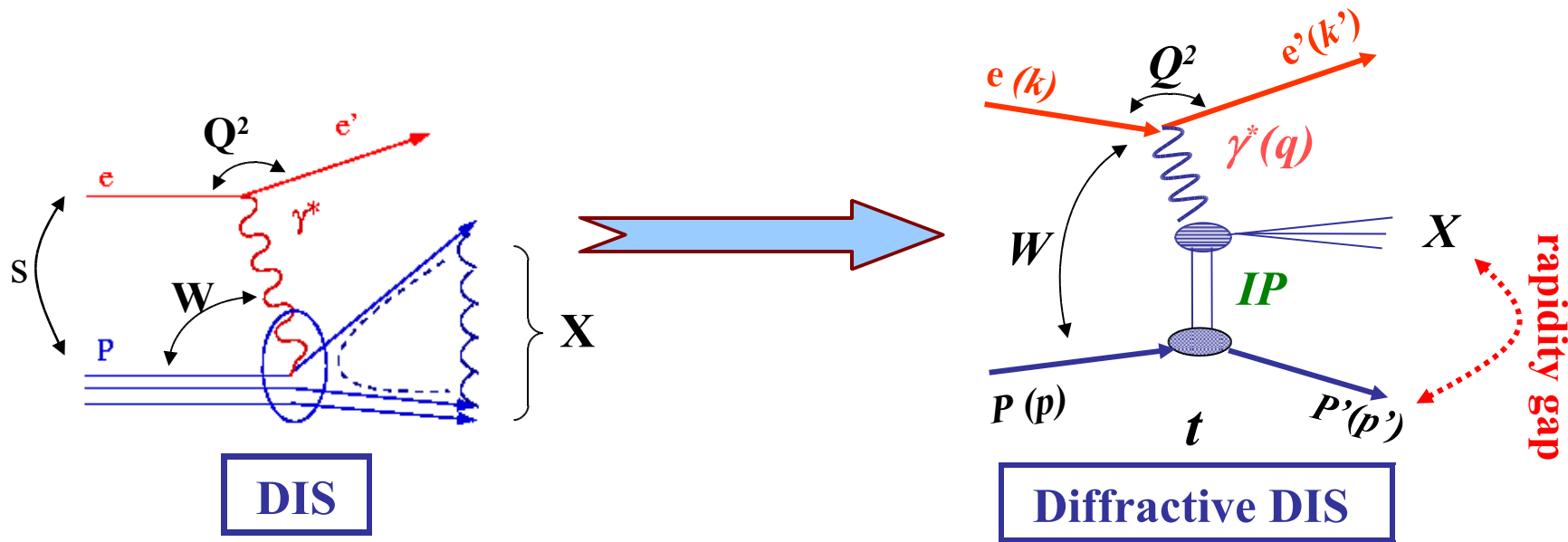
Diffractive exclusive final states in ep collisions

Salvatore Fazio, Calabria University and INFN (Cosenza, Italy)
on behalf of the ZEUS and H1 Collaborations



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

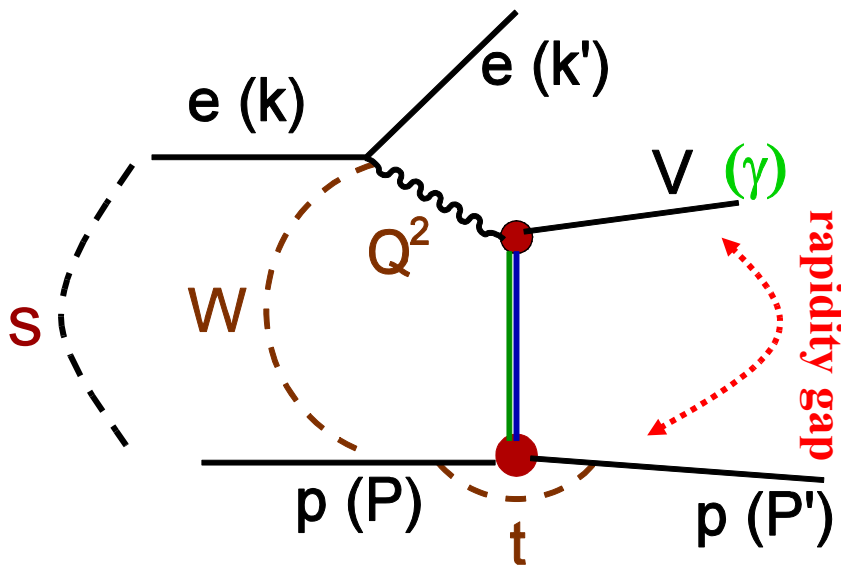
Diffraction at HERA



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
 \mapsto **no colour flux** \mapsto **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:

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

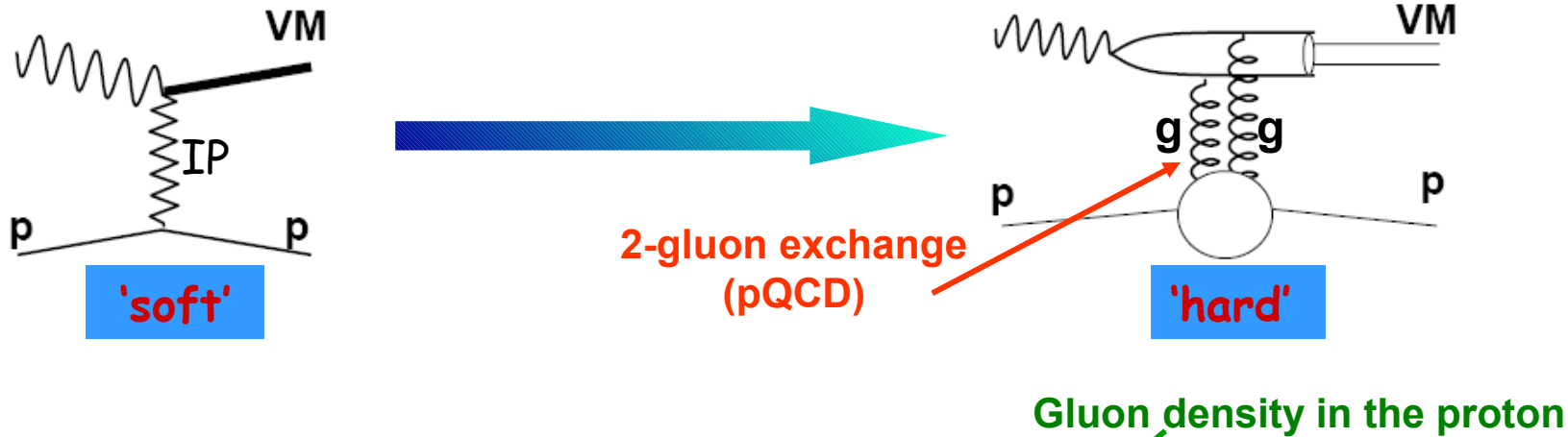
square 4-momentum at the p vertex:

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

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

Soft and hard diffraction

Vector Meson production ($\rho, \phi, J/\psi, Y, \gamma$)



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

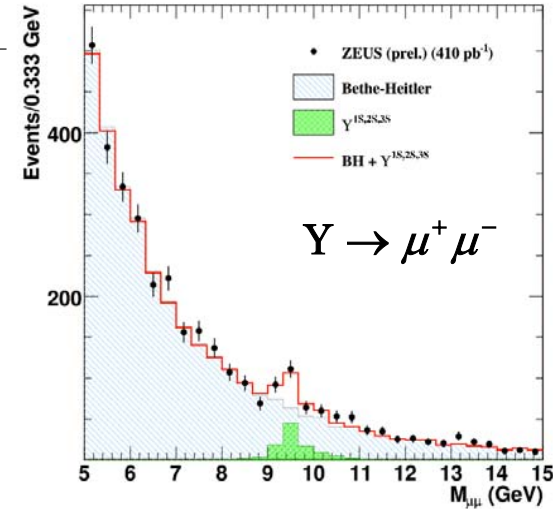
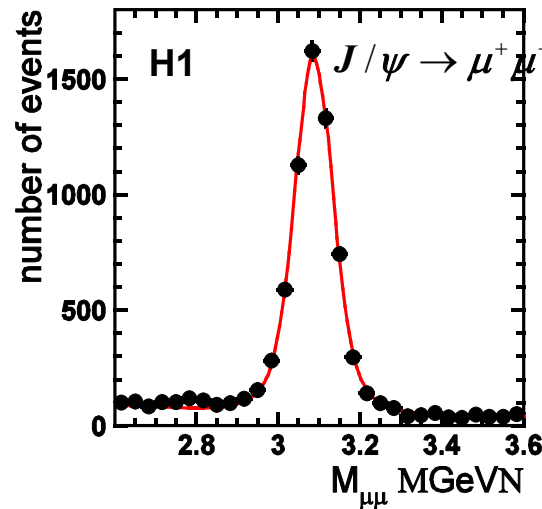
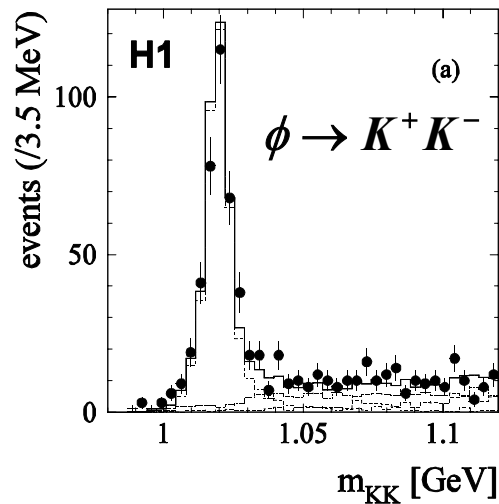
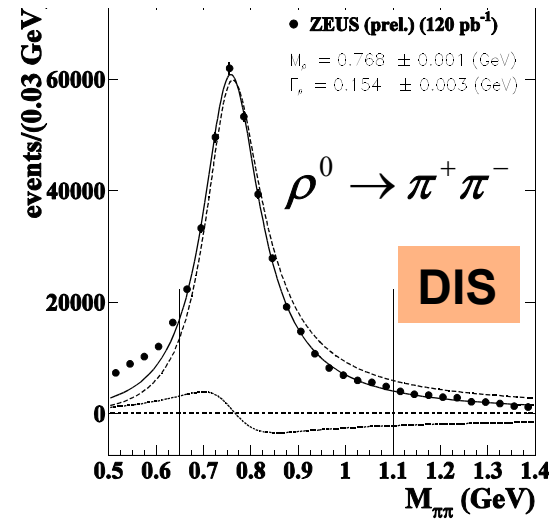
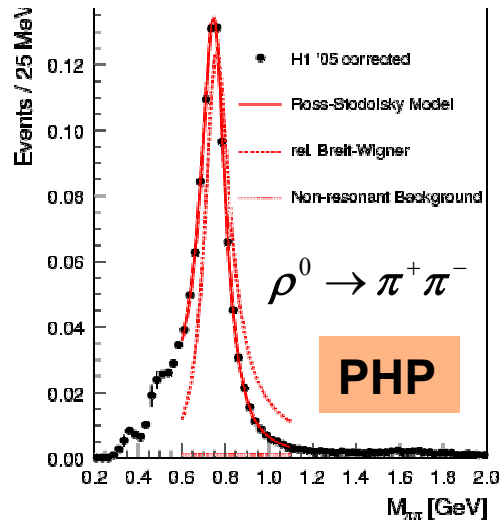
$$\begin{cases} \sigma \propto [x g(x, \mu^2)]^2 \leftarrow ! \\ \mu^2 \propto (Q^2 + M_V^2) \leftarrow ? \end{cases}$$

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

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

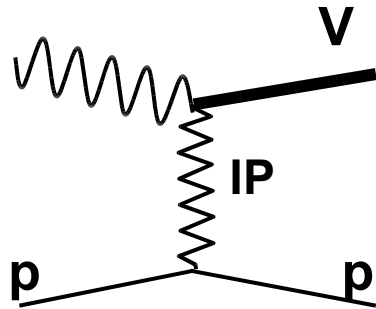
VM mass distributions

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

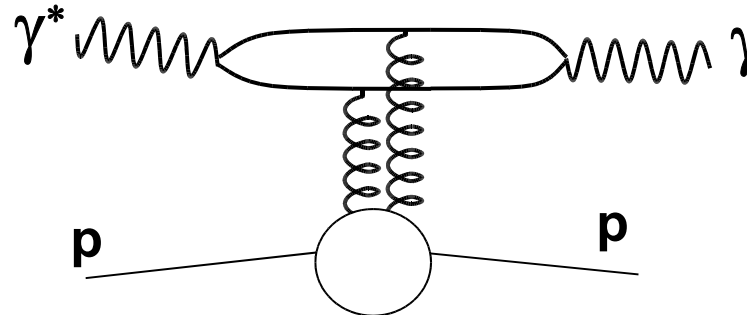


Deeply Virtual Compton Scattering

VM ($\rho, \omega, \phi, \psi, Y$)



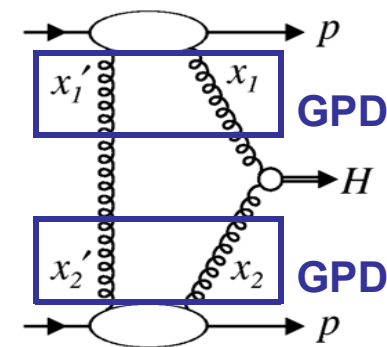
DVCS (γ)



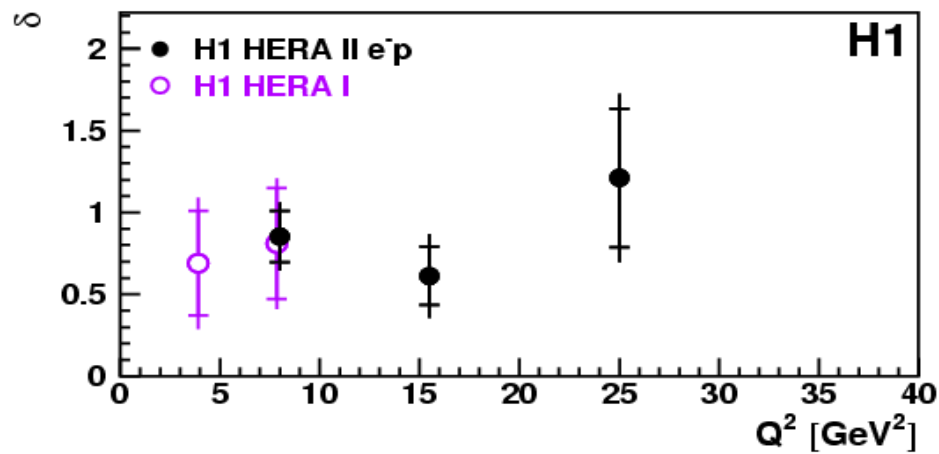
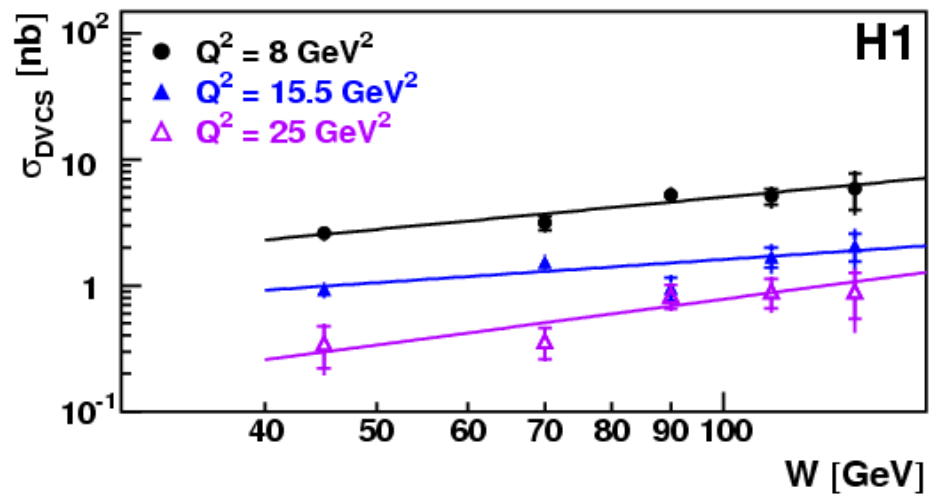
Scale: $Q^2 + M^2$ \longleftrightarrow Q^2

DVCS properties:

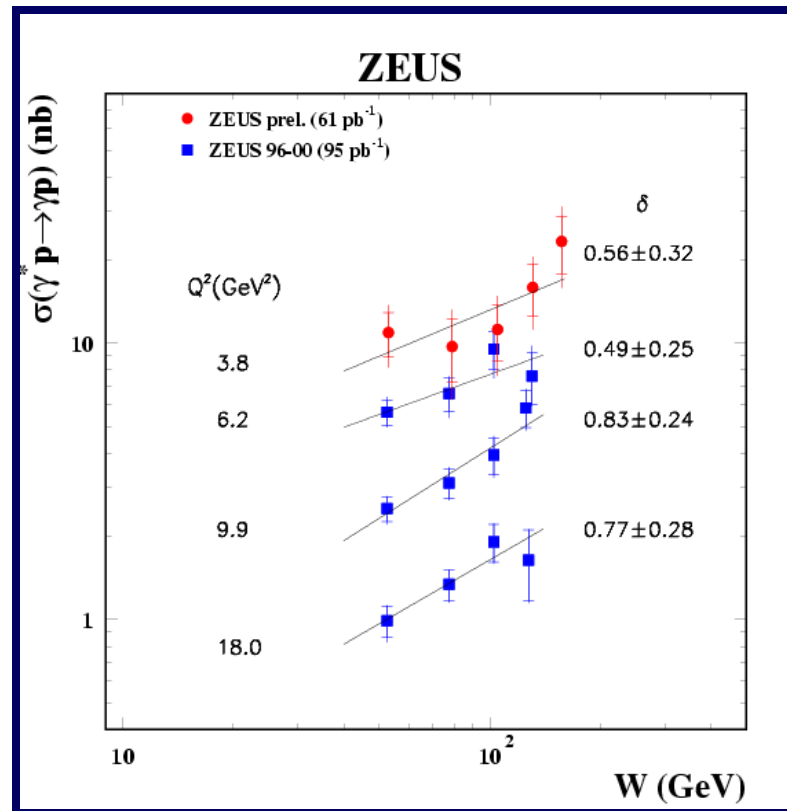
- Similar to VM production, but γ instead of VM in the final state
- No VM wave-function involved
- Important to determine Generalized Parton Distributions sensible to the correlations in the proton
- GPD_s are an ingredient for estimating diffractive cross sections at LHC



DVCS: W-dependence



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

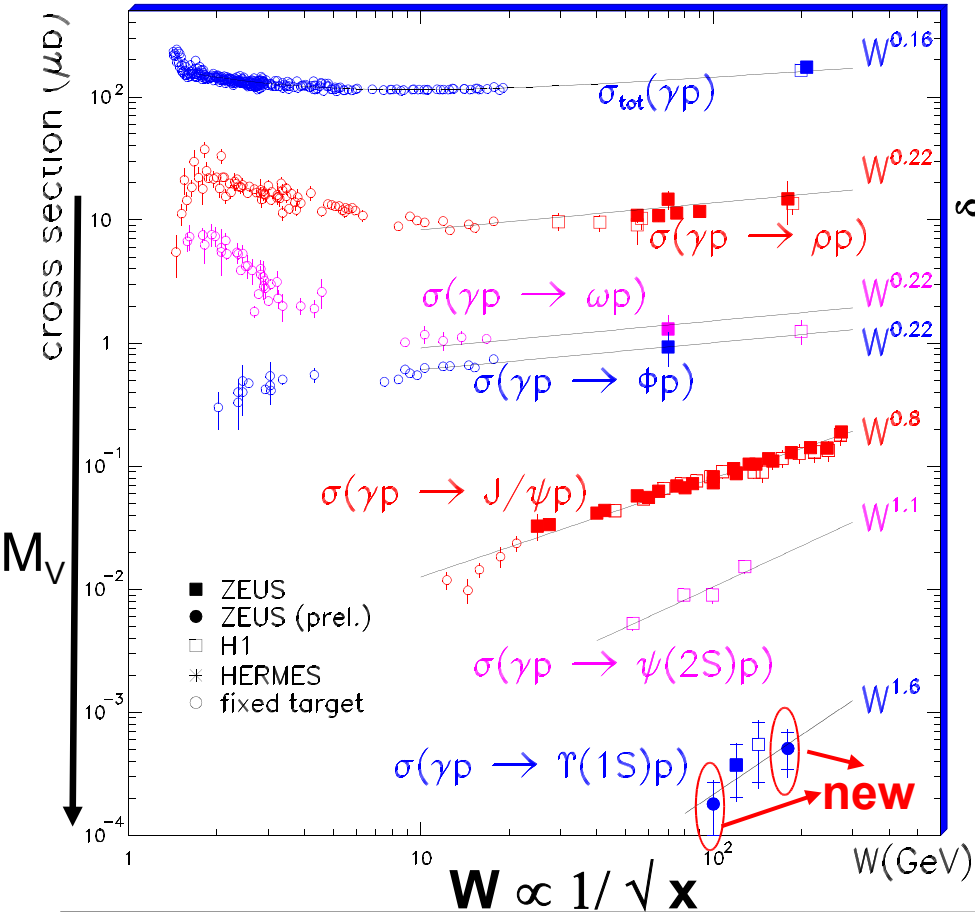


We can't say anything about the Q^2 dependence for the W slope within the uncertainties!

VM: W-dependence

Large M_V supplies a scale for hard processes \rightarrow apply pQCD models

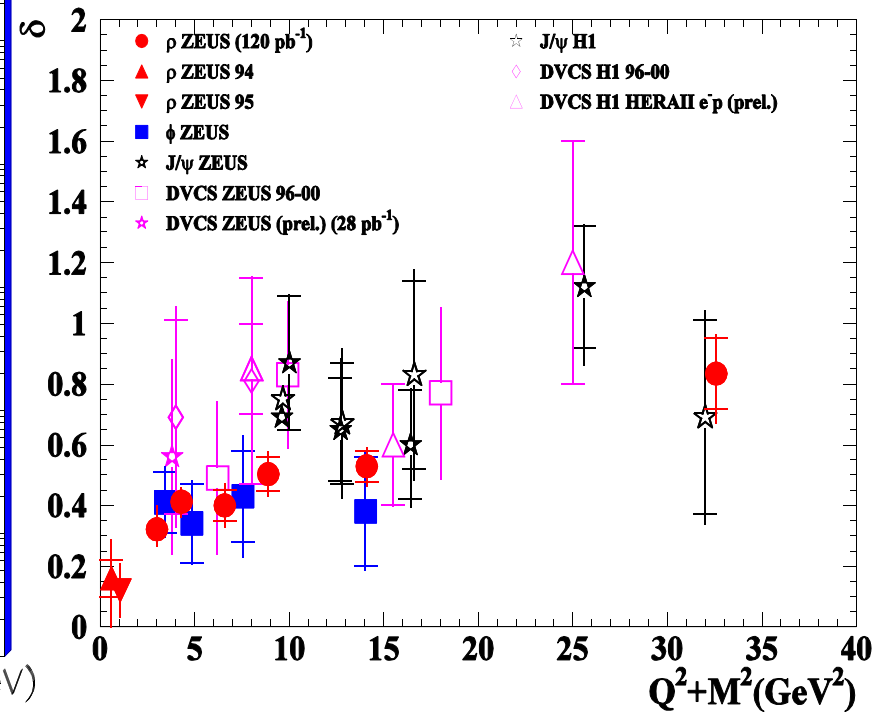
$\sigma(\gamma p \rightarrow Vp), Q^2=0$



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

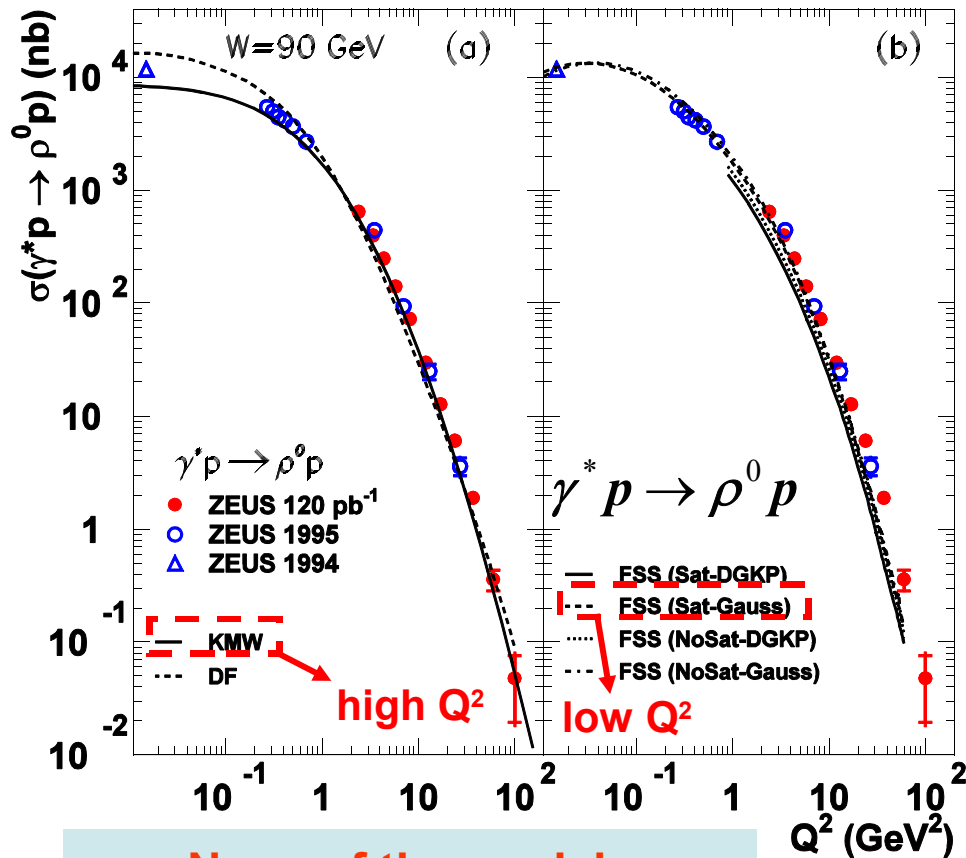
W -slope is $(Q^2 + M_V^2)$ scale dependent

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



ρ^0 : cross section

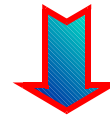
$\gamma^* p \rightarrow \rho^0 p$ ZEUS



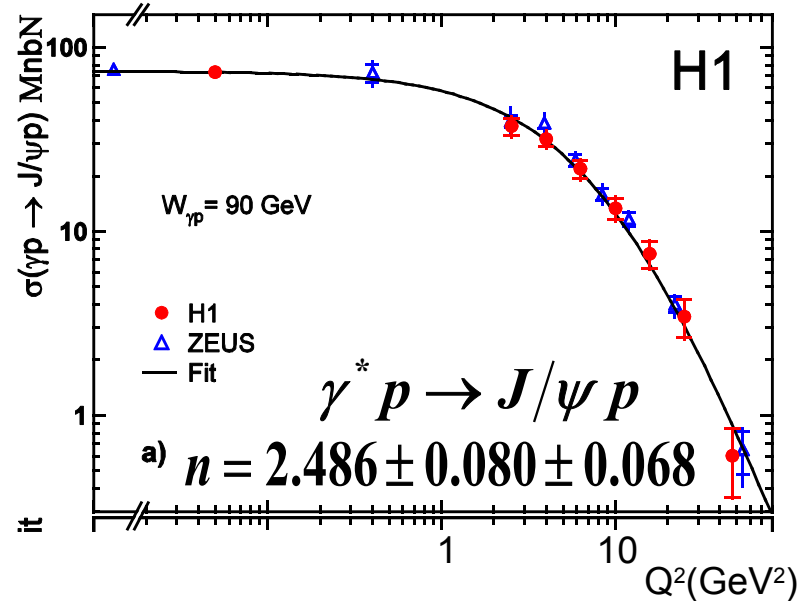
None of the models reproduces the data over the full kinematic range

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

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



n increasing with Q^2 appears to be favored

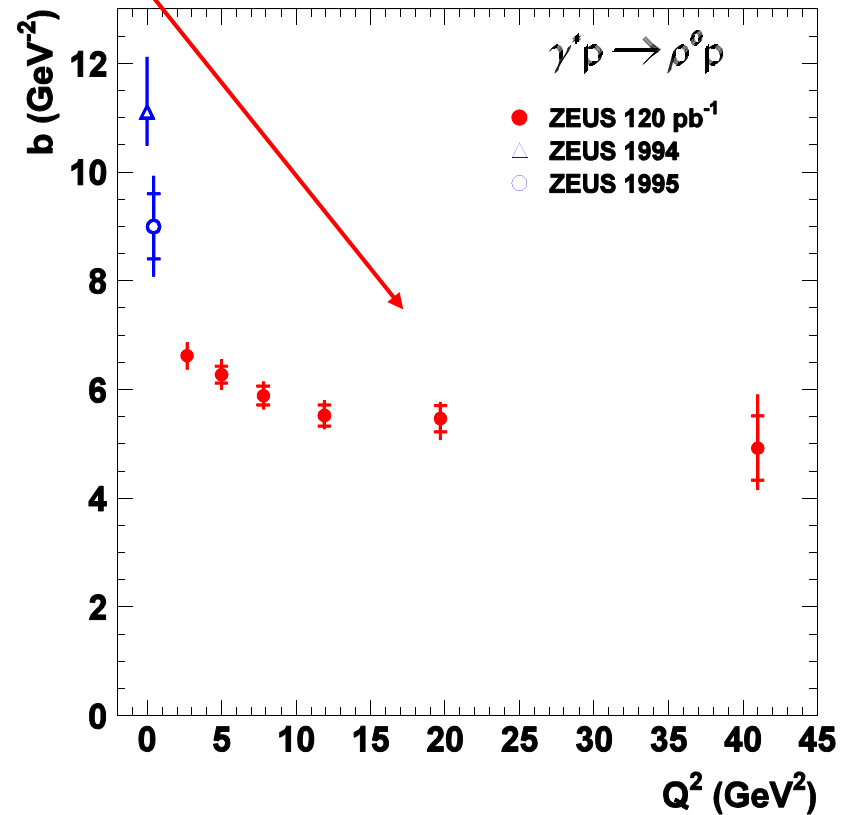
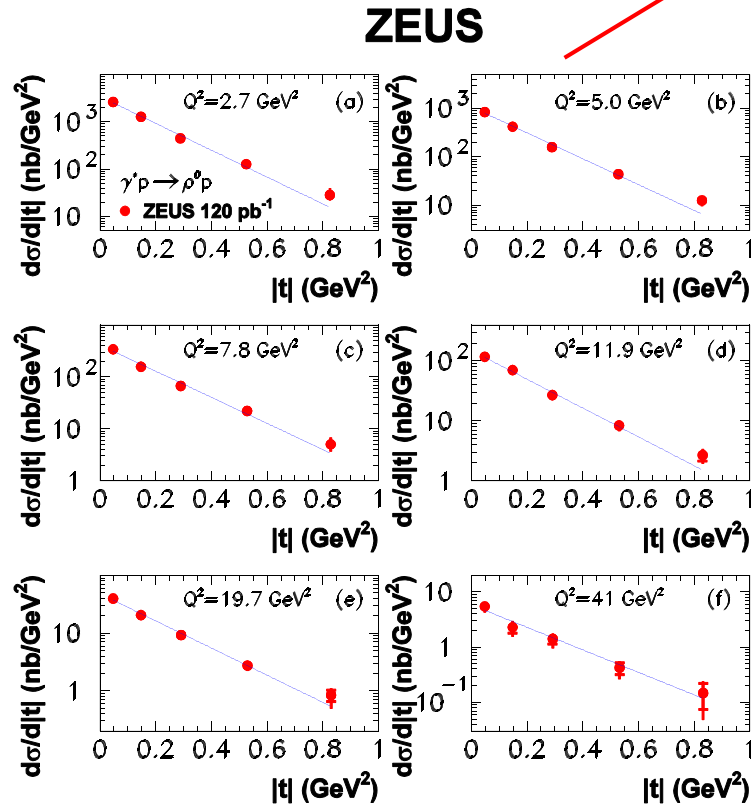


ρ^0 : t dependence

$$\gamma^* p \rightarrow \rho^0 p$$

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

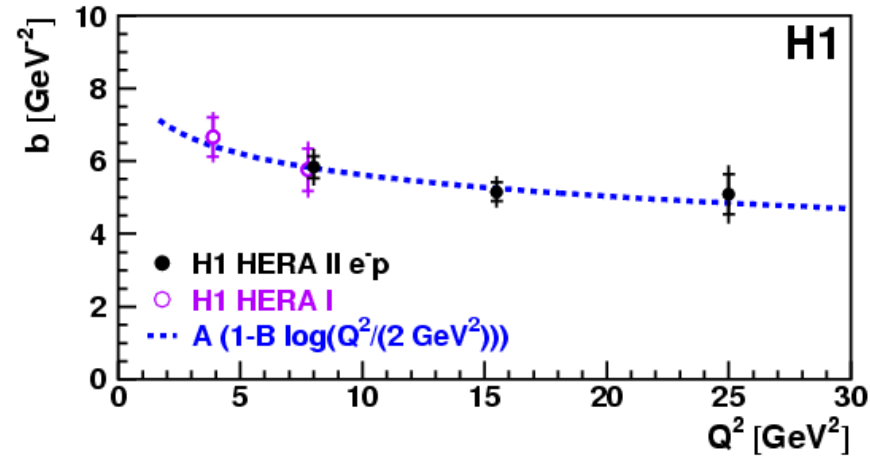
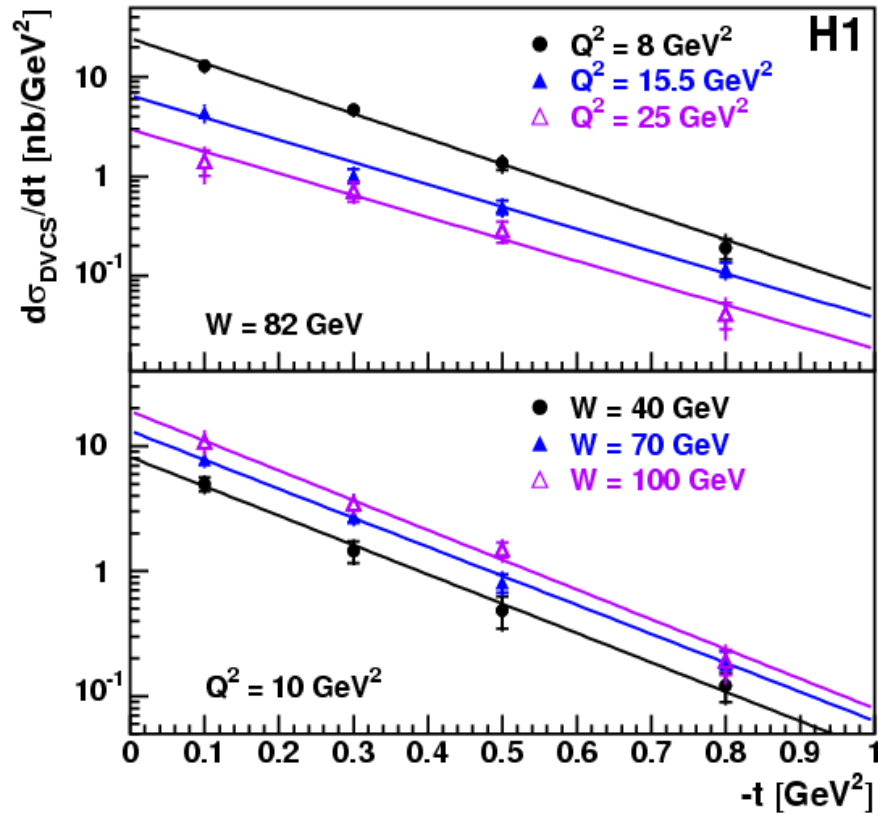
ZEUS



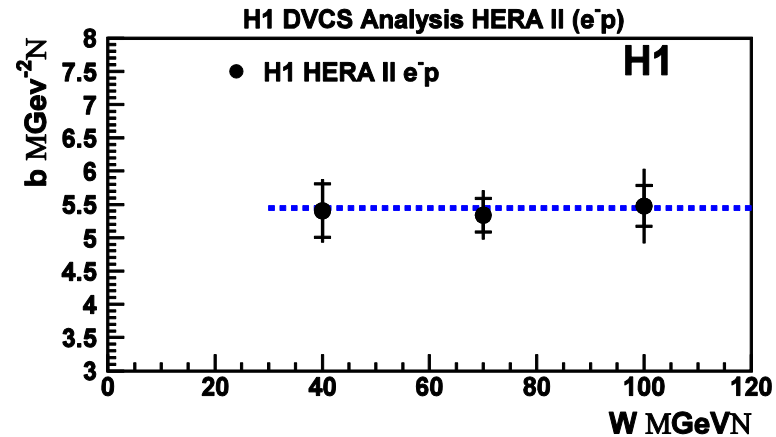
b decreases from soft values to pQCD expected values ($\sim 4-5$ GeV⁻²)

DVCS: t dependence

H1 DVCS



b decreases with increasing Q^2

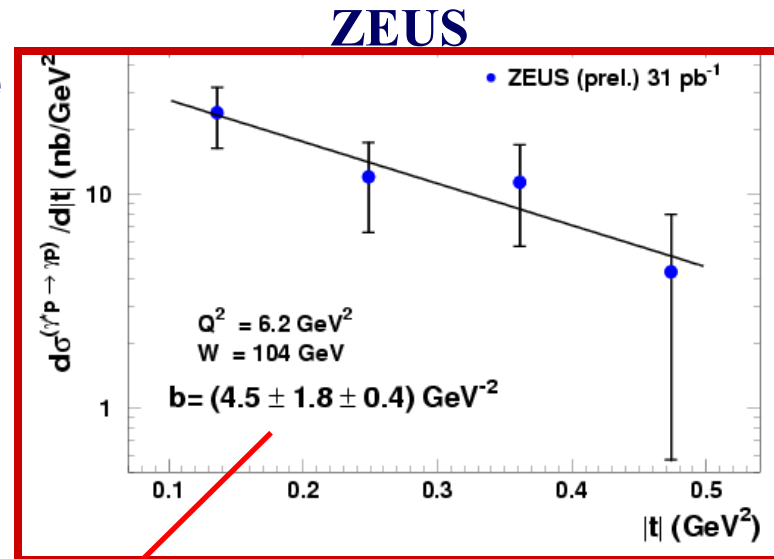
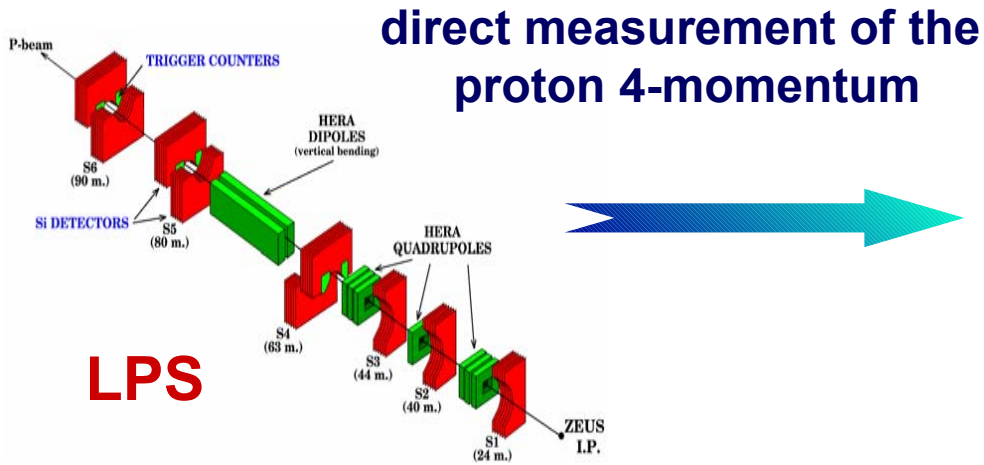


No W dependence of t slope observed



Flat Pomeron?!

DVCS: t dependence



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

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

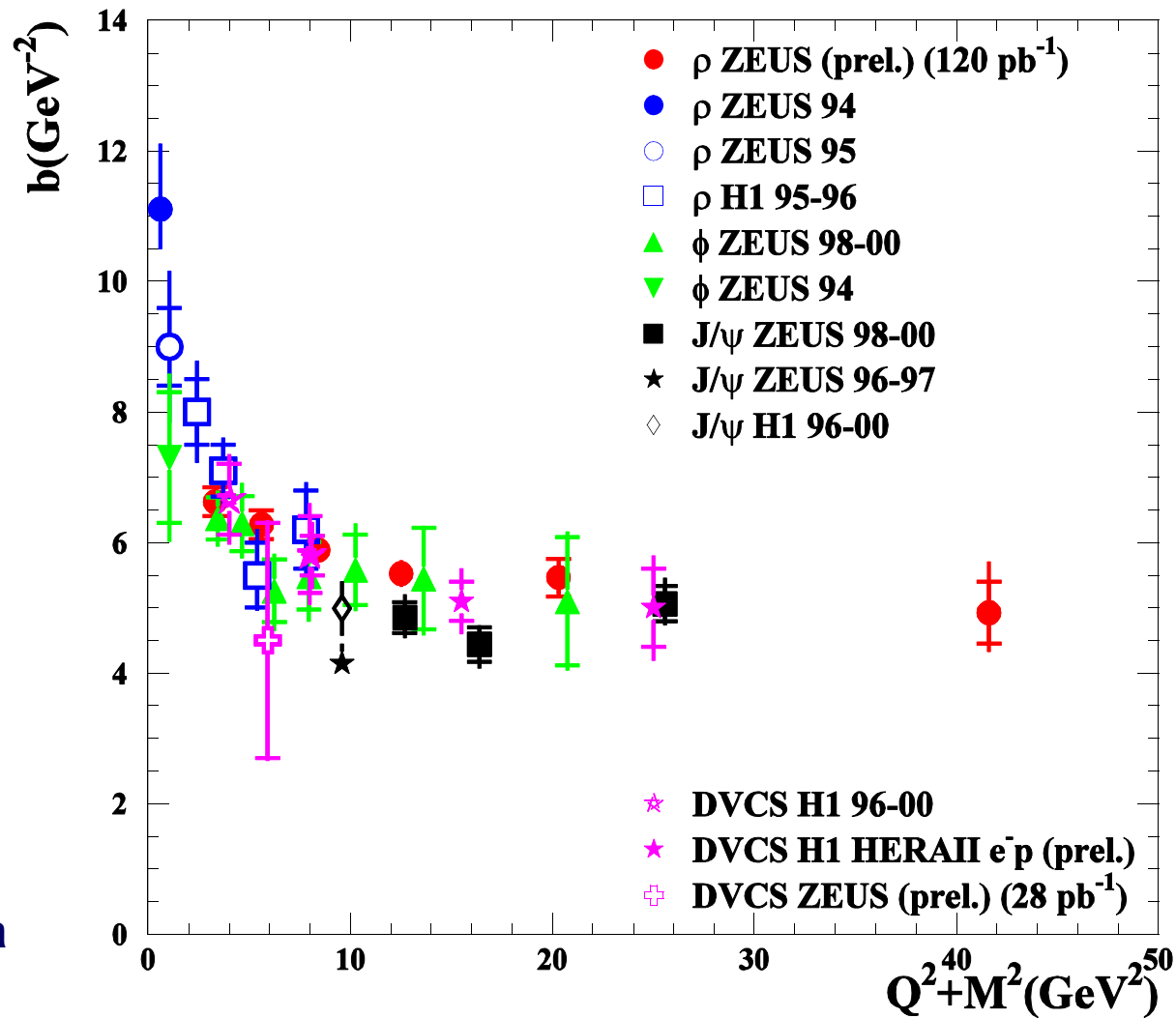
$r_{glue} = 0.56 \text{ fm}$

Proton radius:

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



Gluons confinement area
is smaller than proton



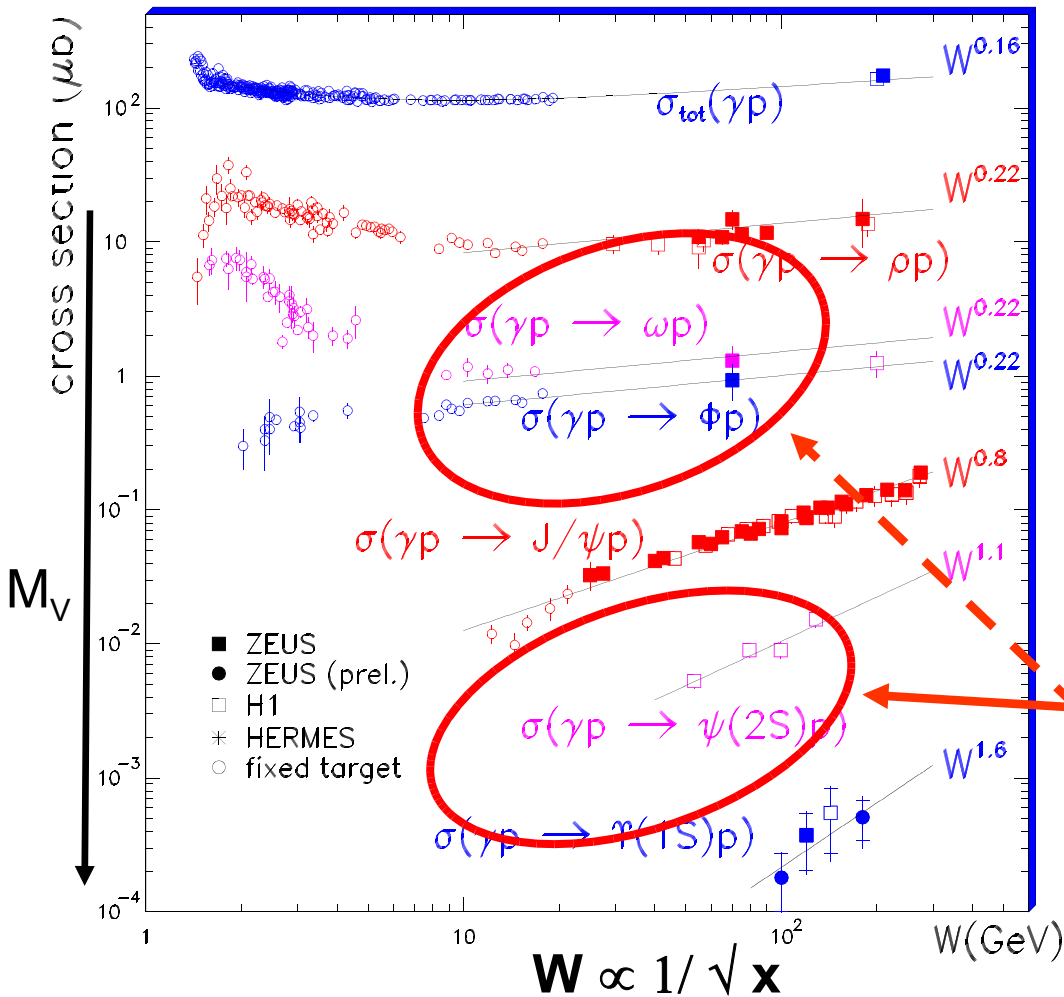
Summary

- ❖ 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

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



Fit: $\sigma \sim W^\delta$ with $\delta = 4(\alpha_p(0) - 1)$

W -dependence steeper with M_V^2 :

$\delta_\rho \sim 0.2 \rightarrow \delta_{\psi(2S)} \sim 1.0$

Large M_V supplies a scale for hard processes \rightarrow apply pQCD models

