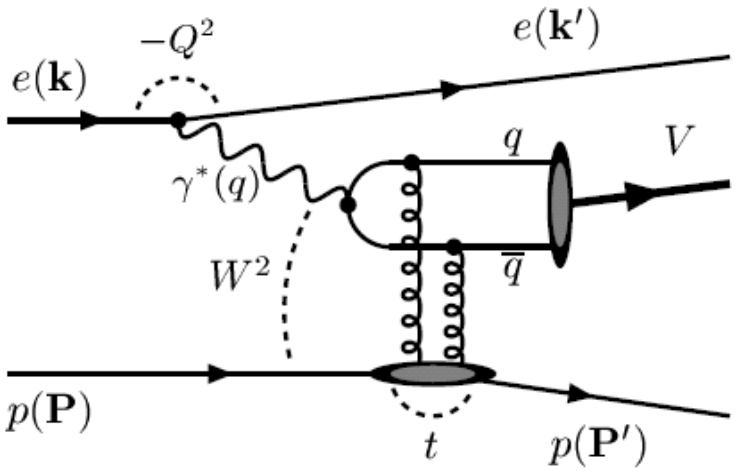
Vector Mesons and DVCS at HERA

Ori Smith

On behalf of H1 and ZEUS

What are we measuring ?

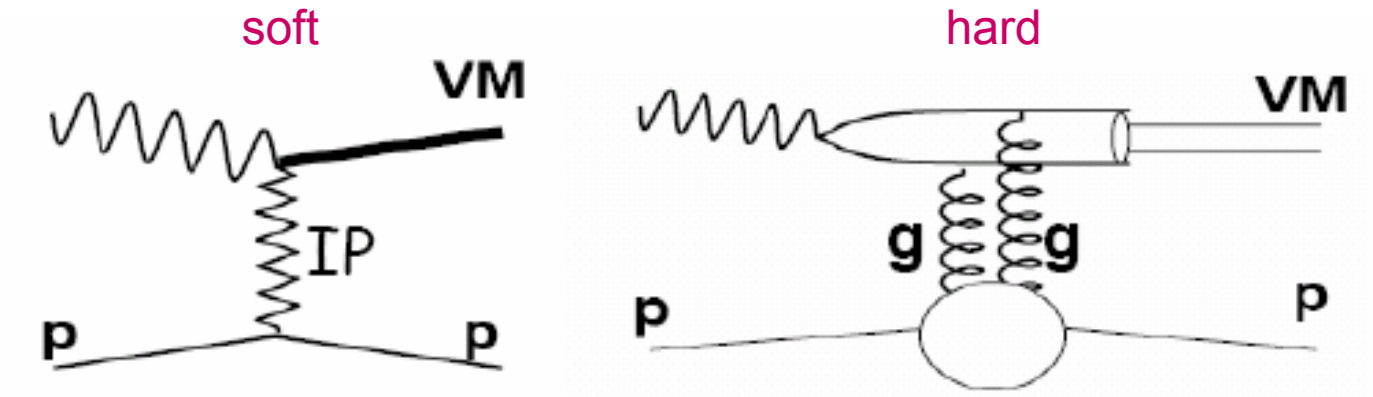


- Diffraction – no quantum numbers are exchanged in the interaction
- Vector mesons $\rho, \phi, J/\Psi, \Upsilon$ and γ production
- The proton can stay intact or dissociate
- Parameterization:

$\sigma(W) \propto W^{\delta}$ W dependence sensitive to gluons ($W^2 \propto \frac{1}{x}$)

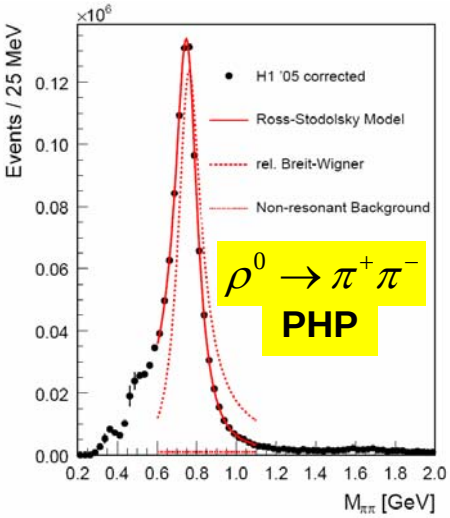
$\frac{d\sigma}{dt} \propto e^{-b|t|}$ b is closely related to the size of the interaction

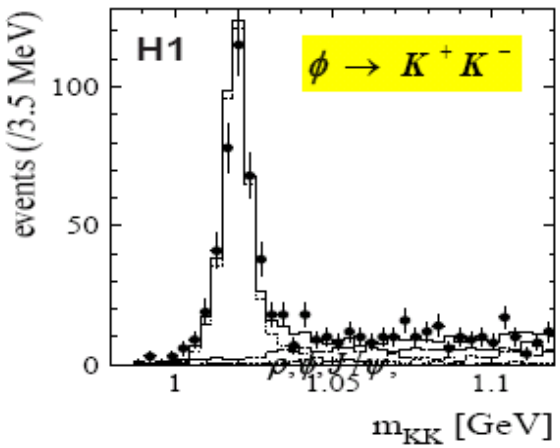
Why are we measuring ?

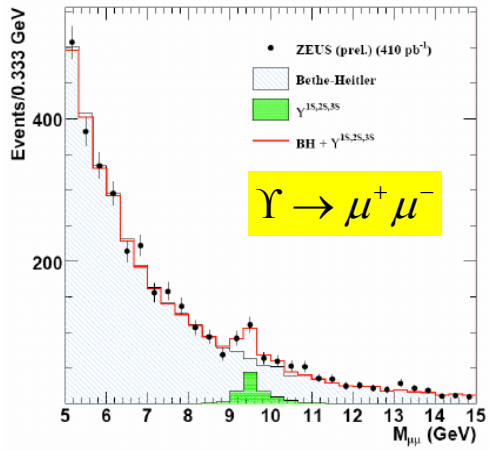


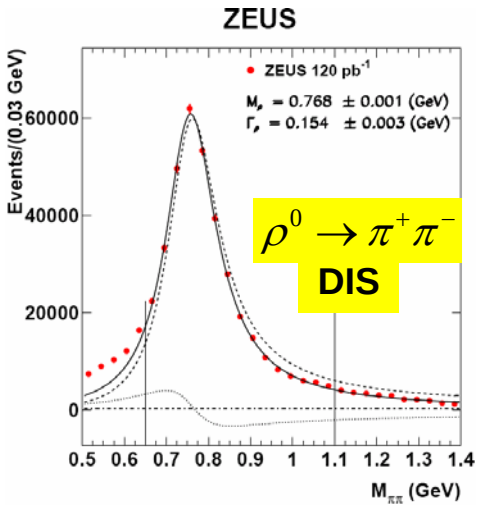
- Where are pQCD calculation applicable and why?
- What is the x dependence of the gluons inside the proton?
- Access to the t dependence enables the determination of the spatial distribution of the gluons in the proton.
- Study the properties of the VM wave function
- Get information on the GPD

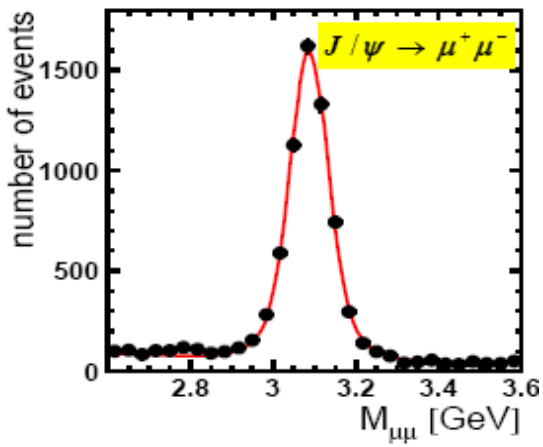
Which VM do we see?



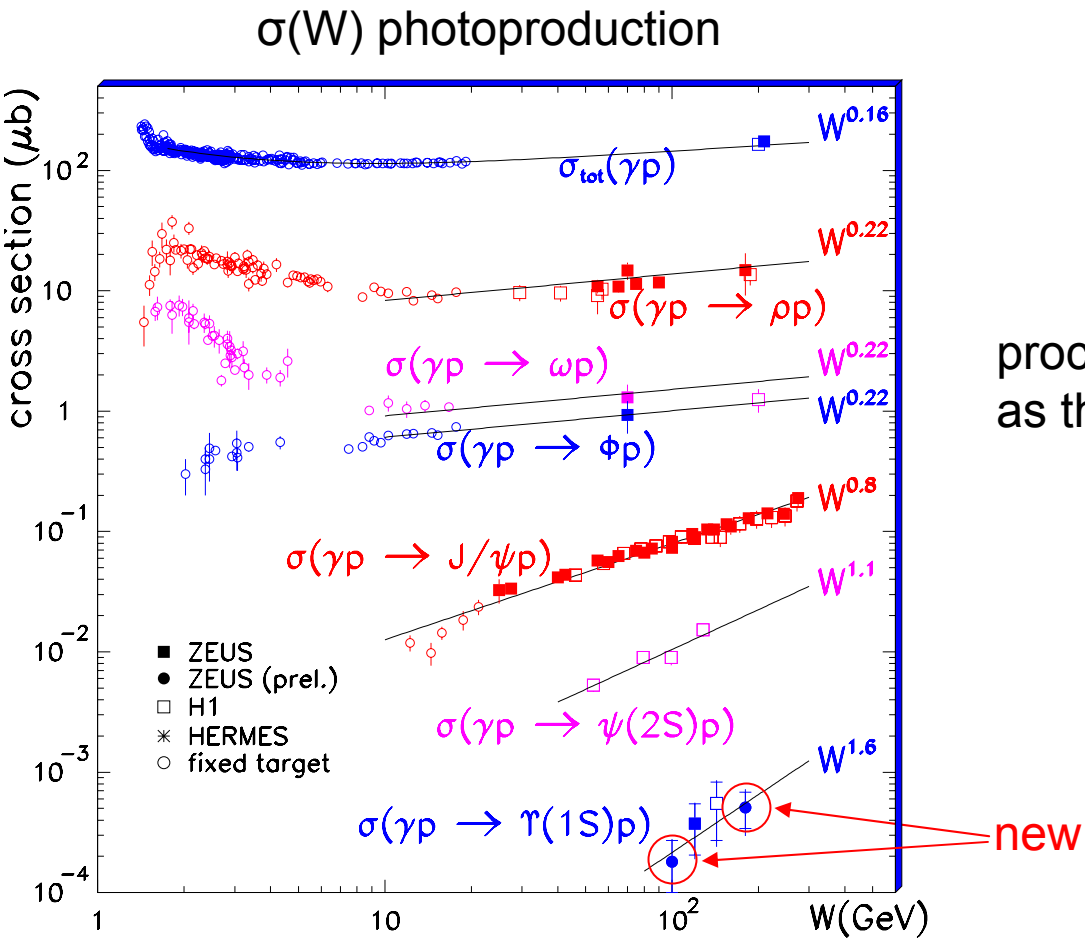






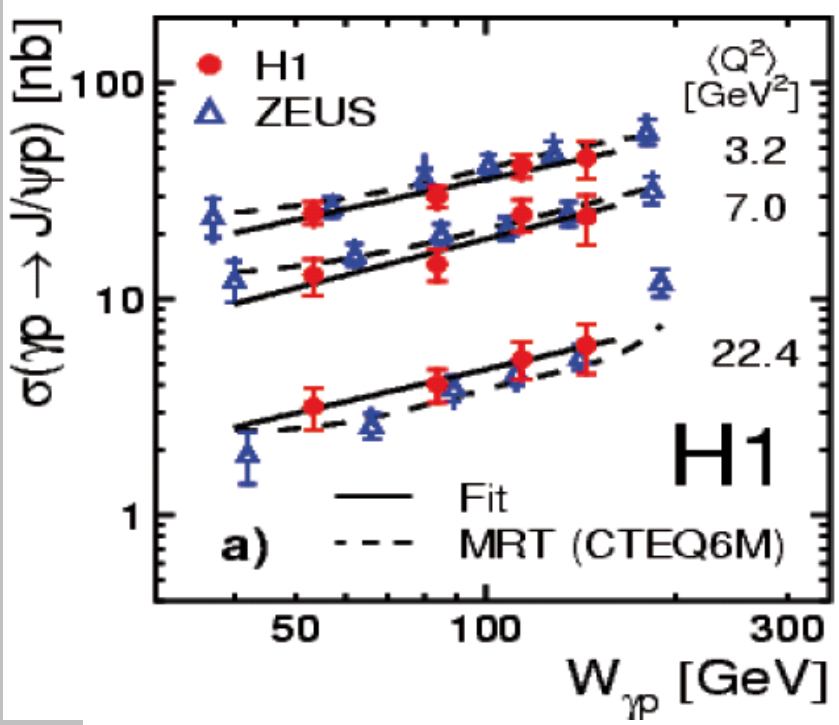


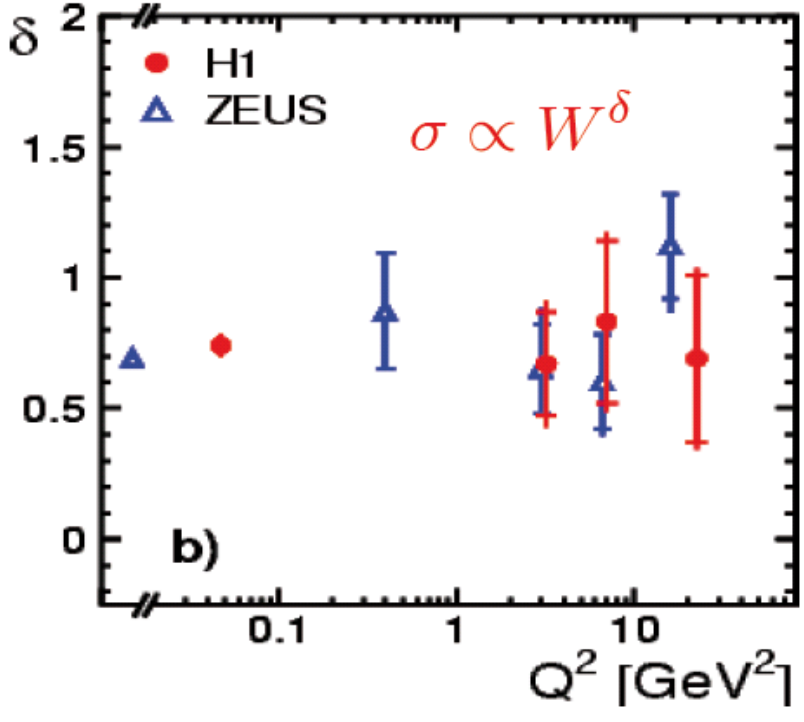
The VM mass as the hard scale



process becomes hard as the mass increase

The VM mass as the hard scale – J/Ψ

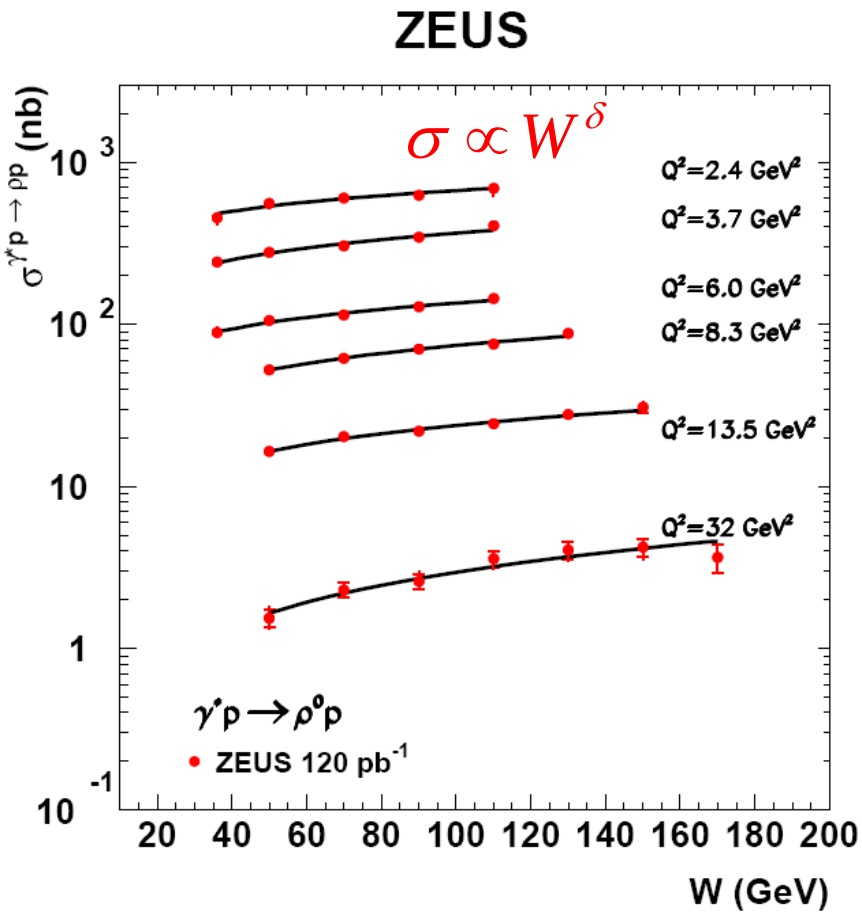


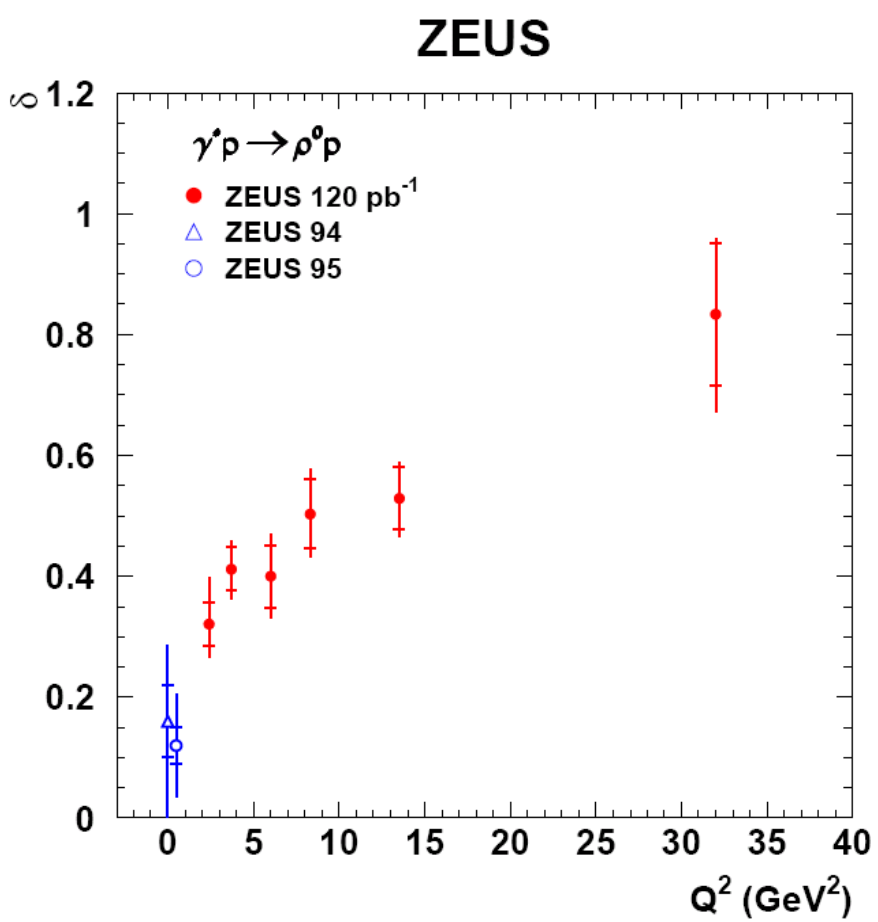


- strong energy dependence
- no significant change with Q^2

$\Rightarrow$ the J/Ψ mass is the dominant scale

Q^2 as the hard scale - ρ^0





But…

- Inclusive scattering:

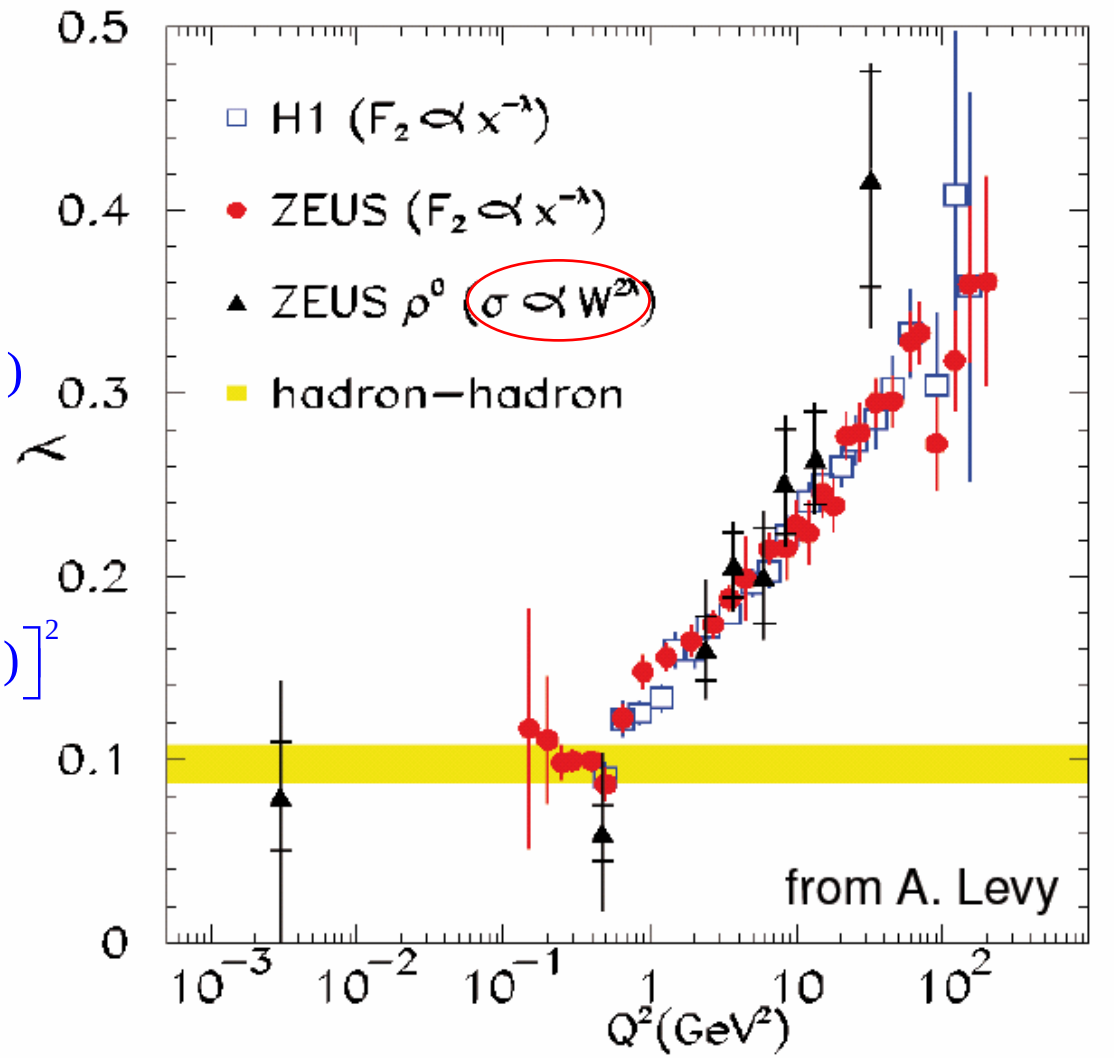
$$\sigma\left(\gamma^* p \to X\right) \propto xG(x,\mu^2)$$

$$\propto x^{-\lambda} \propto W^{2\lambda}$$

- If VM via 2 gluons:

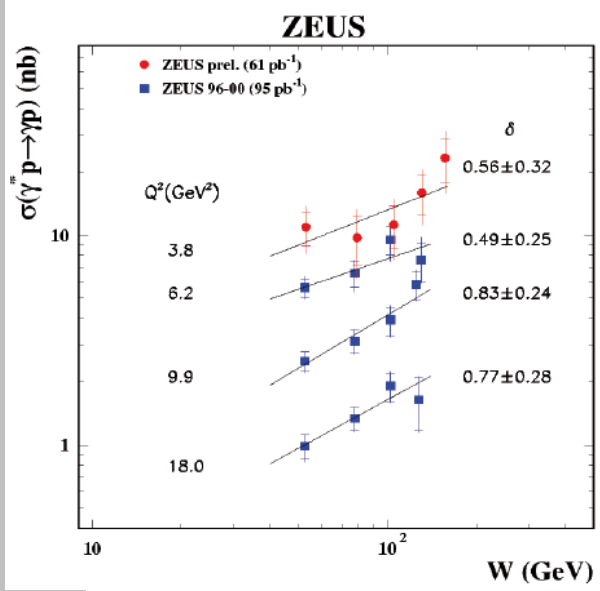
$$\sigma\left(\gamma^* p \to \rho p\right) \propto \left[xG(x,\mu^2)\right]^2$$

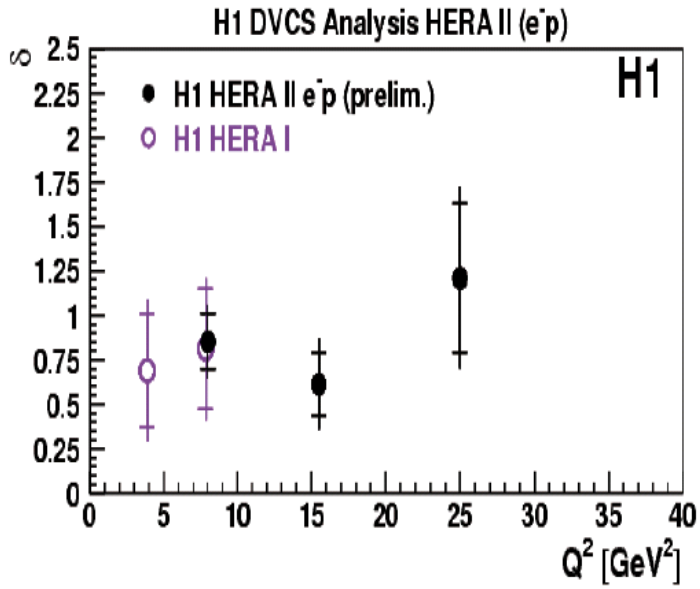
$$\propto x^{-2\lambda} \propto W^{4\lambda}$$



Q^2 as the hard scale - DVCS

(DVCS – deeply virtual compton scattering)





Steep rise for large Q^2 observed in H1 and ZEUS

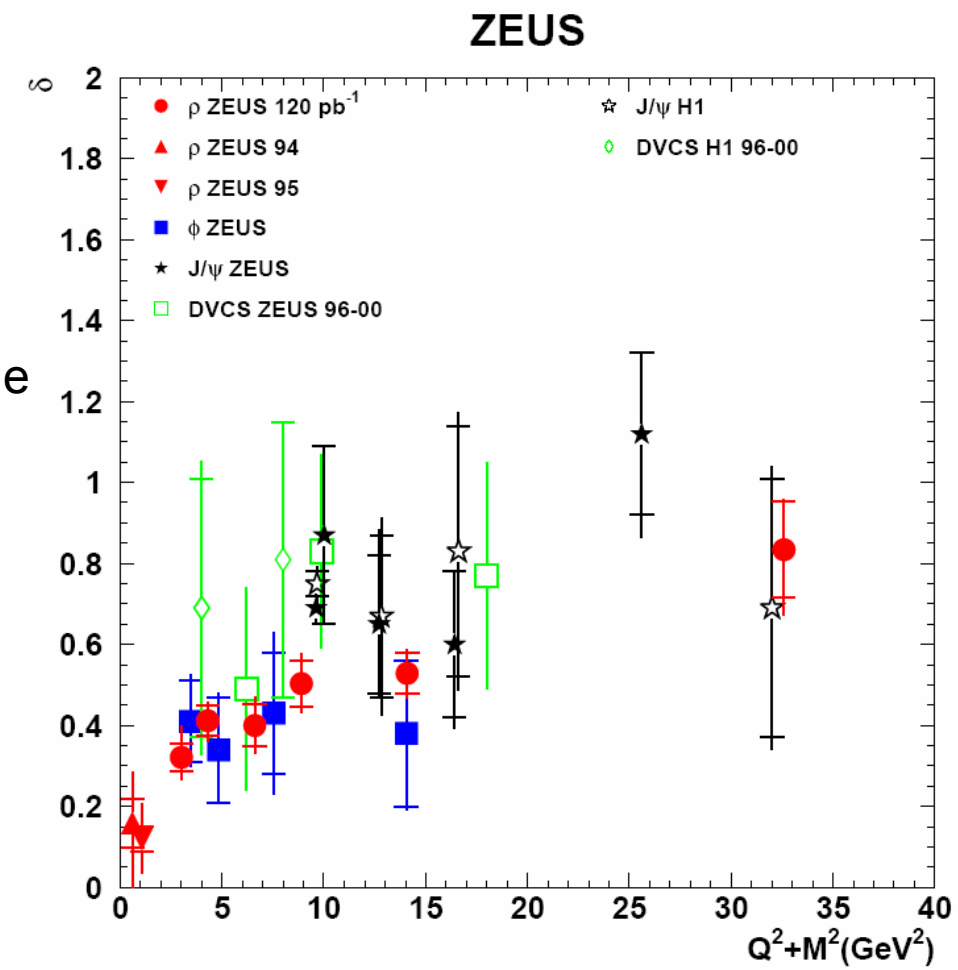
=> similar behavior to heavy VM

=> DVCS show hard behavior even at low Q^2 and no mass

=> May suggest that the most sensitive part to soft scale is the WF

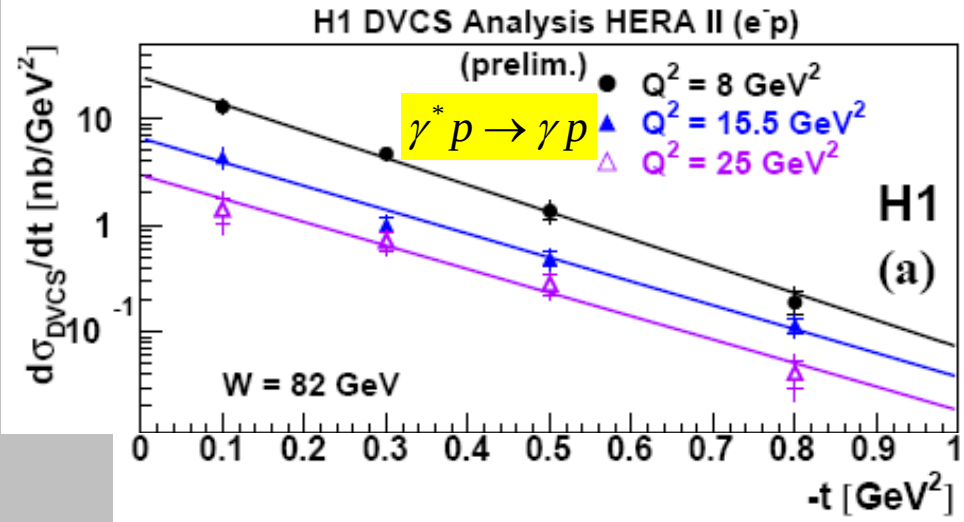
$\delta(Q^2+M^2)$ – VM

- Steep slope observed for all VM in the presence of hard scale
- Hard scale = Q^2 and/or M^2

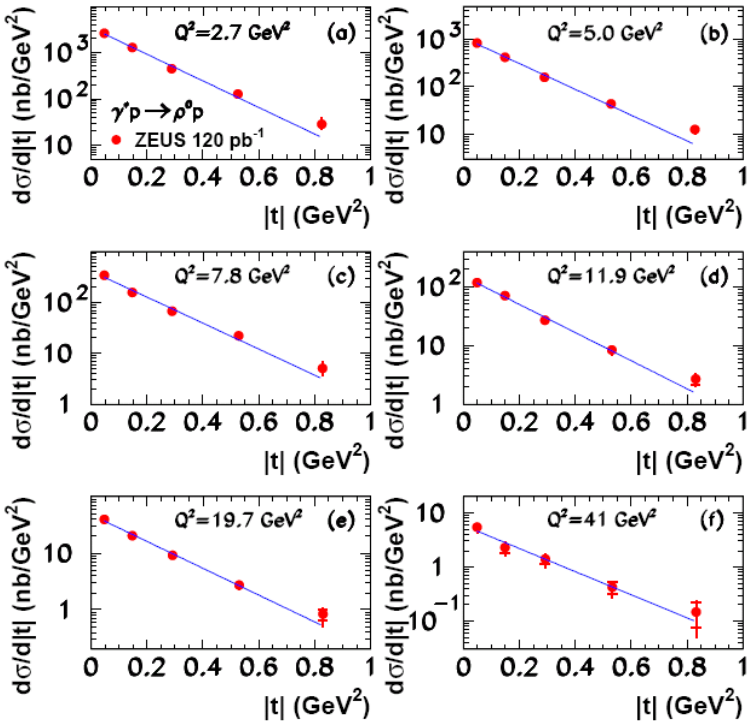


b(Q^2) – the *t* slope parameter

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



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



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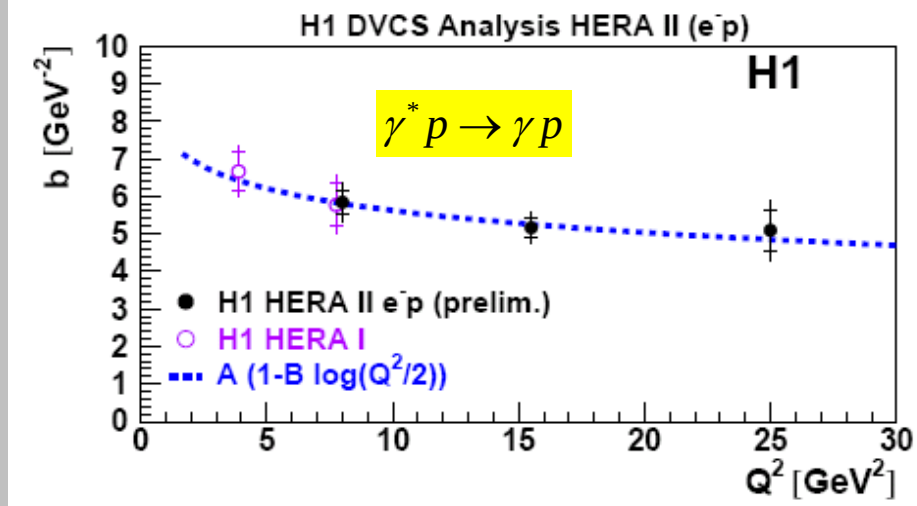
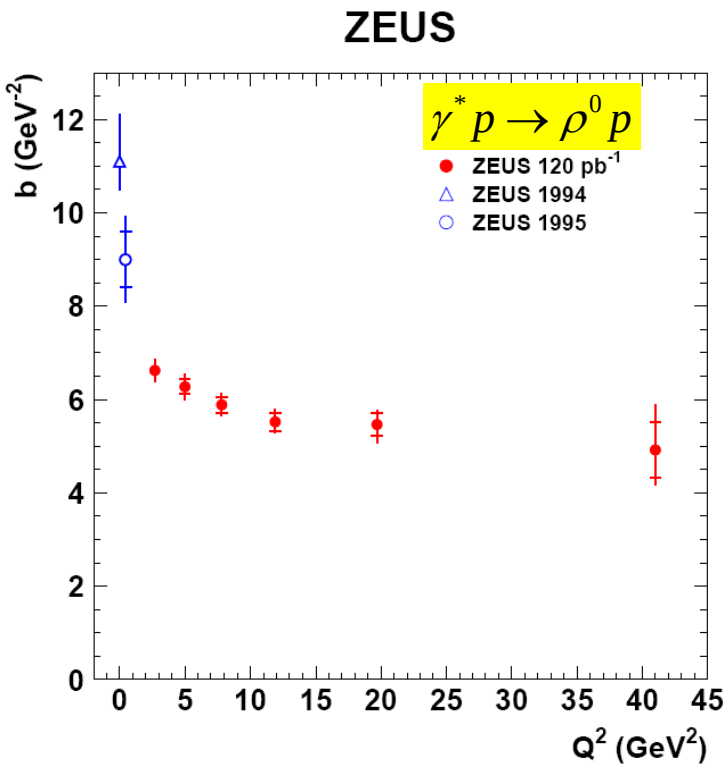




Slope of ρ decreases from pp collision value to pQCD expected value

$b(Q^2)$ – All VM

- Similar slope for all VM as a function of $(Q^2 + M^2)$

- size taken by gluons:

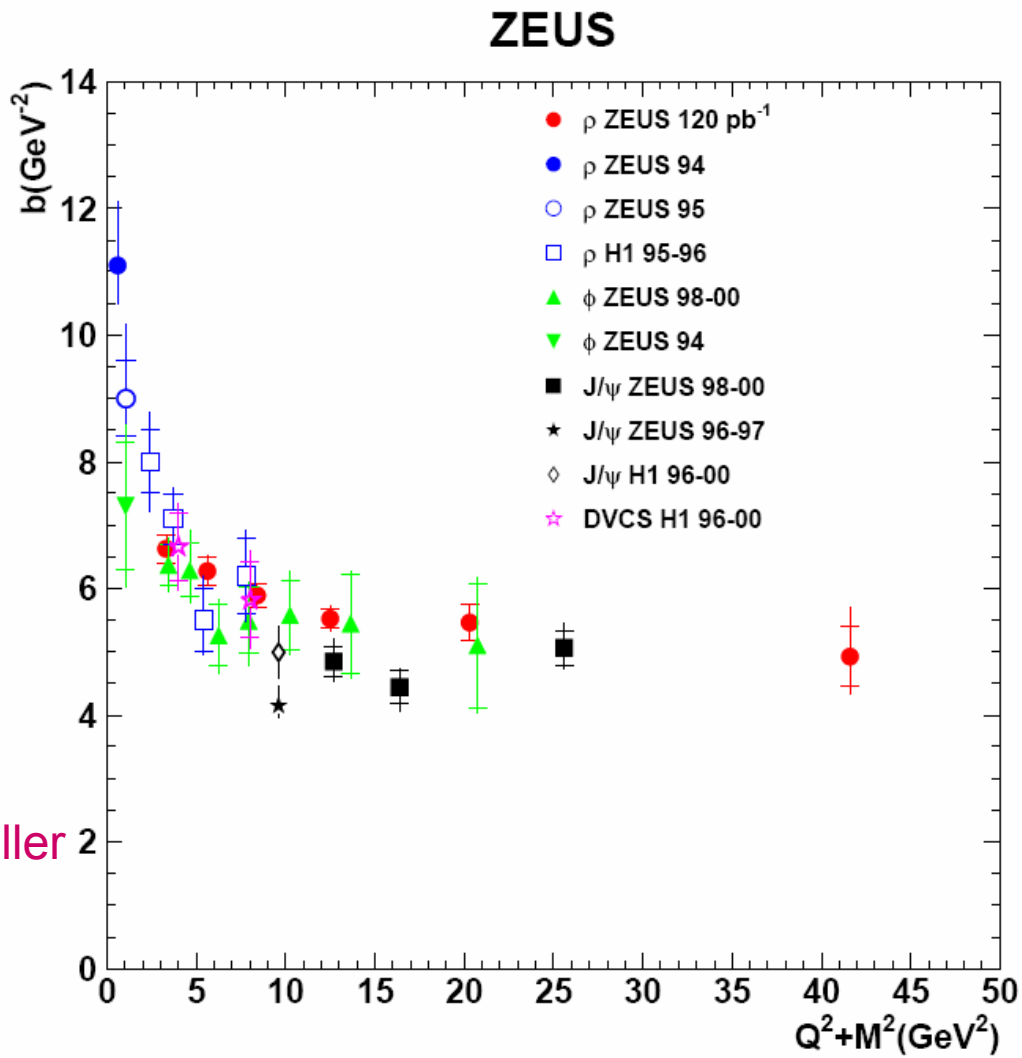
$$\left\langle r^2 \right\rangle = 2 \cdot b \cdot (\hbar c)^2$$

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

- compare to charge radius of the proton:

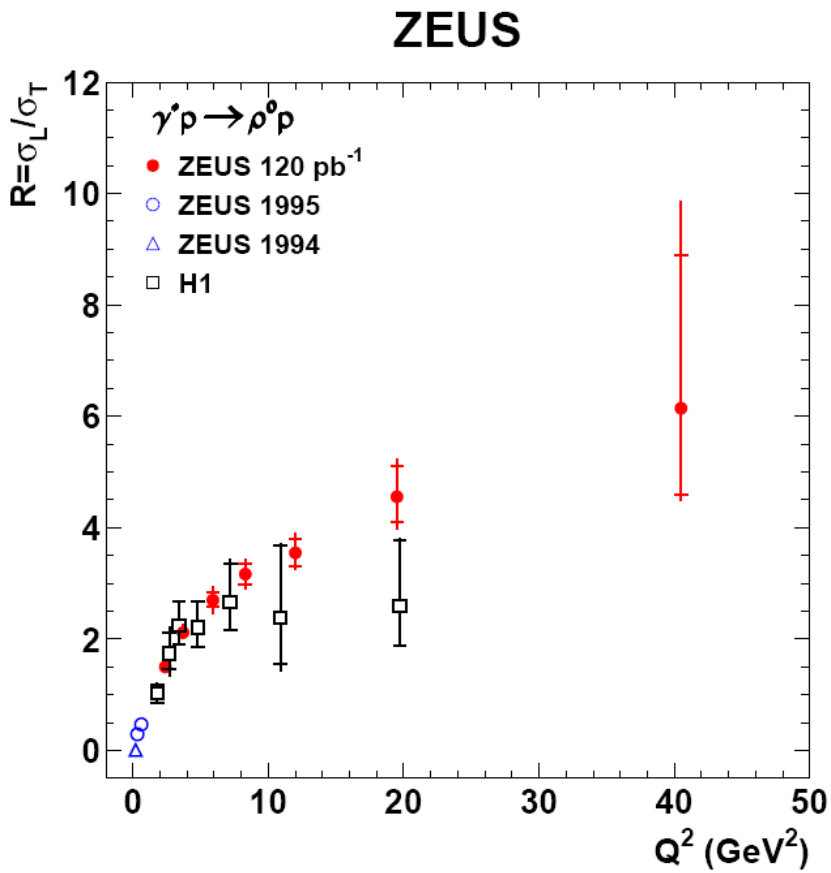
$$\rightarrow r_{proton} = 0.8 \text{ fm}$$

$\Rightarrow$ gluons are confined in smaller area than quarks



$R=\sigma_L/\sigma_T$

- SCHC allows us to get information on σ_L and σ_T separately



$\Rightarrow$ as the scale gets harder σ_L dominates

$\Rightarrow$ fits expectations of pQCD

$R=\sigma_L/\sigma_T$

σ_L	σ_T
small spatial configuration (large k_T) => steep rise with W	large spatial configuration dominates => slow rise with W

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σ_L	σ_T
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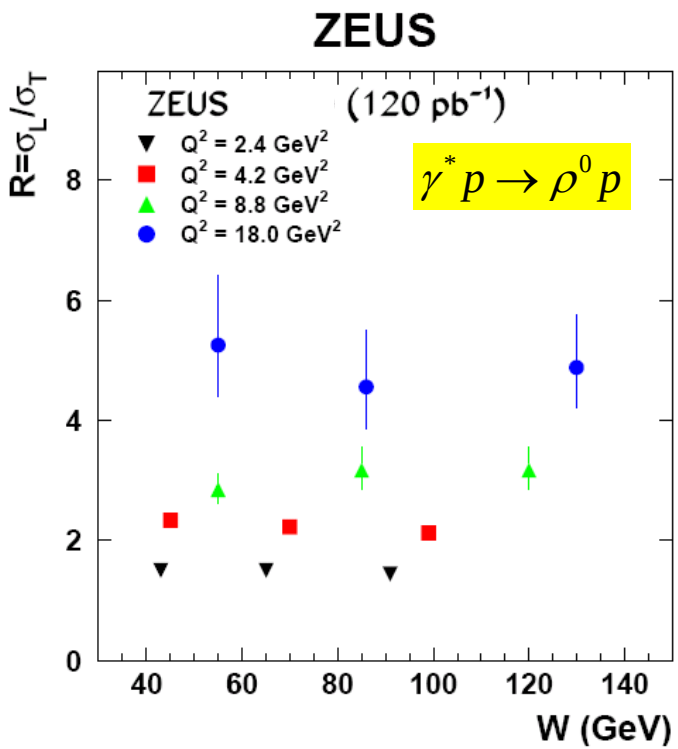
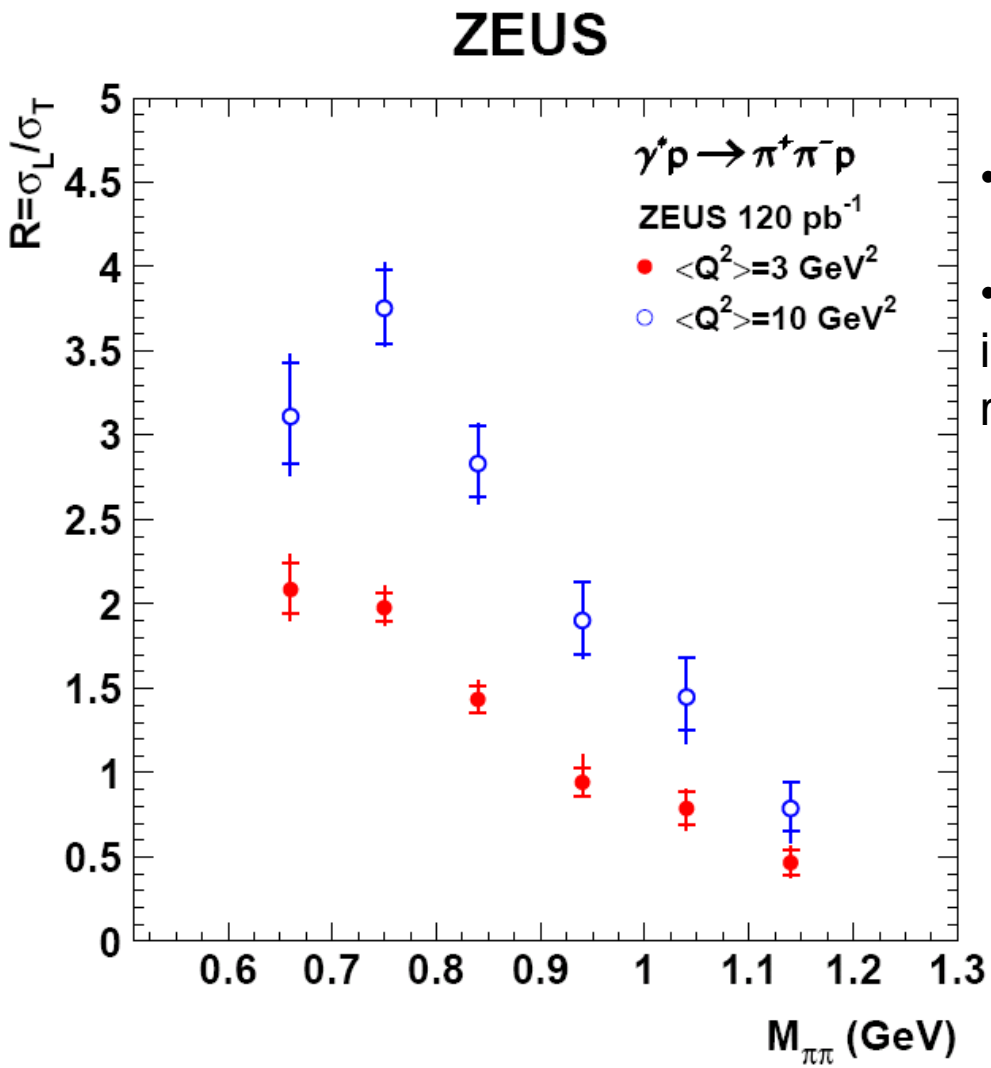
BUT…



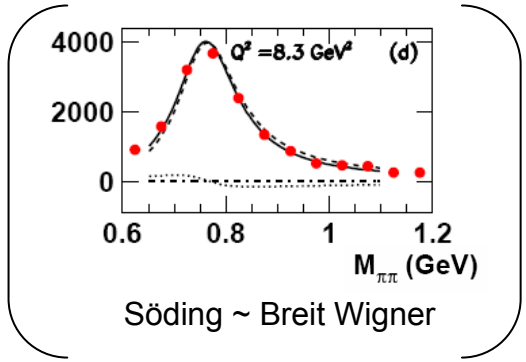
R is independent of W!

$\Rightarrow$ large γ^*_T configurations seem to be suppressed.

$R(M_{\pi\pi})$ in the region of the ρ resonance

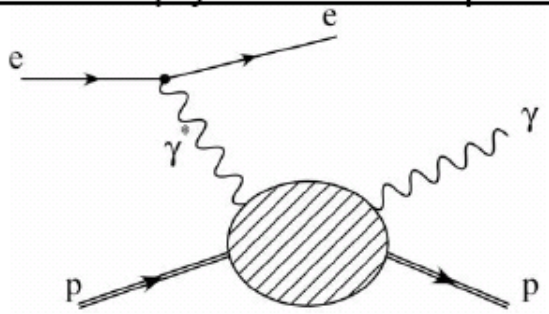


- strong dependence on the mass
- can not be explained by the interference term with the non resonant ππ production

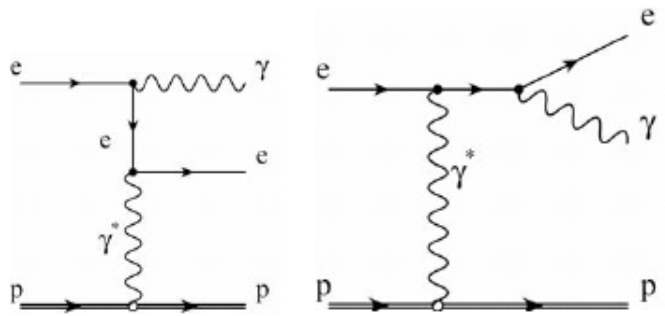


DVCS: Beam Charge Asymmetry

DVCS – Deeply Virtual Compton Scattering



BH – Bethe-Heitler



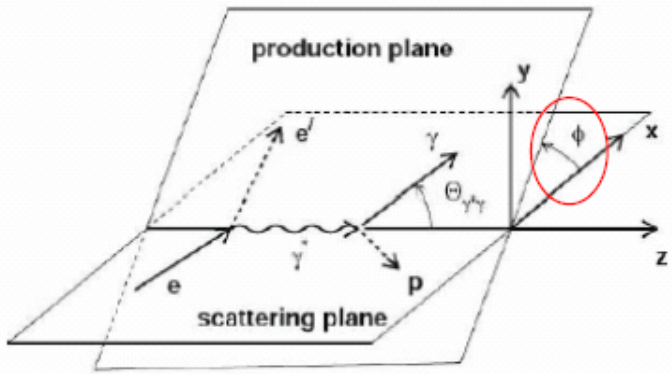
$$d\sigma = d\sigma^{BH} + d\sigma^{DVCS} \pm Interference.Term$$

\+ for beam lepton charge (+)

\- for beam lepton charge (-)

$$\sigma^{+} - \sigma^{-} \sim \mathrm{Re}(Interference.Term)$$

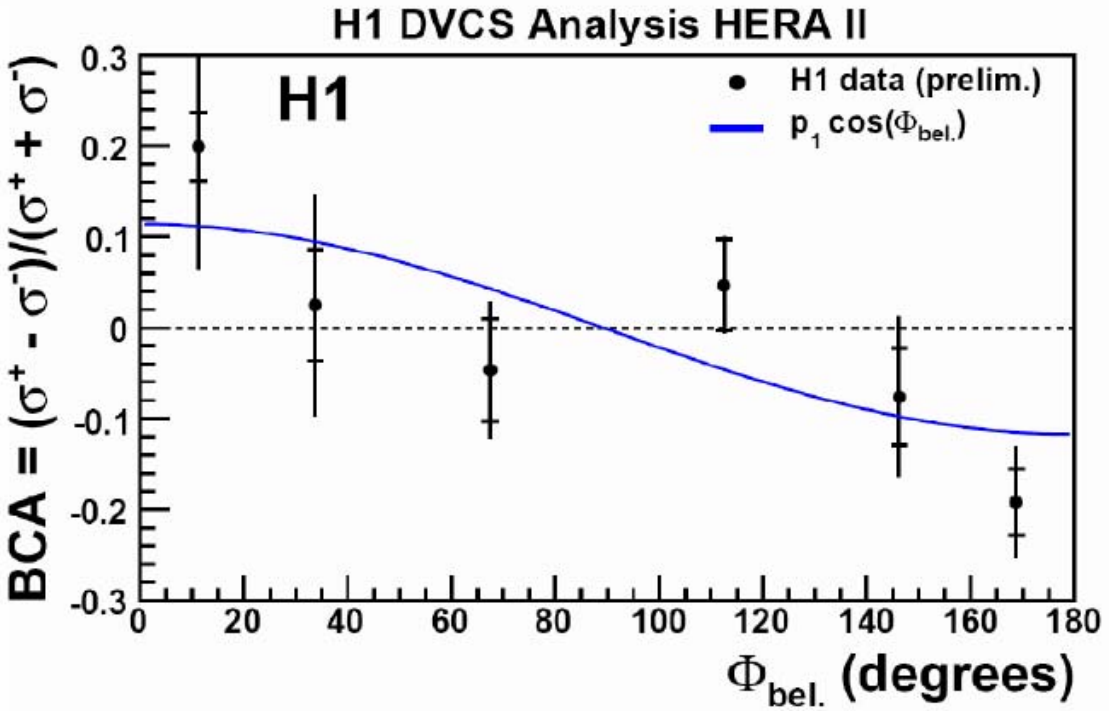
$$BCA = \frac{\sigma^{+} - \sigma^{-}}{\sigma^{+} + \sigma^{-}} = p_1 * \cos(\phi) + \ldots \,, \; p_1 \sim GPD$$



DVCS: Beam Charge Asymmetry

HERA II data with 291 pb^{-1} analysed
(equally shared in the e+ & e- samples)

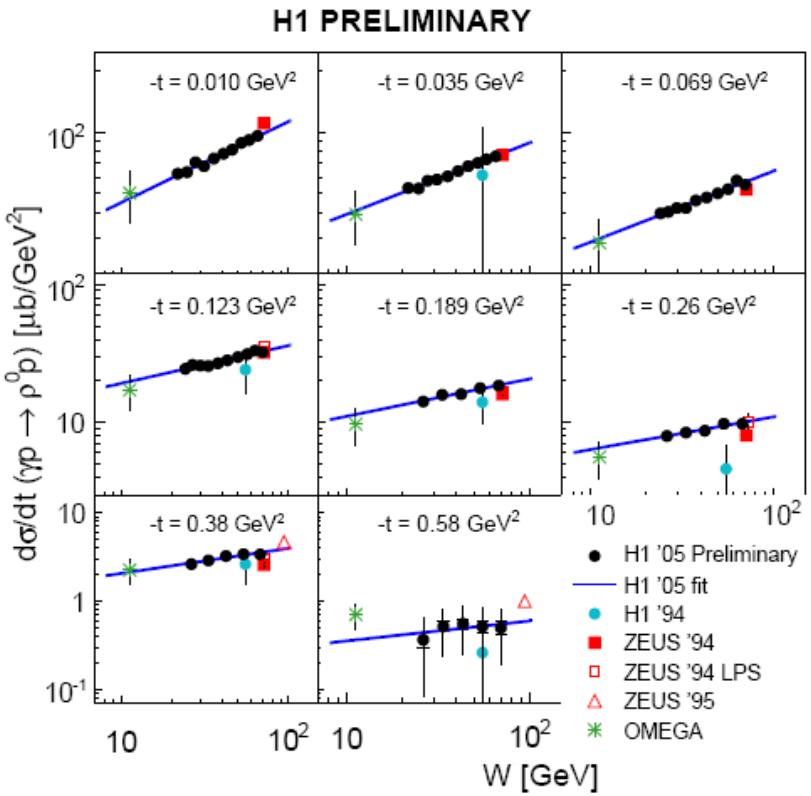
$BCA = \sigma^+ - \sigma^- / \sigma^+ + \sigma^- \sim p1 \cos(\phi)+\ldots$



BCA via p_1 gives us information about GPDs

Effective Pomeron trajectory

Get effective pomeron trajectory from dσ/dt(W) at fixed t



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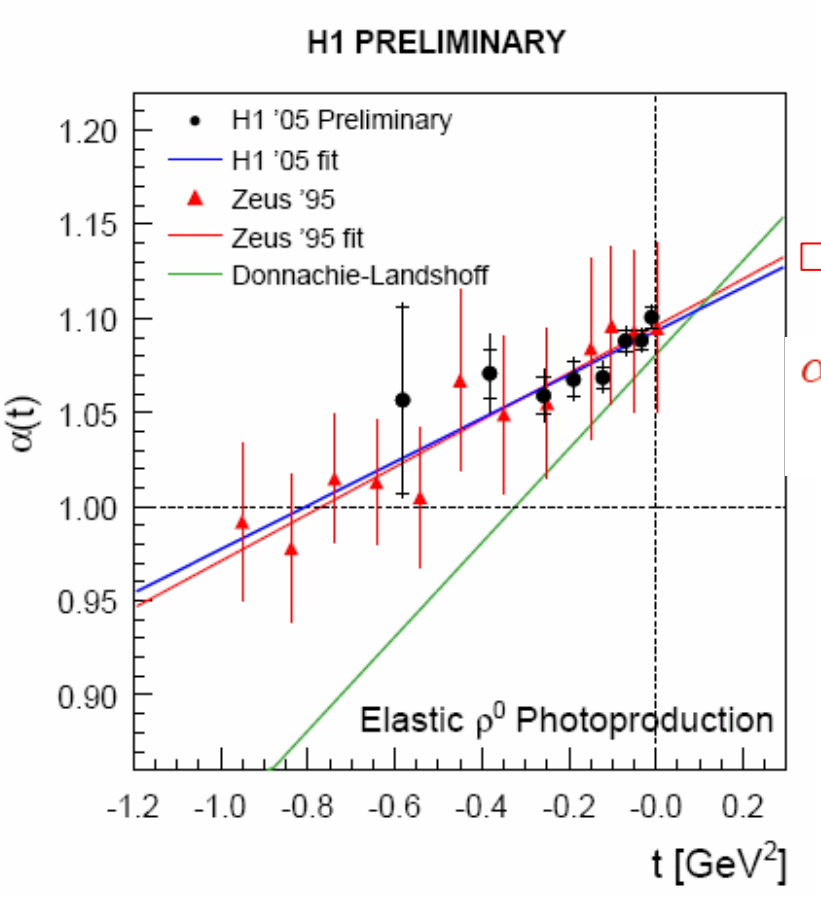
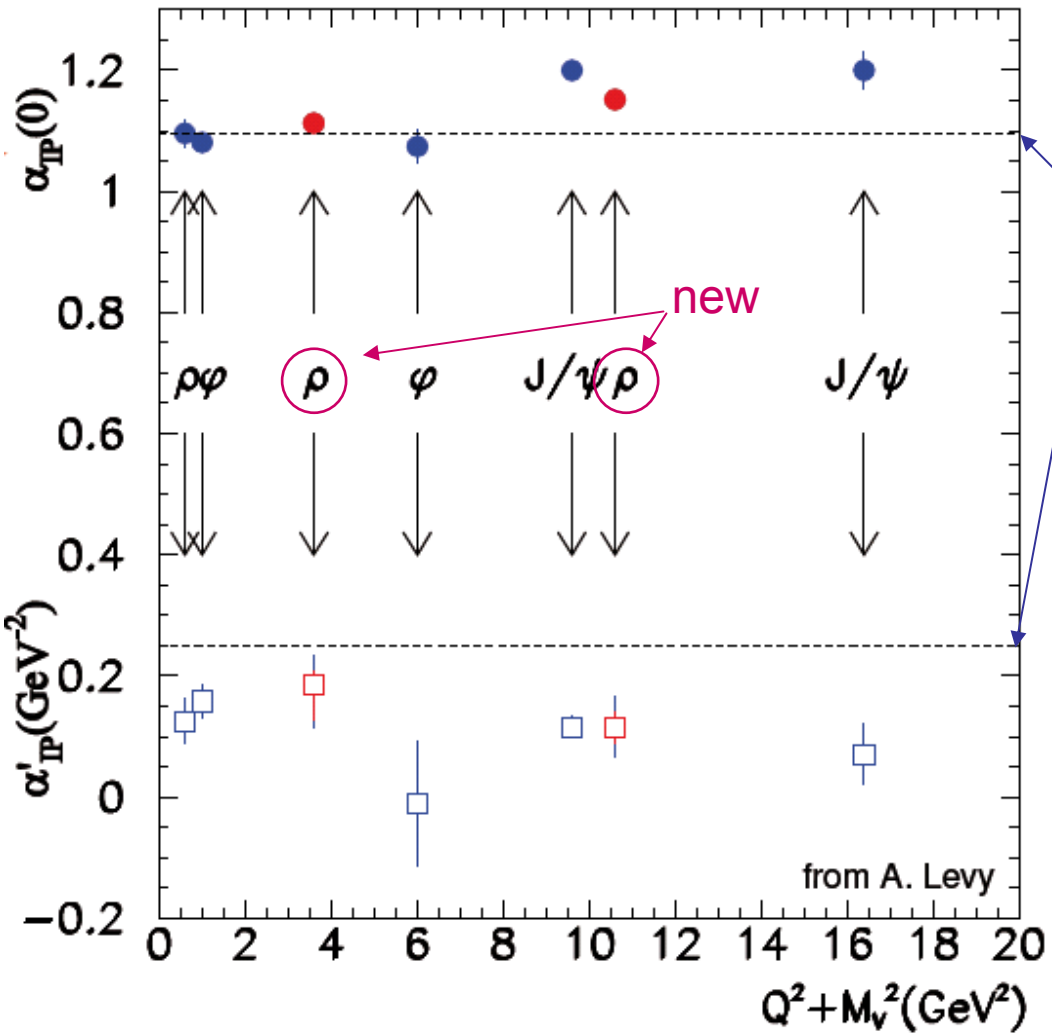


$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP} \cdot t$$
$$= 1.096 \pm 0.021 + (0.125 \pm 0.038) \cdot t$$

α'_{IP} in ρ γp is smaller than expected from soft hadronic interaction !

Effective Pomeron trajectory



Soft Pomeron

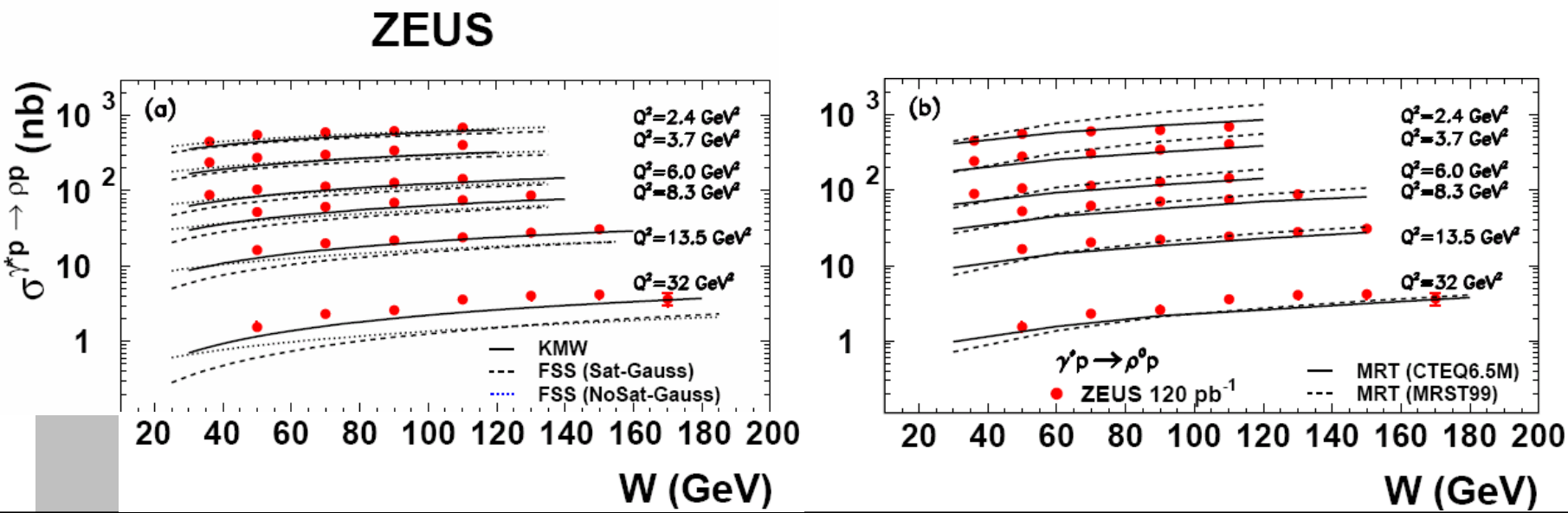
⇒ As the scale gets harder the intercept grows and the slope seems to get smaller

ρ^0 data – comparison to theory

data compared to 4 models:

Martin-Ryskin-Teubner (MRT) } More sensitive to different Gluon densities

Forshaw-Sandapen-Shaw (FSS)
Kowalski-Motyka-Watt (KMW)
Dosch-Ferreira (DF) } More sensitive to different shapes of the ρ^0 wave function



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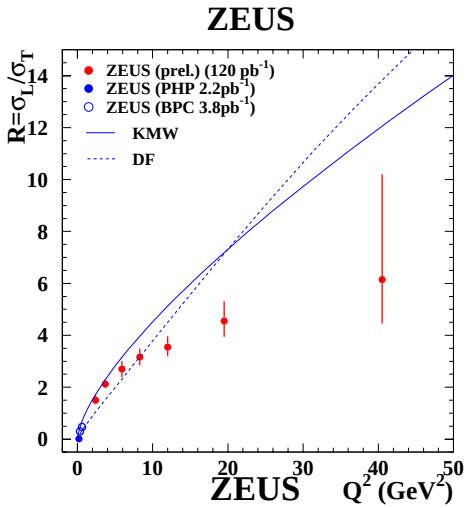
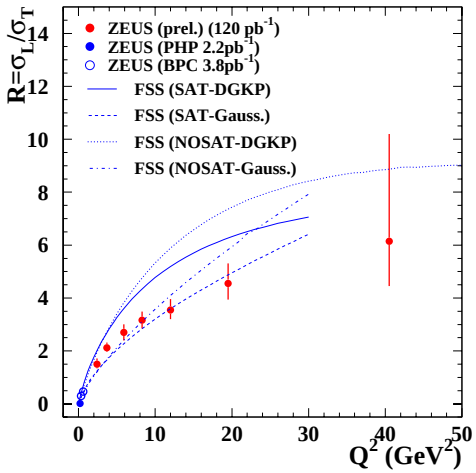
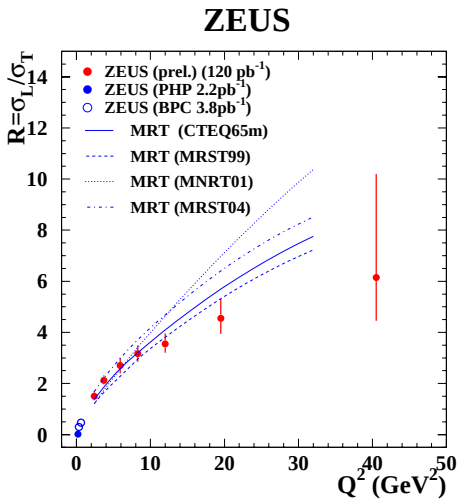
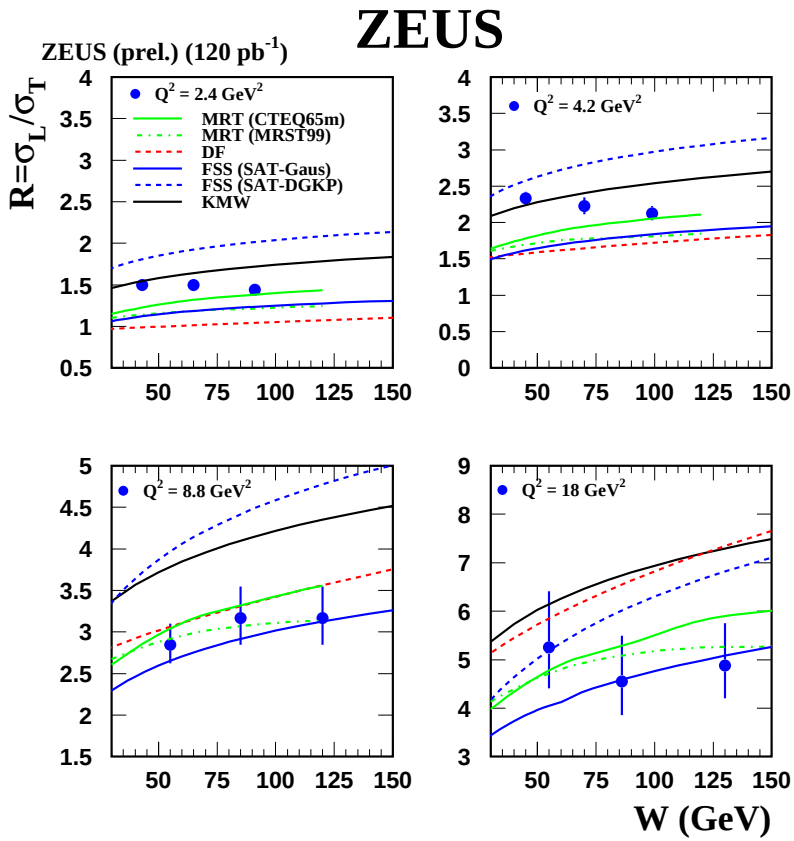




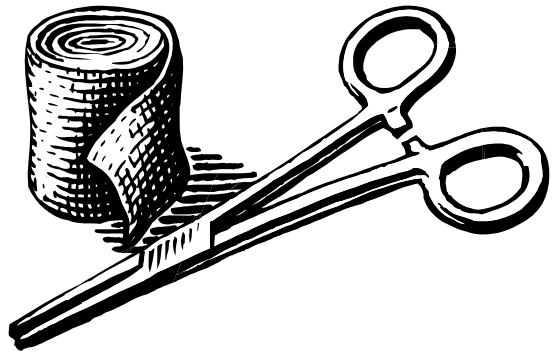




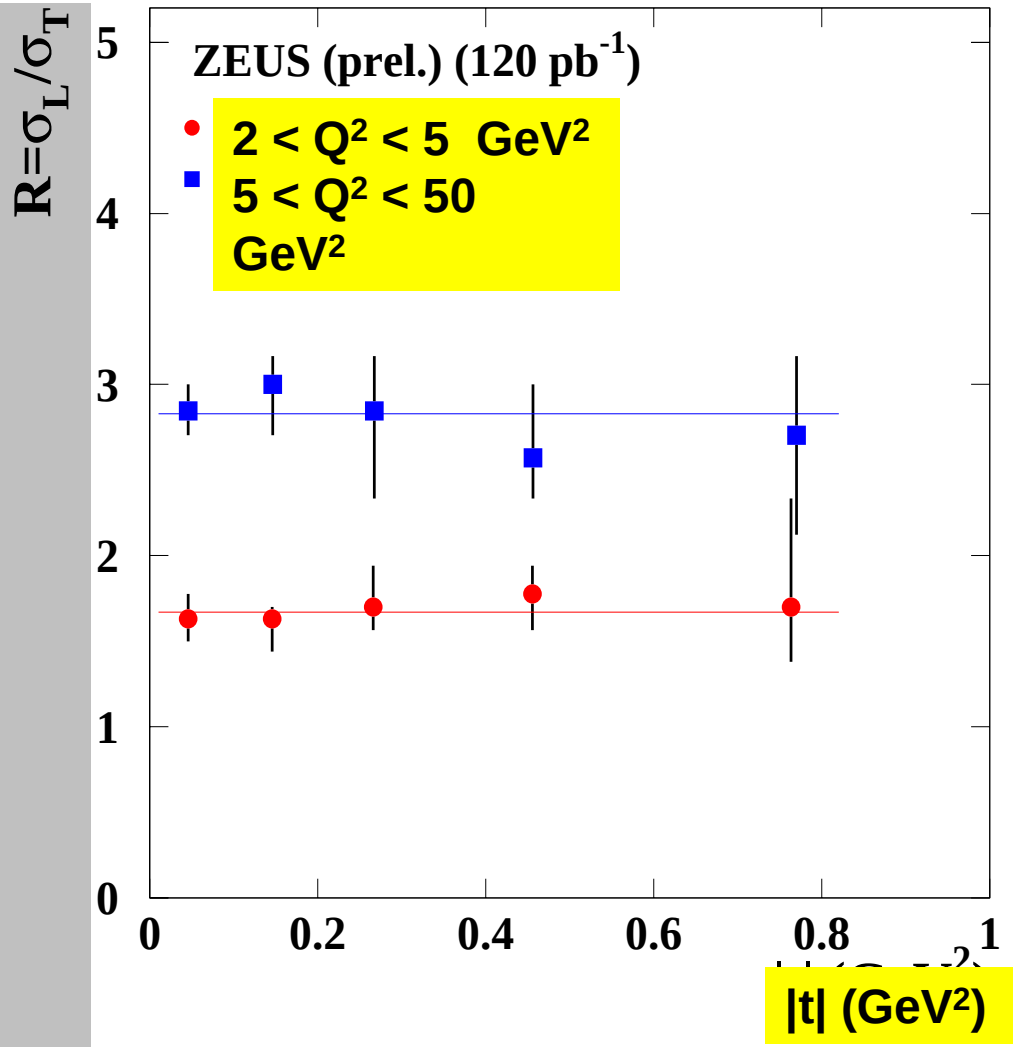
⇒ Still much information that can be extracted on the VM wave function and the Gluon density in the proton

Summary and Conclusions

- New high statistics measurements on γ,ρ and J/Ψ
- New measurement of the Upsilon photoproduction
- The cross section rises with W and the rate of increase grows with the hard scale (Q^2+M^2)
- The exponential slope of the t distribution decreases with Q^2 and levels off at about $b\sim5\ GeV^{-2}$
- The ratio of the longitudinally and transverse cross section increases with Q^2, is independent of W and strongly depends on the mass.
- The effective Pomeron trajectory has a larger intercept and smaller slope than those extracted from soft interactions
- All these features are compatible with expectations of perturbative QCD
- None of the models which have been compared to the ρ^0 measurement are able to reproduce all the features of the data



ZEUS



$$b_L \approx b_T$$