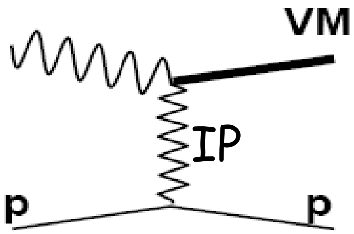
Exclusive processes in ep Collisions at HERA

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

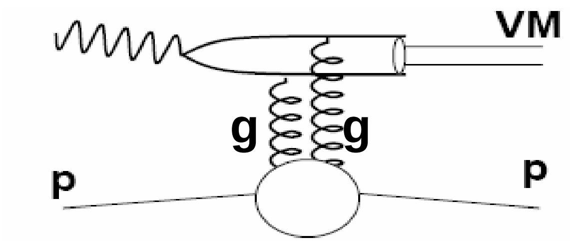
$$V^0 = \gamma, \rho, \phi, J/\psi, \Upsilon$$

Igor Rubinskiy
On behalf of H1 and ZEUS

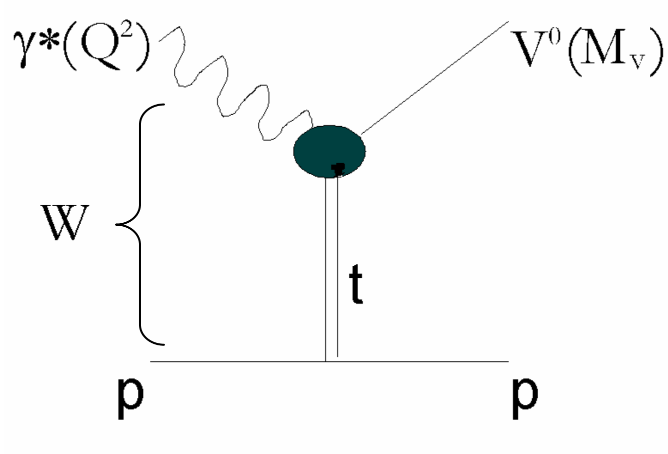
Why are we measuring



'soft'



'hard'



Important parameterizations:

$$\sigma(W) \propto W^{\delta}$$

W sensitive to gluons. Increasing W is similar to going to small x

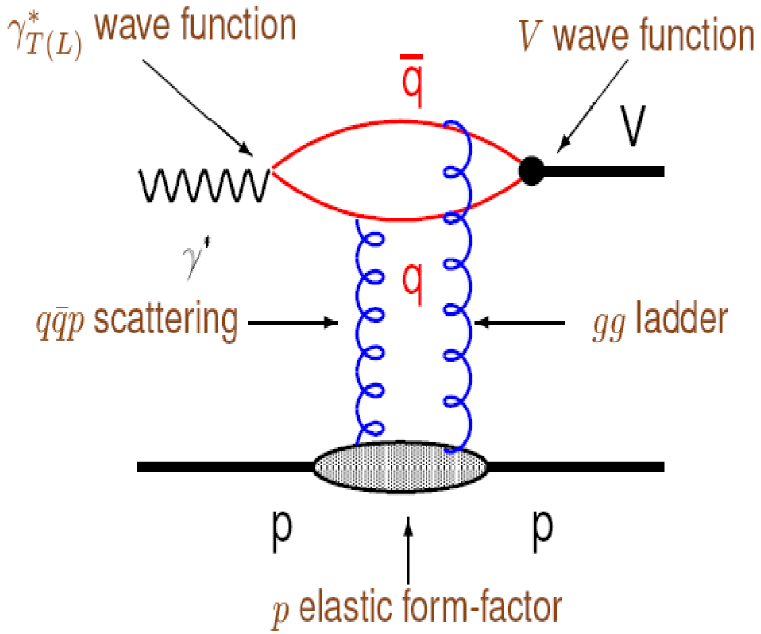
$$\frac{d\sigma}{dt} \propto e^{-b|t|}$$

b is a characteristic of $d\sigma/d|t|$ distribution and shows the size of the interaction

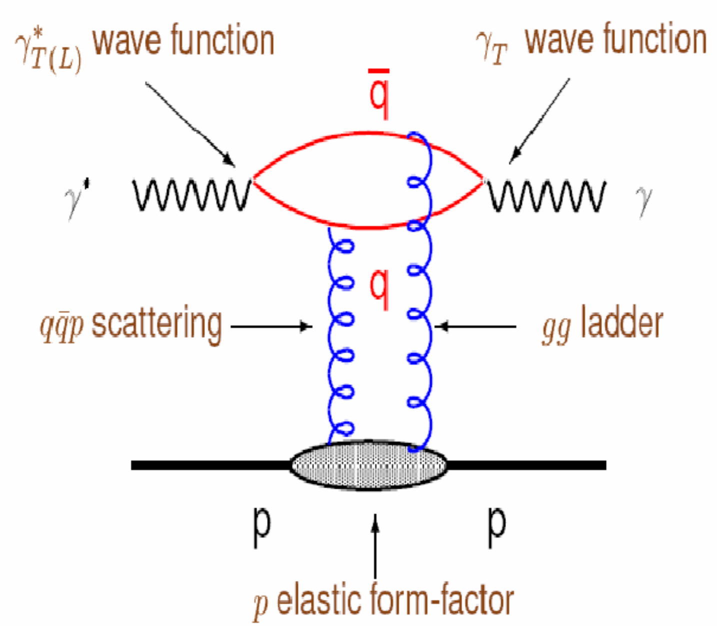
- **Expect δ to increase from soft (~0.2, from 'soft Pomeron' value) to hard (~0.8, from $xg(x,Q^2)^2$)**
- **Expect b to decrease from soft (~10 GeV^{-2}) to hard (~4-5 GeV^{-2})**

Why are we measuring?

<u>Vector Mesons</u>

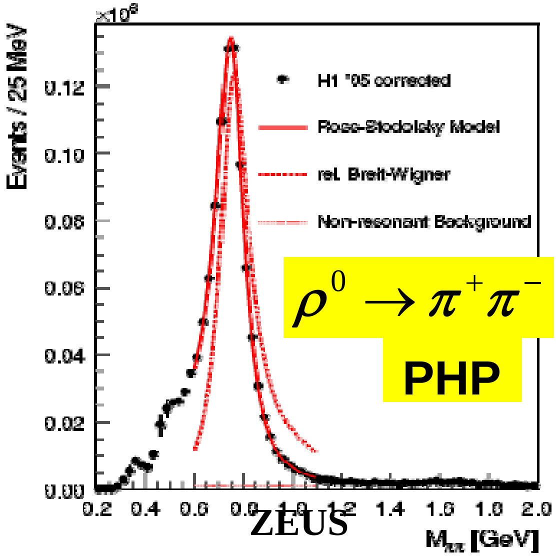


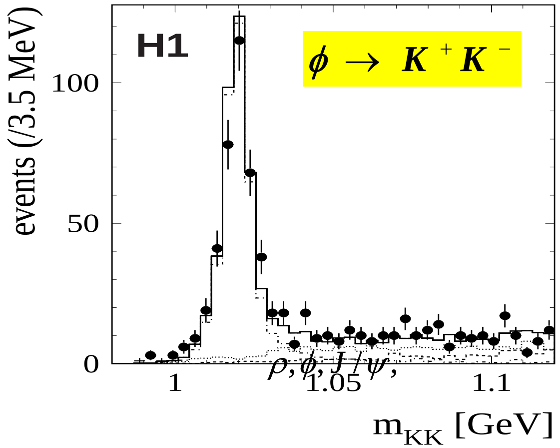
<u>DVCS – Deeply Virtual Compton Scattering</u>

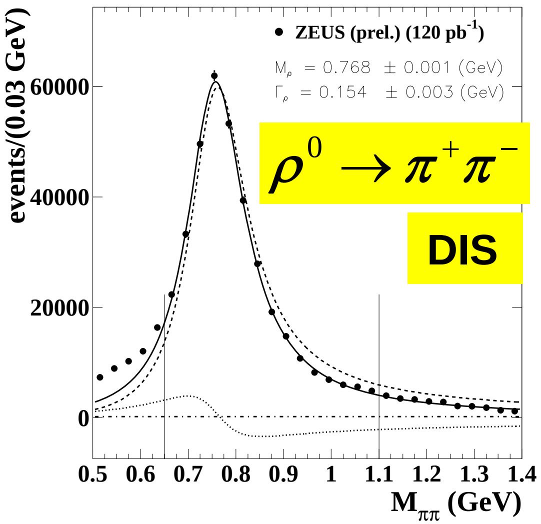


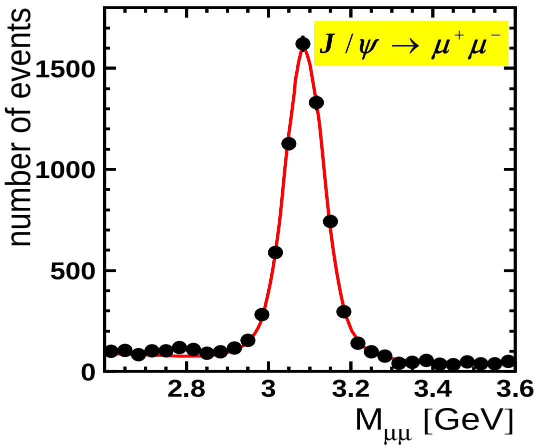
Use QED for photon wave function.
Study properties of VM Wave Fuctions and the Gluon Density in the proton.

Mass distributions ($\rho^0, \phi, J/\psi$)



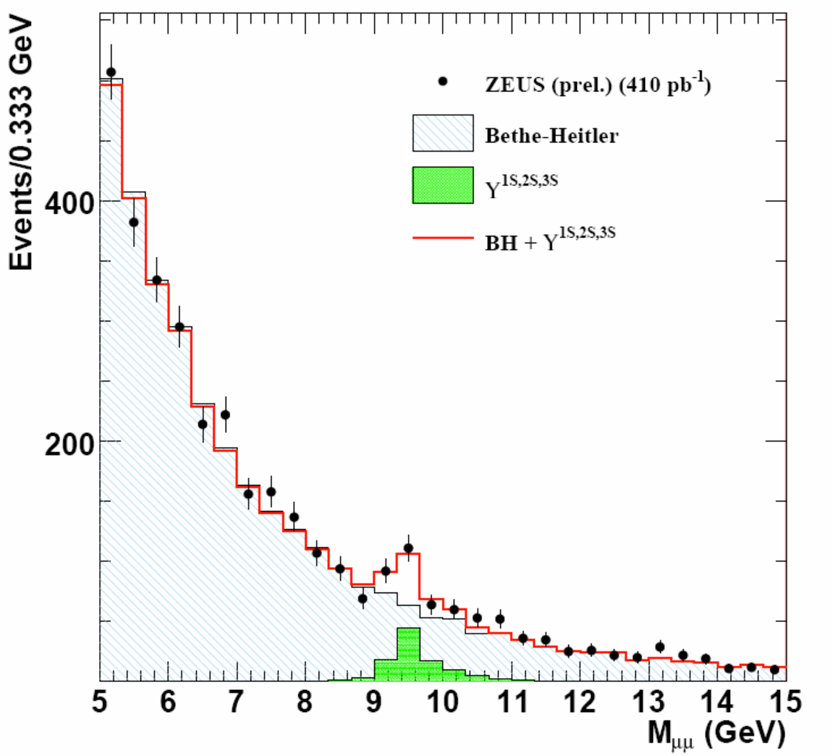


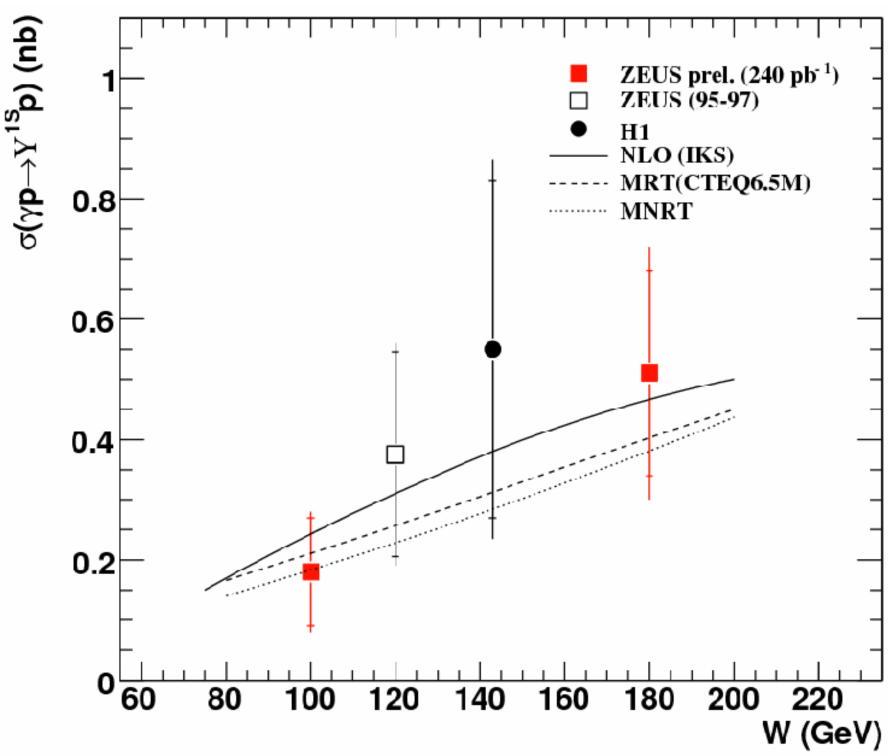




What about Υ ?

Mass distributions (ϒ)



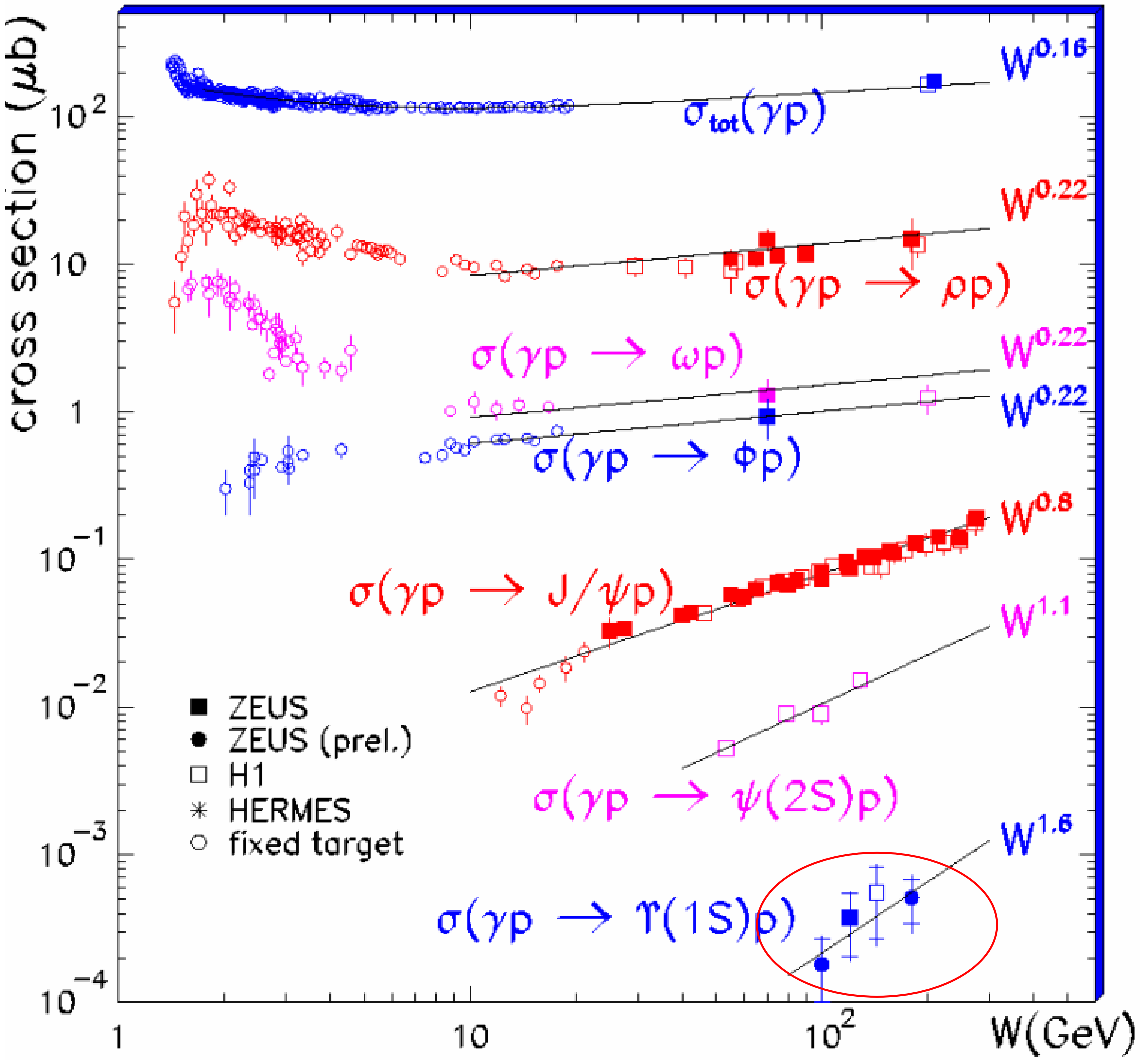


All ZEUS data with Ep=920 GeV

5 sigma signal in data

New ZEUS 240 pb^{-1} two data points
NLO calculations done by Ivanov, Krasnikov, Szymanowski (IKS)[hep-ph/0412235]
MRT – Martin, Ryskin, Teubner, based on CTEQ6.5M gluon.
MNRT – Martin, Nockles, Ryskin, Teubner, based on diffractive J/Ψ data alone.

σ(W)- all VM (M$_V$ – hard scale)



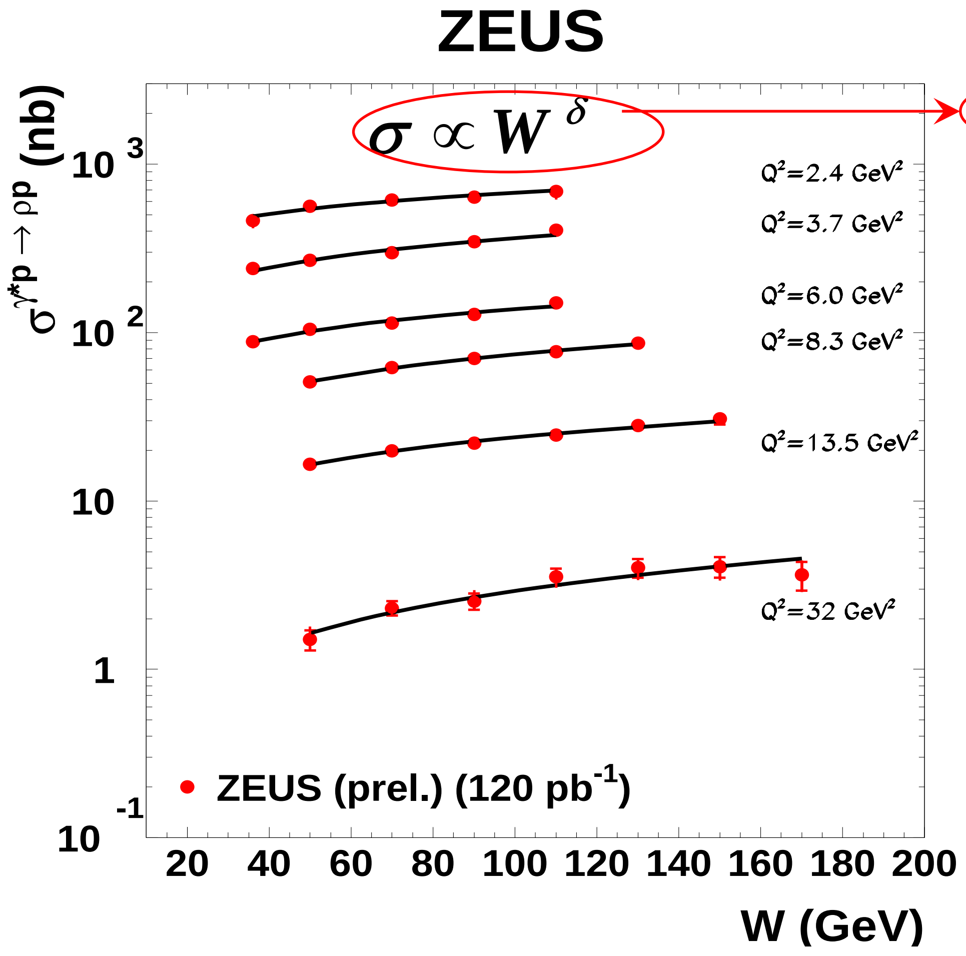
$$\sigma \propto W^{\delta}, \delta = f(M_V)$$

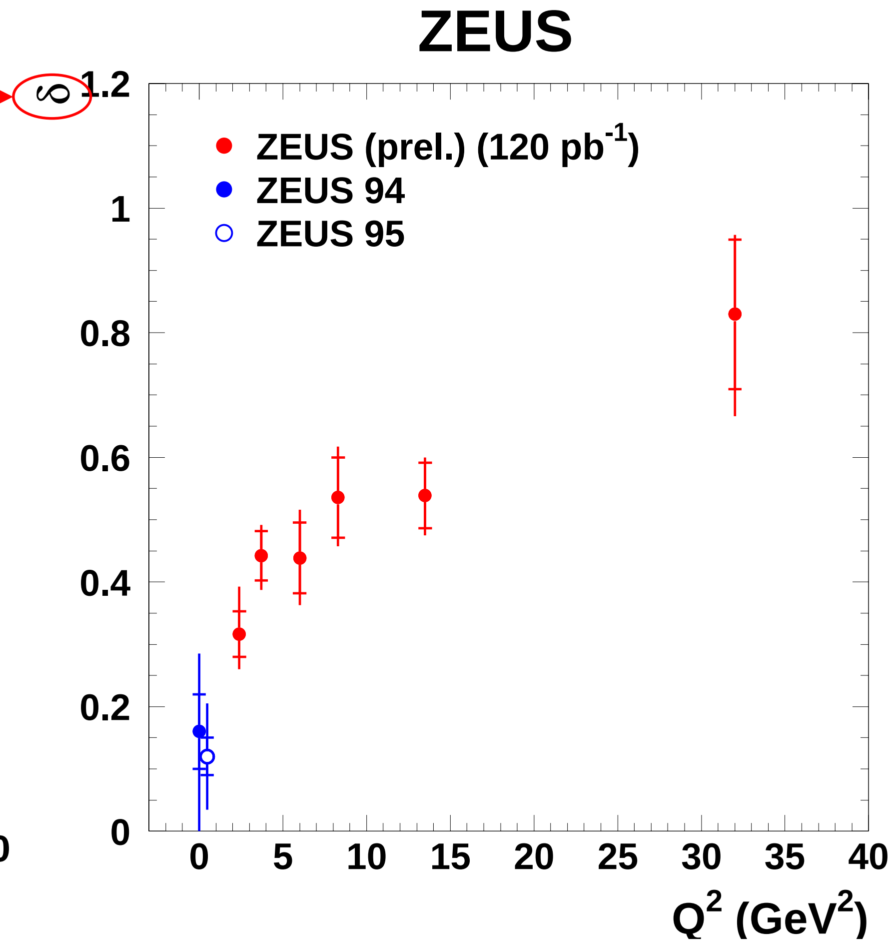
process becomes hard as scale (mass) becomes larger.

For the Υ we have 4 points now, and $W^{1.6}$ comes from the fit to these 4 points.

$\sigma(W) - \rho^0$ (Q^2 - hard scale)

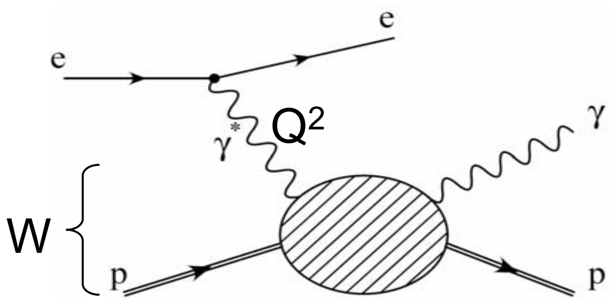
… also in electroproduction we have $\sigma \propto W^{\delta}, \delta = f(Q^2)$





σ(W) - γ (DVCS) (Q² - hard scale)

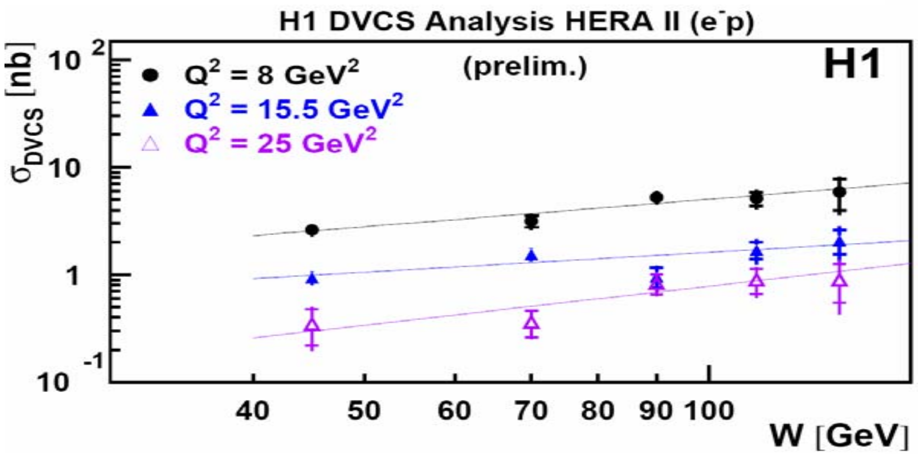
DVCS – Deeply Virtual Compton Scattering

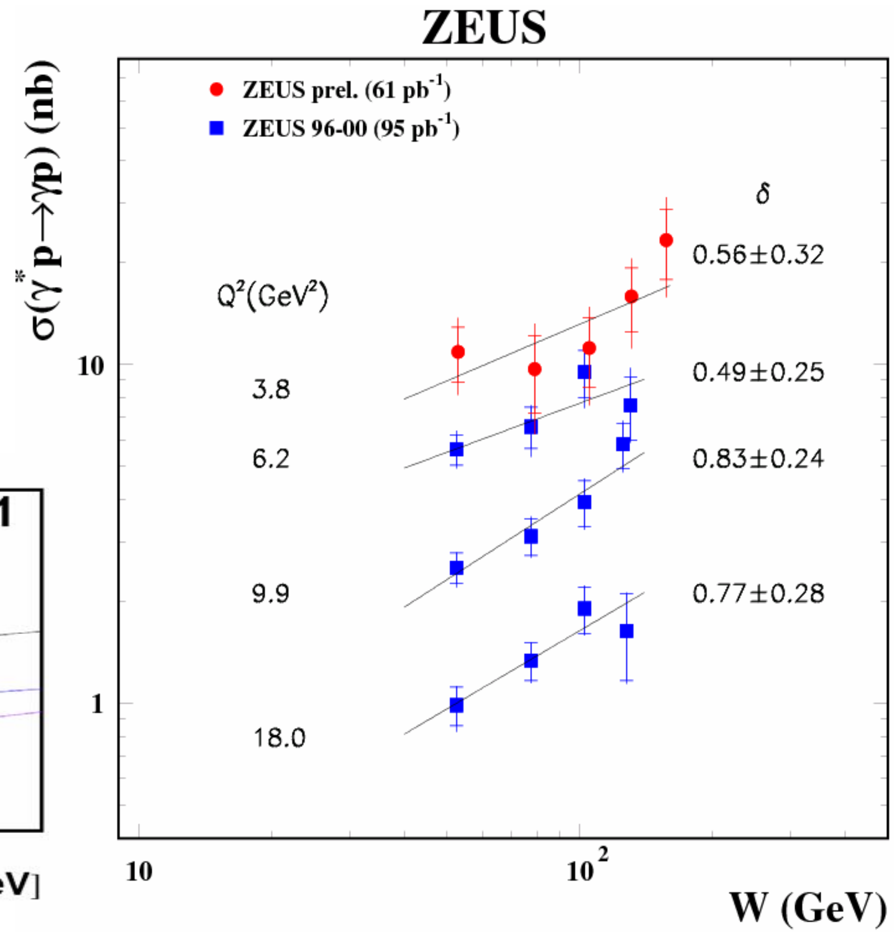


reminder:

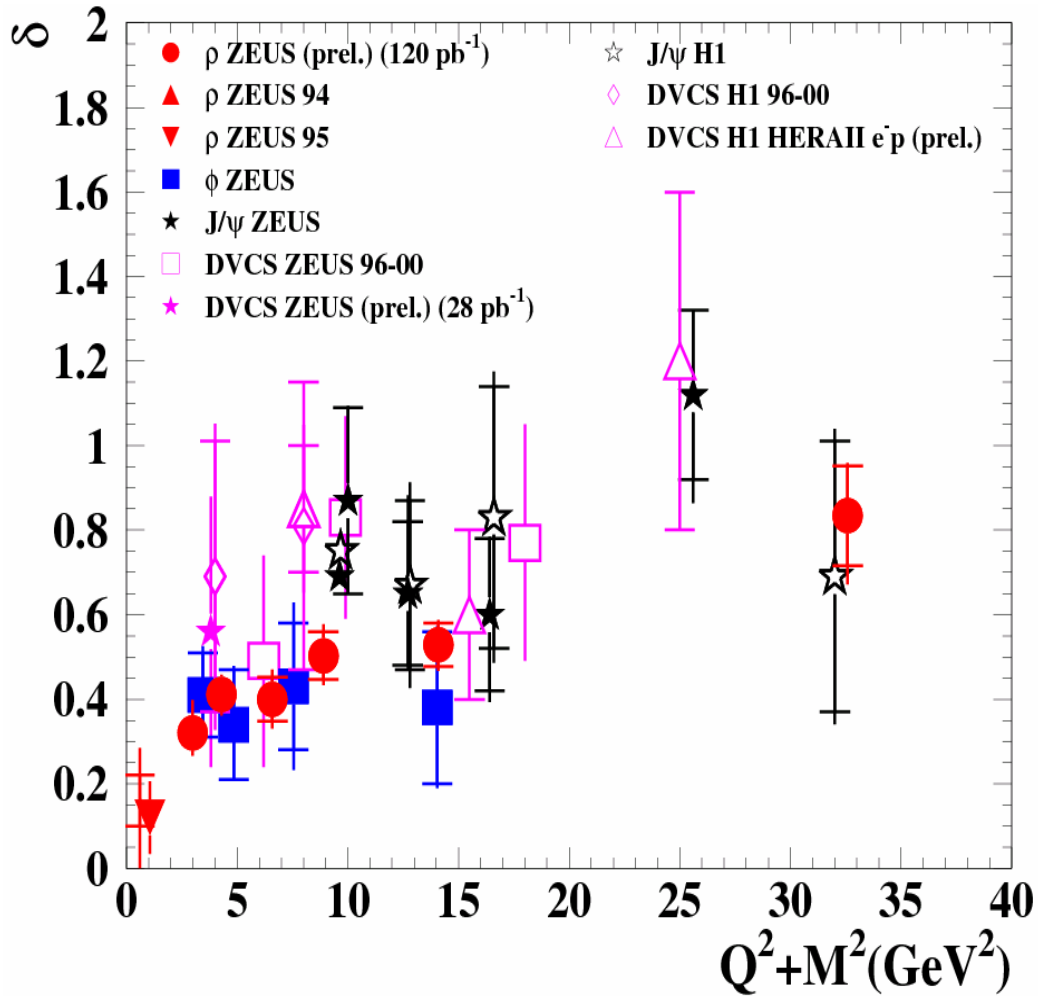
Q^2 – virtuality of photon

W – γ^*p system energy





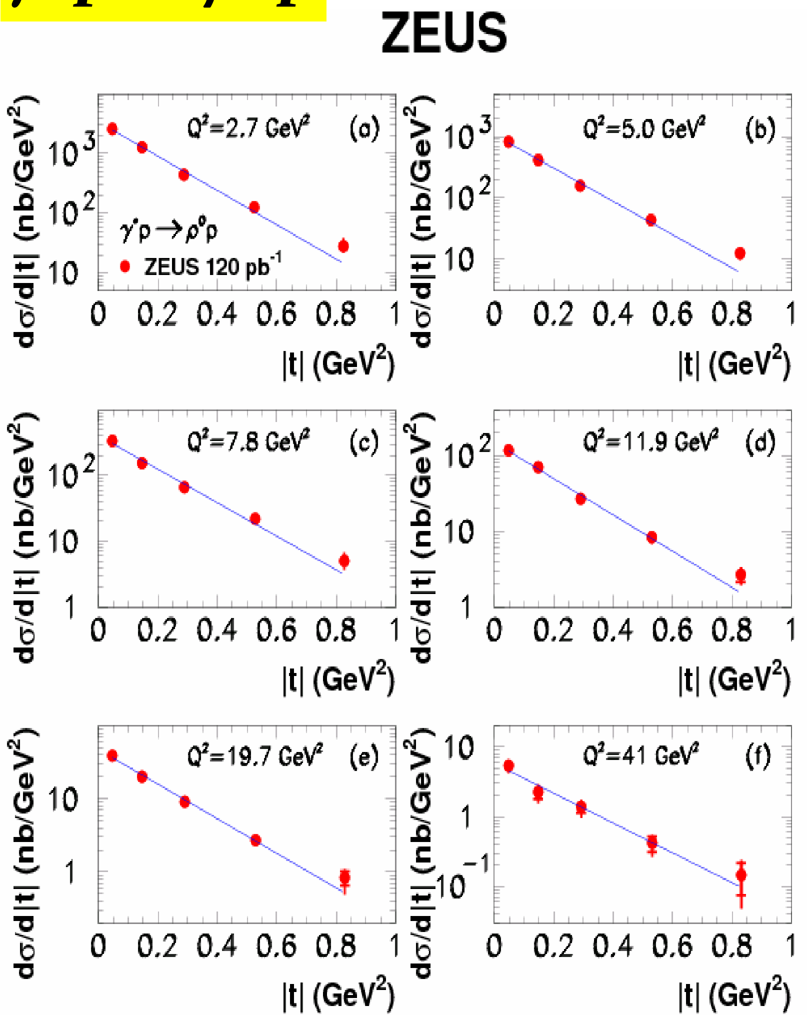
δ (Q²+M²) all VM,γ



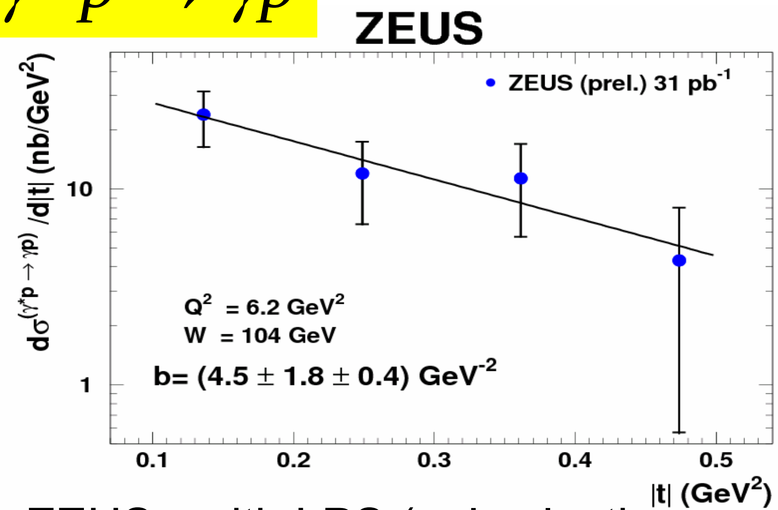
Rise of δ with the hard scale ($Q^2+M_V^2$) is clearly seen

$d\sigma/dt$ - ρ^0, γ (Q^2 - hard scale)

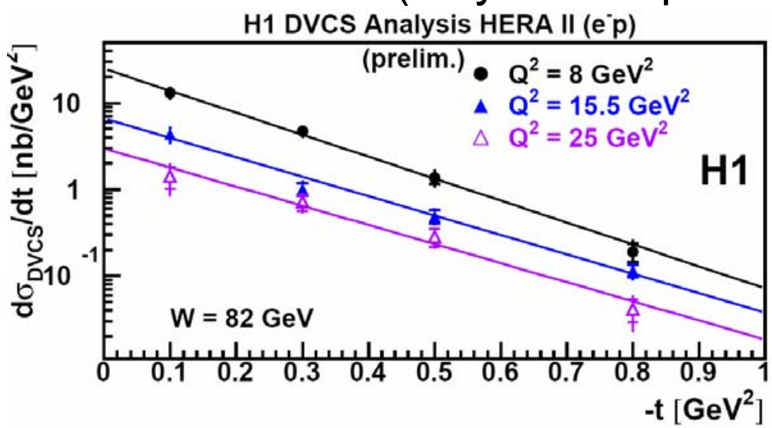
$\gamma^* p \rightarrow \rho^0 p$



$\gamma^* p \rightarrow \gamma p$

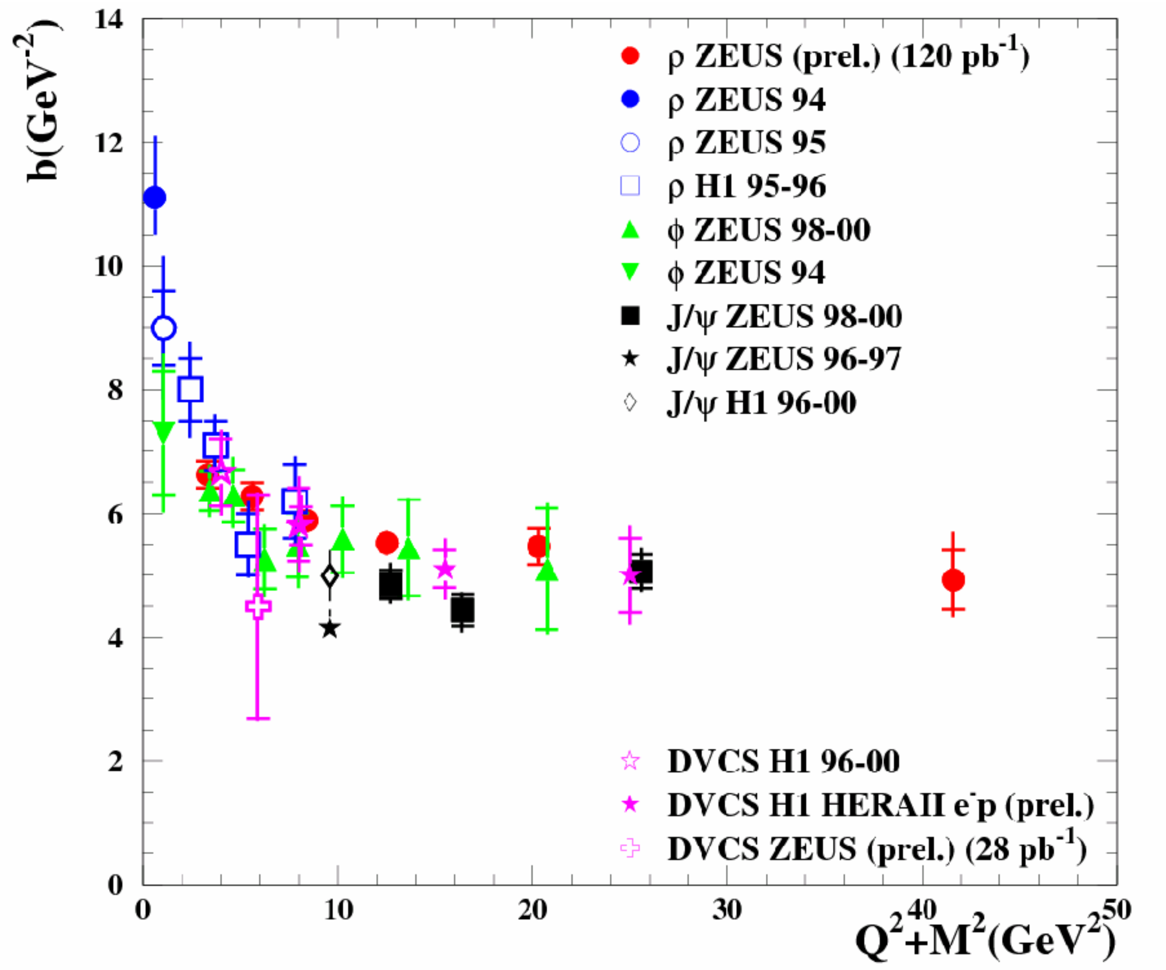


ZEUS - with LPS (only elastic process)



H1- with rapidity gaps (have to correct for proton dissociation contamination)

b(Q^2+M^2) all VM,γ



Magic formula : $\langle r^2 \rangle = b \bullet \hbar c$

$r_{glue} = 0.56$ fm

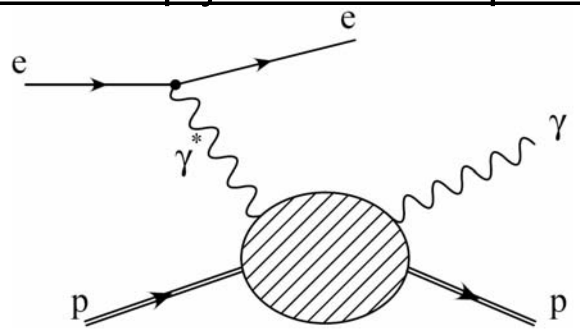
Can be compared to the charge radius of the proton

$r_{proton} = 0.8$ fm

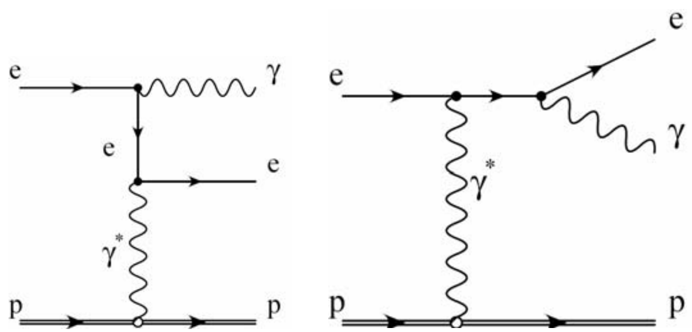
(Hofstadter)

DVCS: Beam Charge Asymmetry

DVCS – Deeply Virtual Compton Scattering



BH – Bethe-Heitler



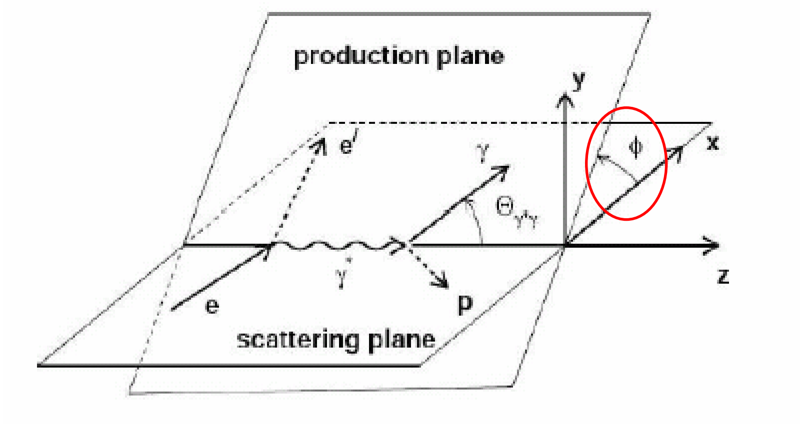
$$d\sigma = d\sigma^{BH} + d\sigma^{DVCS} \pm Interference.Term.$$

+ for beam lepton charge (+)

- for beam lepton charge (-)

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

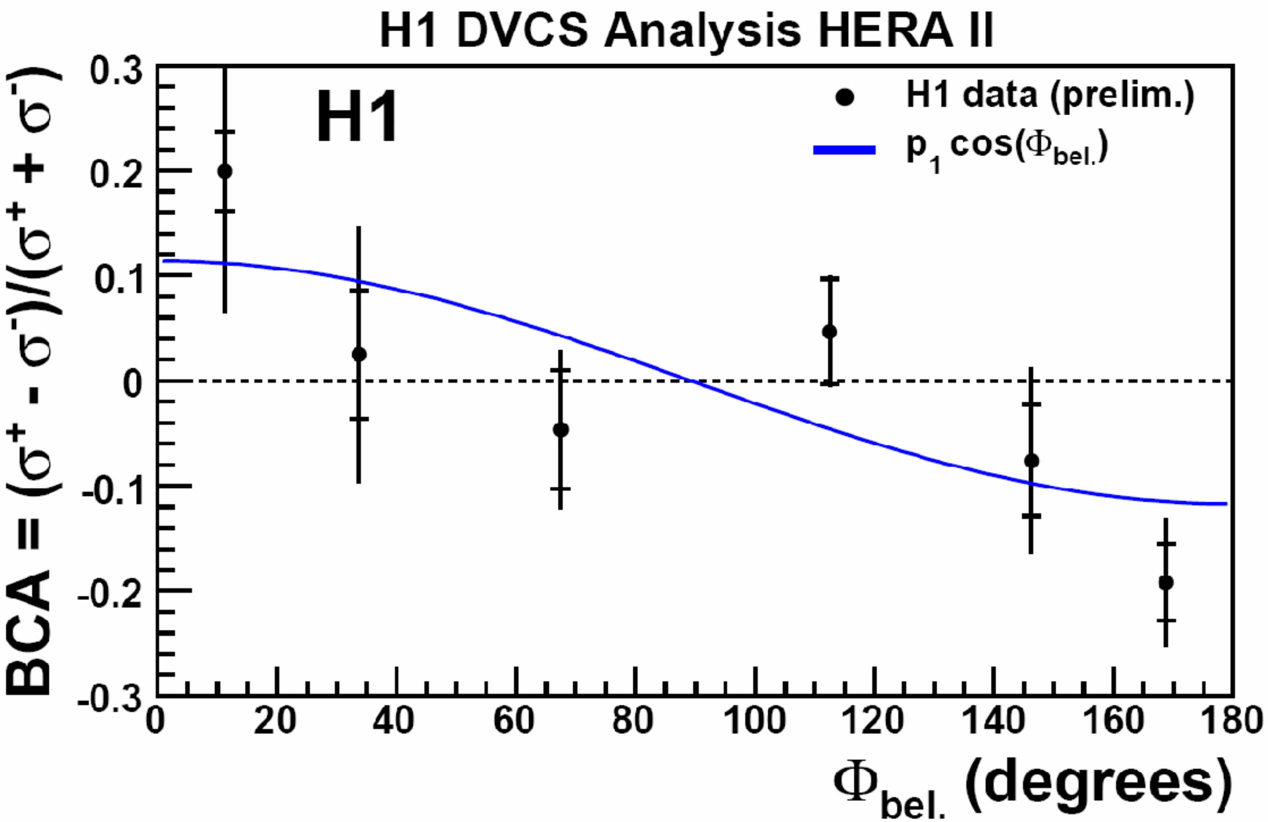
$$BCA = \frac{\sigma^{+} - \sigma^{-}}{\sigma^{+} + \sigma^{-}} = p_1 * \cos(\phi) + \ldots \;,\; p_1 \sim GPD$$



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(ϕ)+…



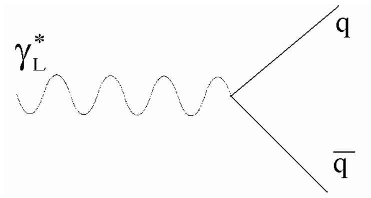
BCA via p_1 gives us information about GPDs

$R = \sigma_L/\sigma_T (Q^2)$ (Q^2 - hard scale)

γ^* has two components:

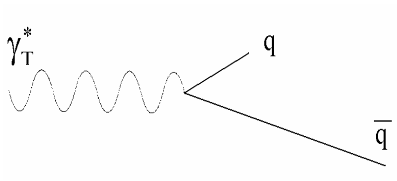
longitudinally polarized, γ^*_L

transversely polarized , γ^*_T



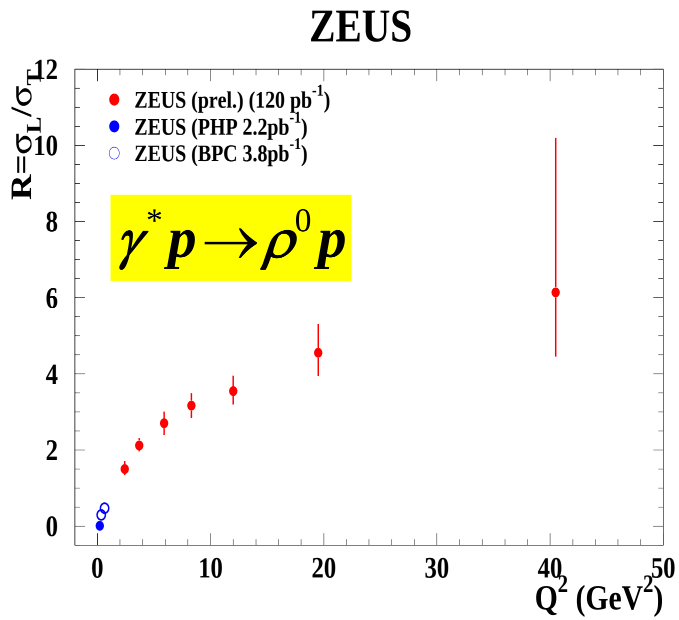
Small spatial configuration (large k_T).

σ_L steep rise with W



Large spatial configuration dominates (small k_T)

σ_T slow rise with W

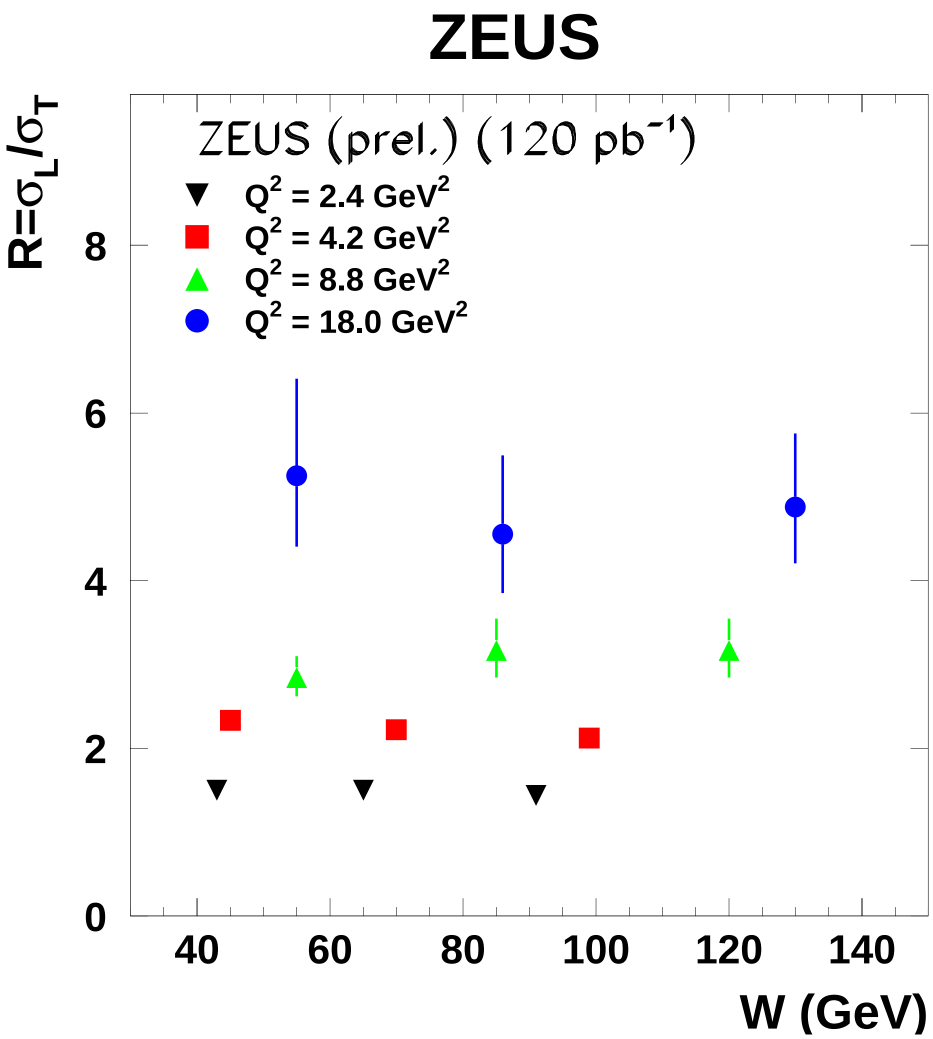


SCHC allows us to get information on both components.

As the scale gets harder, one should expect σ_L to dominate – as indeed seen in the data.

Since γ^*_L and γ^*_T are expected to have different W dependence, it is interesting to study R(W)

$R = \sigma_L/\sigma_T(W)$ no W dependence!

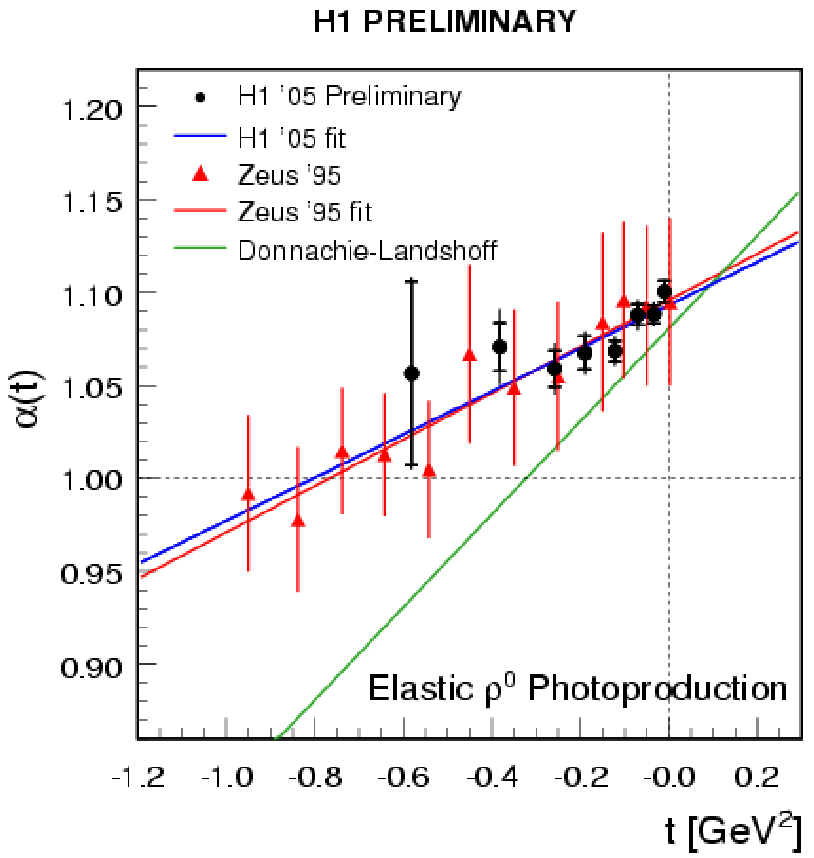


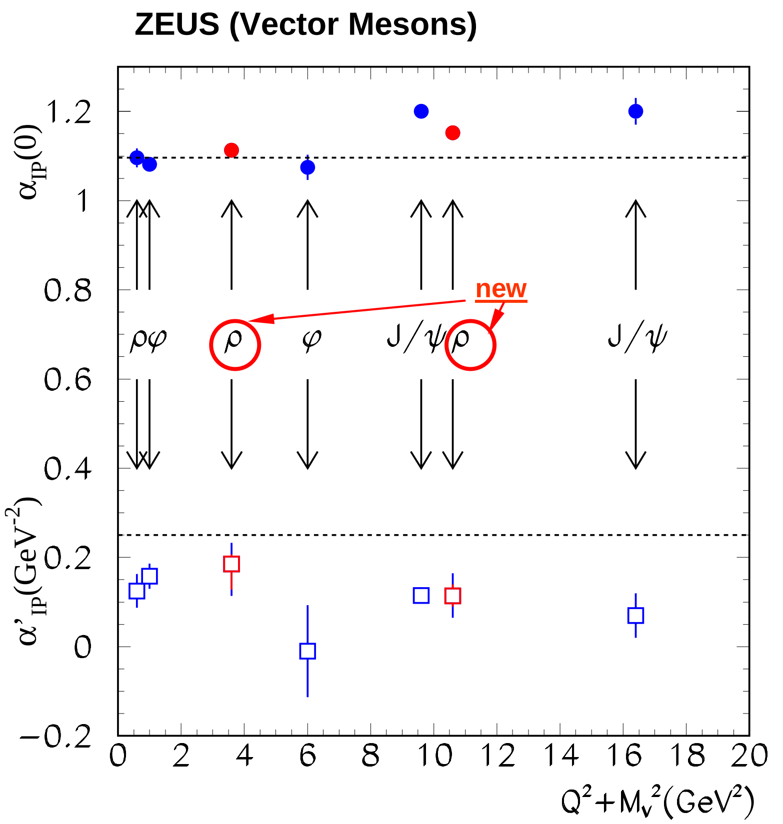
Surprisingly, R(W) is independent of W !

$\Rightarrow$ σ_L, σ_T have same W dependence.

$\Rightarrow$ large γ^*_T spatial configuration seems to be suppressed.

Effective Pomeron trajectory (back to Regge)

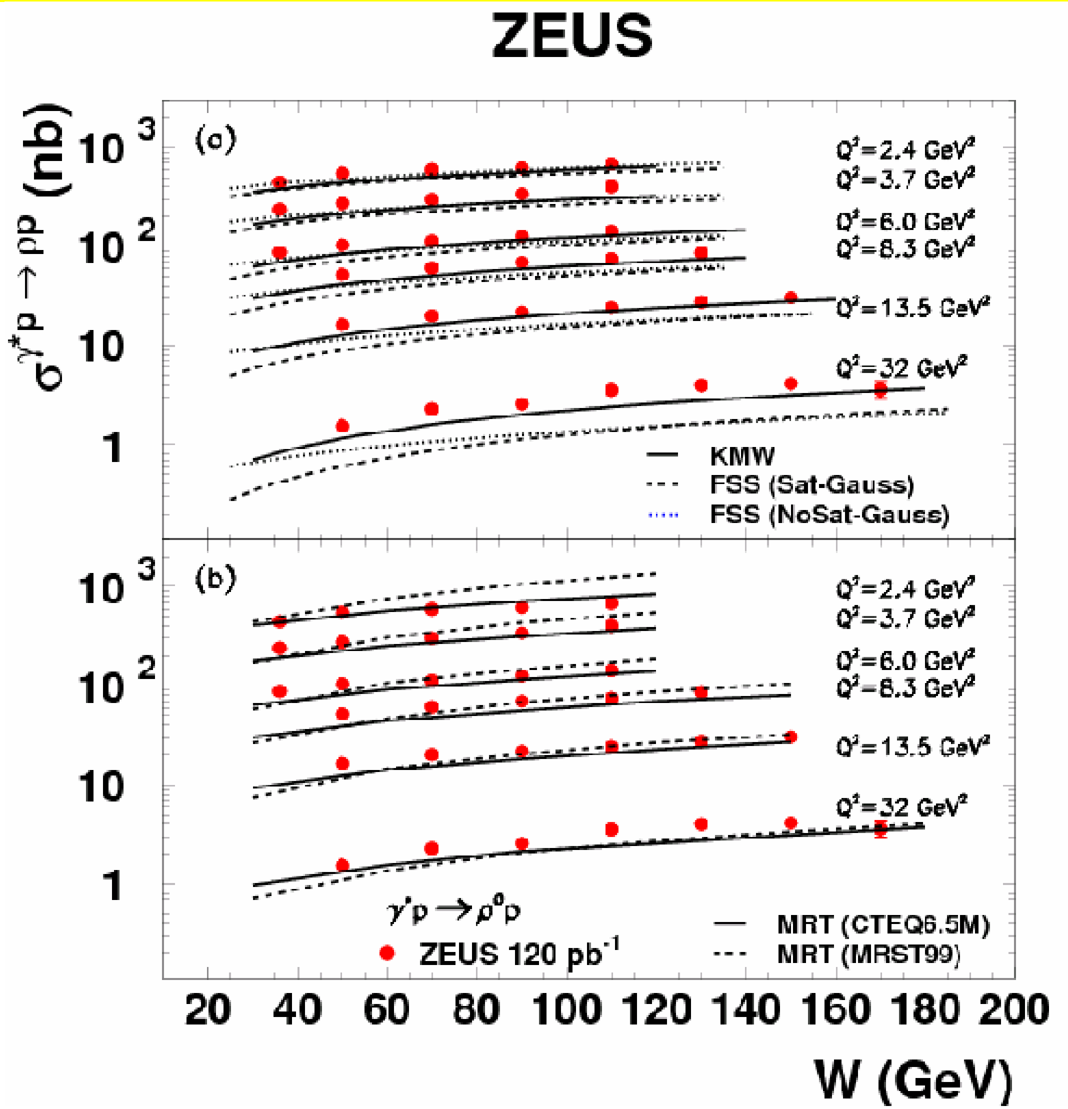




Dashed lines come from proton-proton collision.

As the scale gets harder the intercept grows and the slope gets smaller.

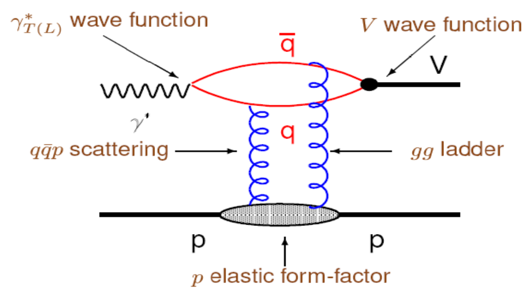
ρ^0: $\sigma(W)$ and calculations



Experiment is coming to the precision level where we can really improve our understanding of the vector meson WF and Gluon Density in the proton.

MRT – sensitive to different Gluon Densities

DF,FSS,KMW – sensitive to different shapes of the ρ^0 Wave Function



Summary and conclusions

- New high statistics measurements of ρ^0 electroproduction and on DVCS.
- New measurement on the Upsilon photoproduction.
- The cross section rises with W and its logarithmic derivative wrt W increases with the hard scale ($Q^2 + M_v^2$).
- The exponential slope of the t distribution decreases with Q^2 and levels off at about b = 5 GeV^{-2}.
- The ratio of cross sections induced by longitudinally and transversely polarised virtual photons increases with Q^2, but is independent of W.
- 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 measurements are able to reproduce all the features of the data.

Backup

- MRT – A.D. Martin, M. G. Ryskin, T. Teubner
- DF – H.G.Dosch, E.Fereirra
- FSS – J.R.Forshaw, R.Sandapen, G.Shaw
- KMW – H.Kowalski, L.Motyka, G.Watt