Measurements of diffractive processes at HERA

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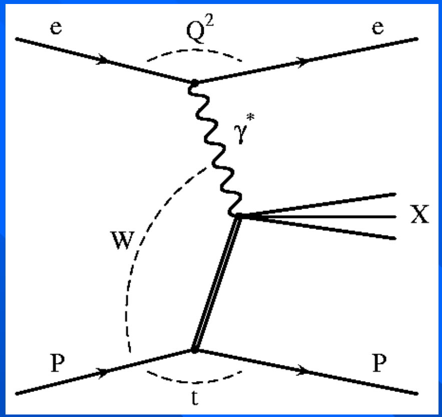
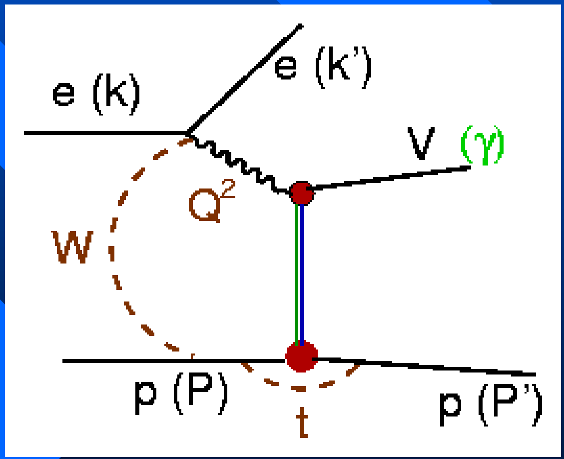
Outline

- Inclusive processes

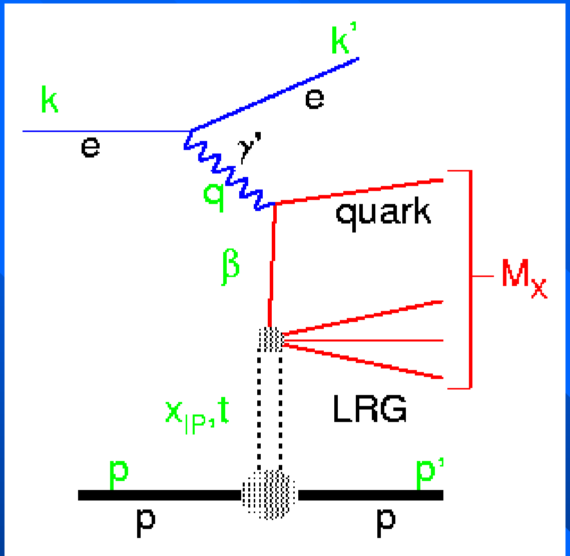


- Exclusive vector mesons



- DVCS

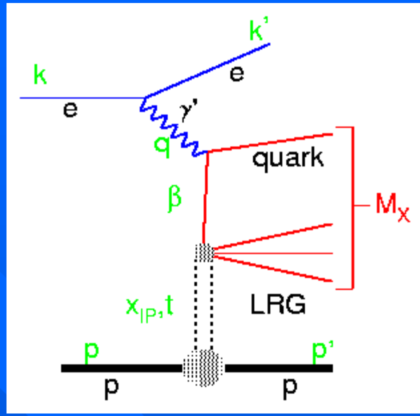
Kinematics in ep scattering



$$Q^2 = -q^2 = -(k-k')^2$$
$$x = \frac{Q^2}{2p\cdot q}$$
$$y = \frac{q\cdot p}{k\cdot p}$$
$$s = (k+p)^2$$
$$W^2 = (q+p)^2$$

$$x_{IP} = \frac{q\cdot(p-p')}{q\cdot p} \simeq \frac{Q^2+M_X^2}{Q^2+W^2}$$
$$\beta = \frac{Q^2}{2q\cdot(p-p')} \simeq \frac{Q^2}{Q^2+M_X^2}$$
$$t = (p-p')^2$$

Picture of soft diffraction



LRG due to exchange of Pomeron trajectory

$$\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} \cdot t$$

$$\sigma_{\rm tot} \sim s^{\alpha_{I\!P}(0)-1}$$

$$\frac{d\sigma_{\rm el}}{dt} \sim \frac{\sigma_{\rm tot}^2}{16\pi} e^{2(b_0^{\rm el} + \alpha'_{I\!P} \ln s)t}$$

$$\frac{d^2\sigma_{\rm D}}{dt\,dx_{I\!P}} \sim \left(\frac{1}{x_{I\!P}}\right)^{2\alpha_{I\!P}(t)-1} e^{2(b_0^{\rm D} - \alpha'_{I\!P} \ln x_{I\!P})t}$$

D stands for diffraction and

$x_{I\!P}$ is M^2_X/s.

Experimentally α(0)=1+ε

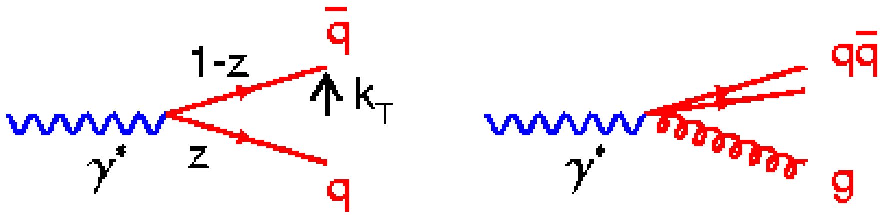
ε=0.08-0.10 and $\alpha'_{I\!P}$ =0.25 GeV^{-2}

- expect $\frac{\sigma_{\rm el,D}}{\sigma_{\rm tot}} \sim s^{\varepsilon}$
- shrinkage of the t slope $x_{I\!P}$
- enhancement of low diffractive masses $\frac{d\sigma_{\rm D}}{x_{I\!P}} \sim \left(\frac{1}{x_{I\!P}}\right)^{1+2\varepsilon}$

Picture of Diffraction in DIS

In the target rest frame:

(1) $\gamma^* \to q\bar{q}$ or $q\bar{q}g$ forming color dipoles



$$\tau_{\text{fluctuation}} \simeq \frac{1}{2mx} \gg 1\,\text{fm}$$

(2) The dipole interacts with the target T

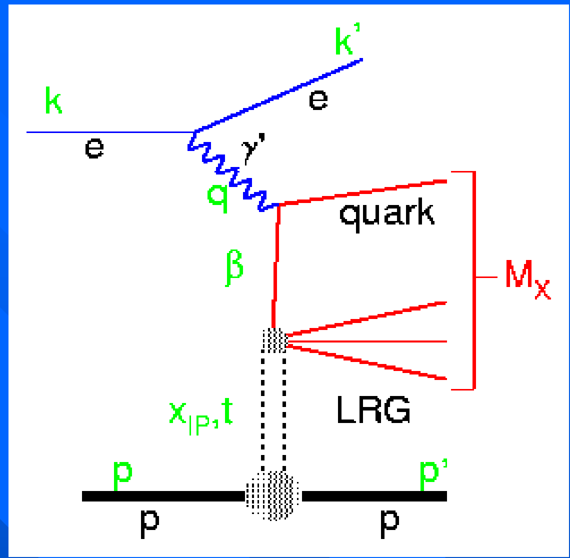
- if k_T large, small transverse size $r \to$ pQCD

$$\sigma_{q\bar{q}T} = \frac{\pi^2}{3} r^2 \alpha_S(Q^2) x G_T(x, Q^2 \simeq \frac{\lambda}{r^2})$$

$$\sigma_{q\bar{q}gT} = \sigma_{ggT} = \frac{9}{4}\sigma_{q\bar{q}T}$$

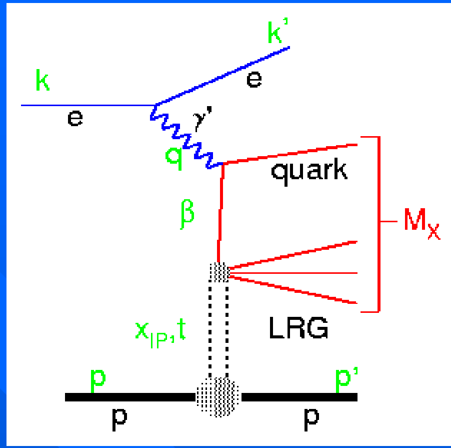
Color transparency

- if k_T small, large transverse size $r \to$ non-perturbative physics dominates



• Diffractive structure function F_2^D

$$\frac{d^4\sigma^D(ep\to epX)}{dx_{I\!P}dt\,dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}(1+(1-y)^2)\frac{d^2F_2^D(x_{I\!P},t,x,Q^2)}{dx_{I\!P}dt}$$



• QCD factorization for diffractive DIS holds

(Collins, Berera & Soper, Trentadue & Veneziano)

$$\frac{d^2F_2^D(x_{I\!P},t,x,Q^2)}{dx_{I\!P}dt} = \sum_i \int dz \frac{d^2f_{i/p}^D(x_{I\!P},t,z,\mu^2)}{dx_{I\!P}dt}\hat{F}_i\left(\frac{x}{z},\frac{Q^2}{\mu^2}\right)$$

diffractive parton distribution functions — pQCD as in incl. DIS

Diffractive parton distributions evolve in μ^2 following DGLAP equation

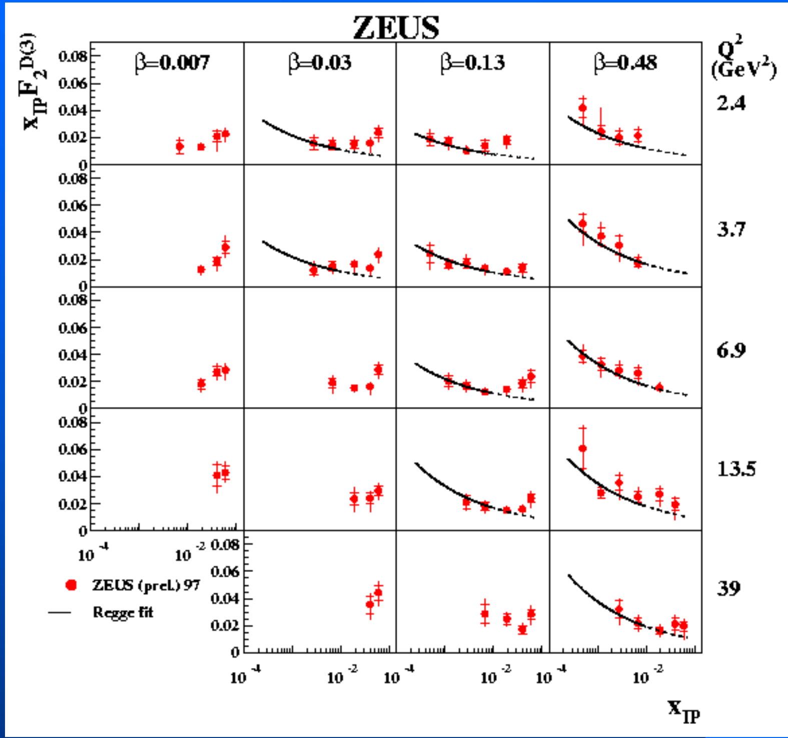
• If in addition postulate Regge factorization (Ingelman & Schlein)

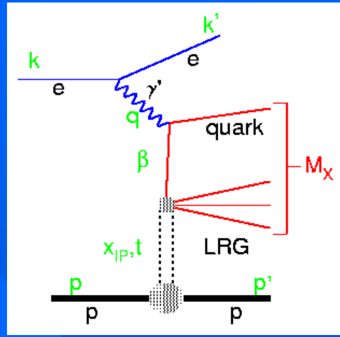
$$\frac{d^2F_2^D(x_{I\!P},t,x,Q^2)}{dx_{I\!P}dt} = f_{I\!P/p}(x_{I\!P},t)F_2^{I\!P}(\beta,Q^2)$$

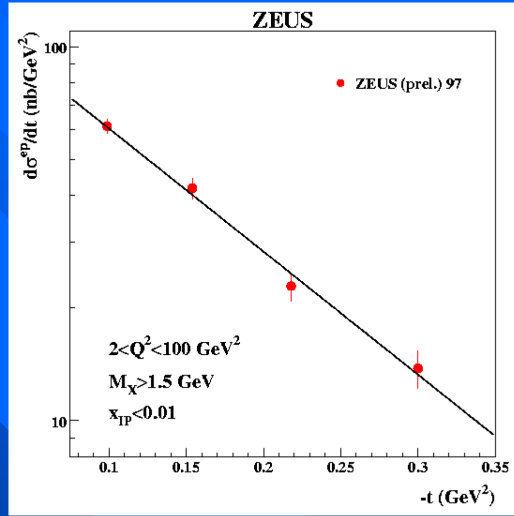
$F_2^{I\!P}(\beta,Q^2)$ evolves following DGLAP equations

Diffractive Structure Function

$F_2^{D(3)}$ – integrate over t

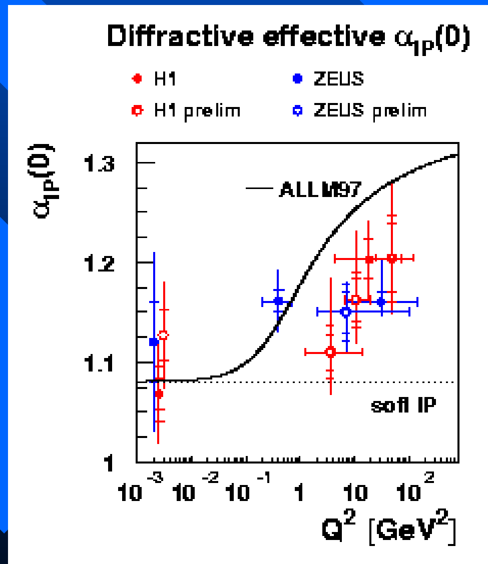


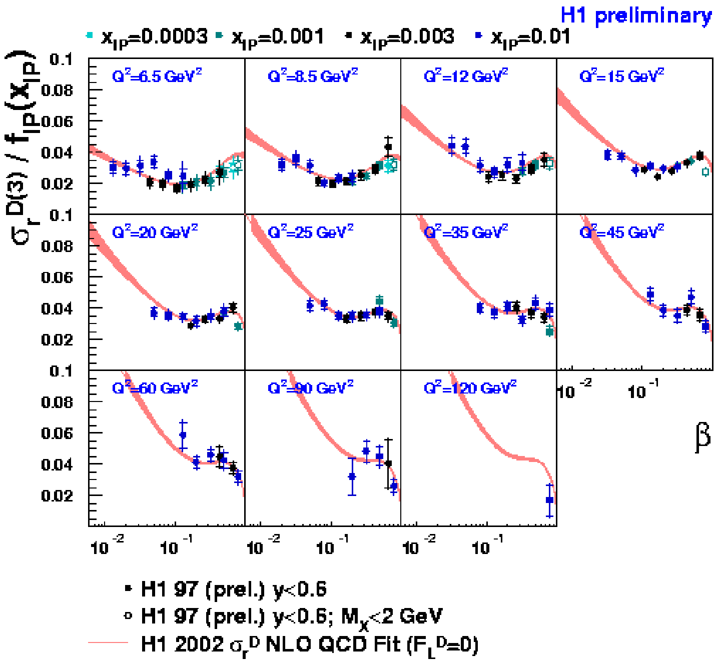


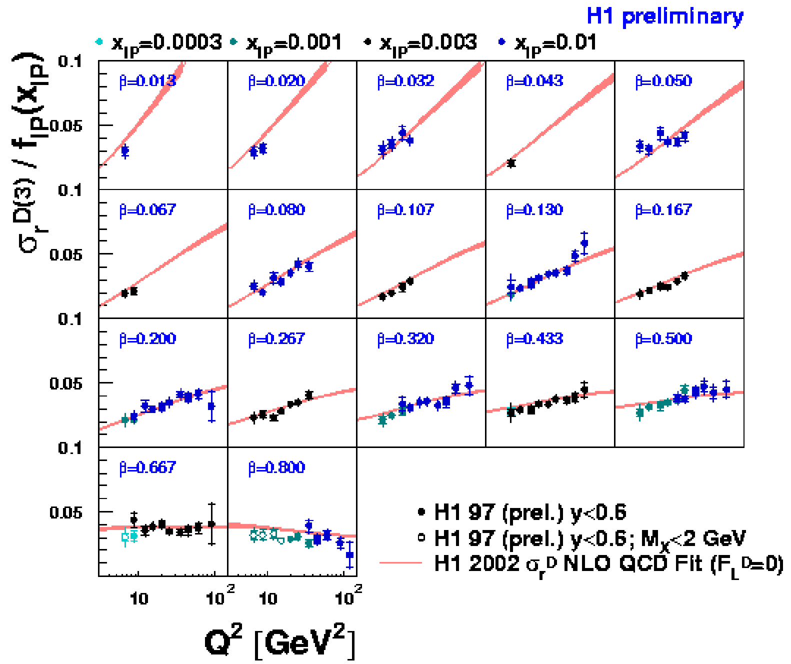


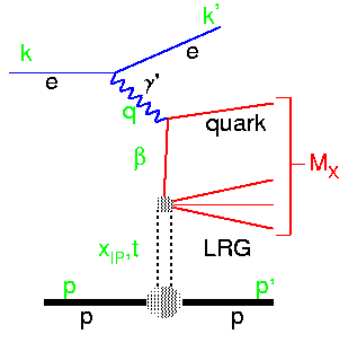
Fit all data with one value of flux factor

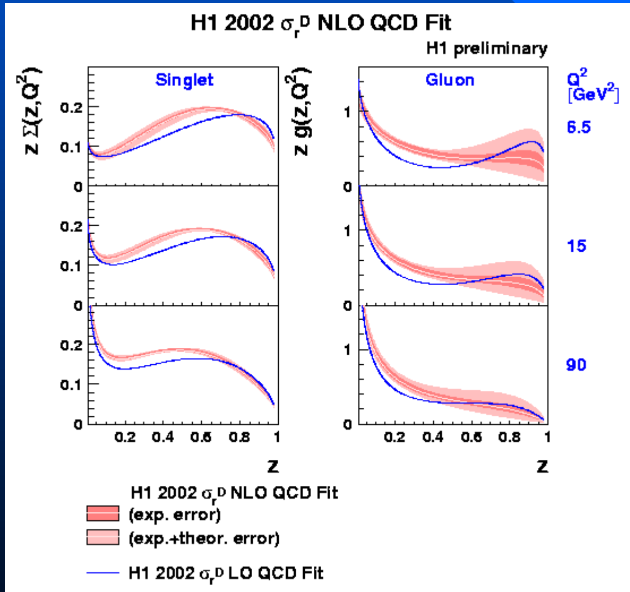
$$x_{I\!P}F_2^{D(3)}(x_{I\!P},\beta,Q^2) \sim \frac{1}{x_{I\!P}^{2\alpha_{I\!P}-2}}F_2^{I\!P}(\beta,Q^2)$$

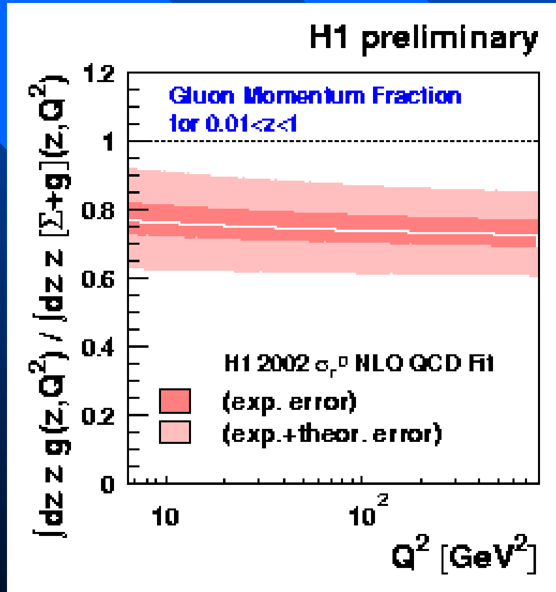










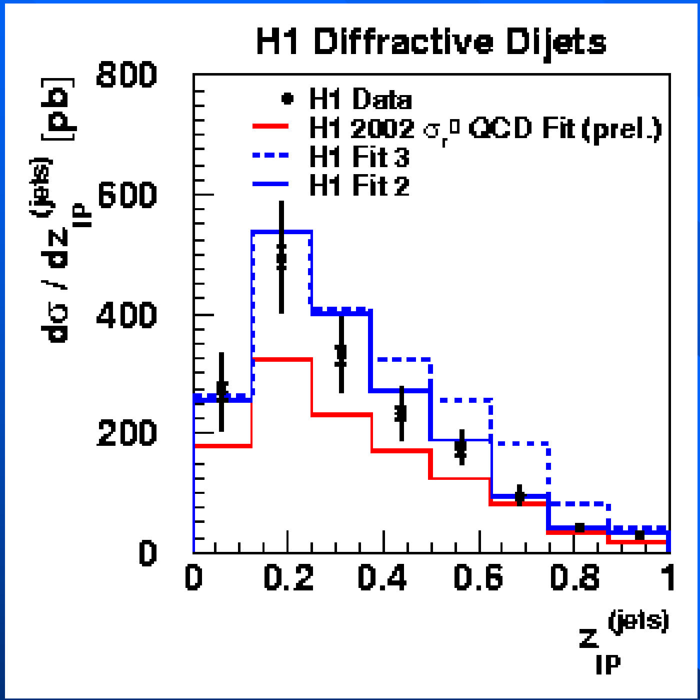


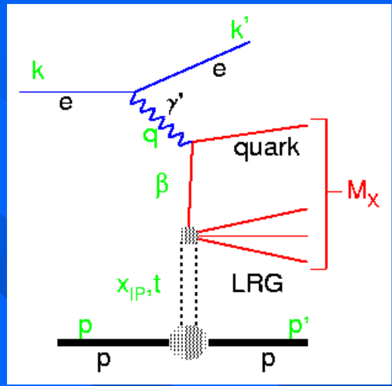
Probability that a gluon from the proton will produce a diffractive process:

at $x=10^{-3}$ and $Q^2=4$ GeV^2, Pg=0.4!! (unitarity limit is 0.5)

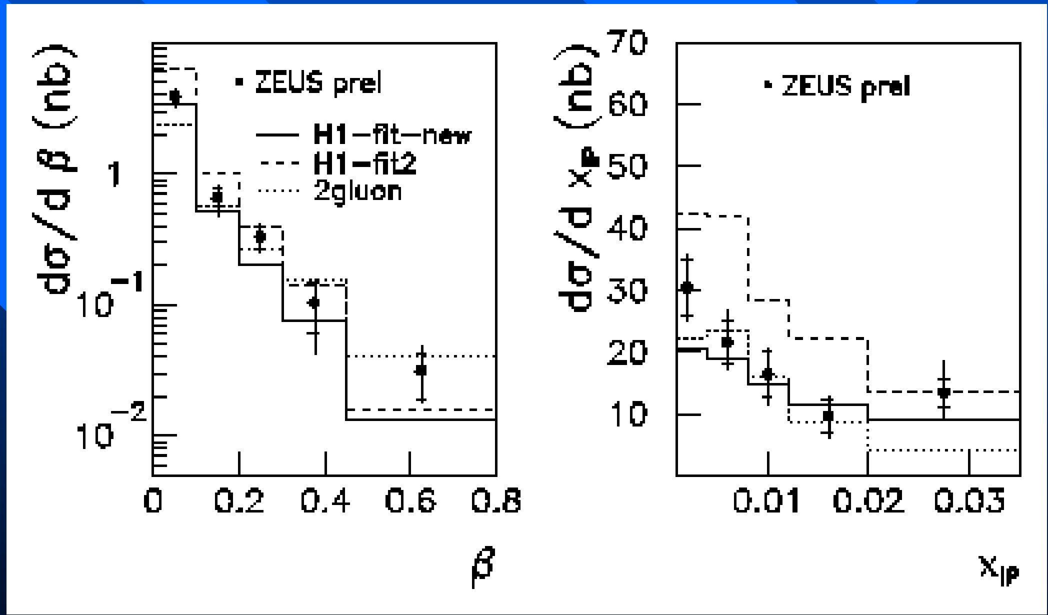
(Frankfurt, Strikman)

Application of diffractive pdfs

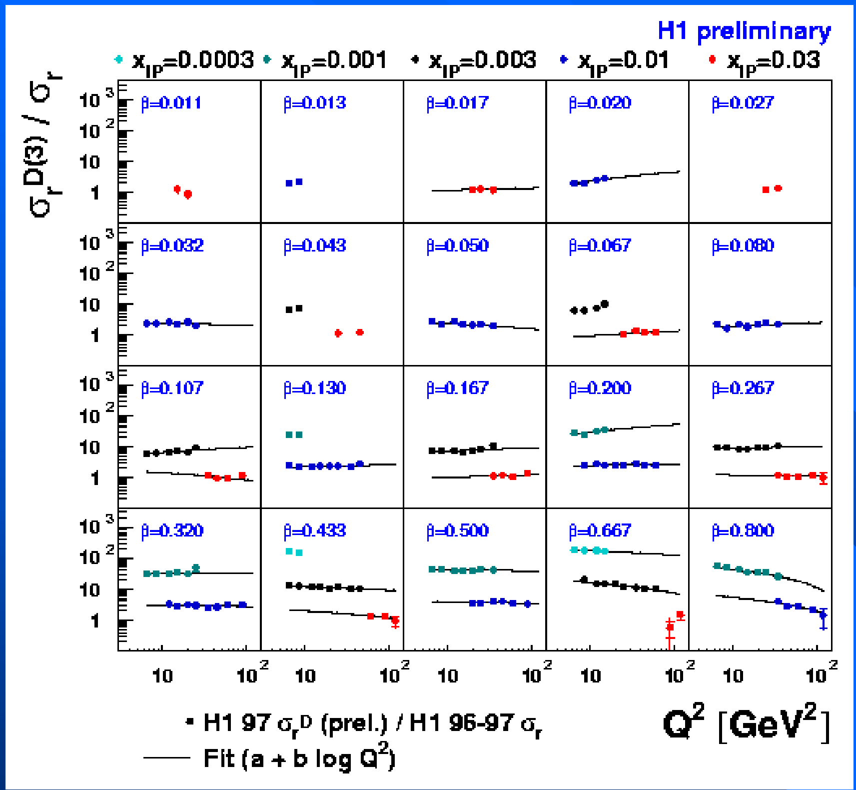


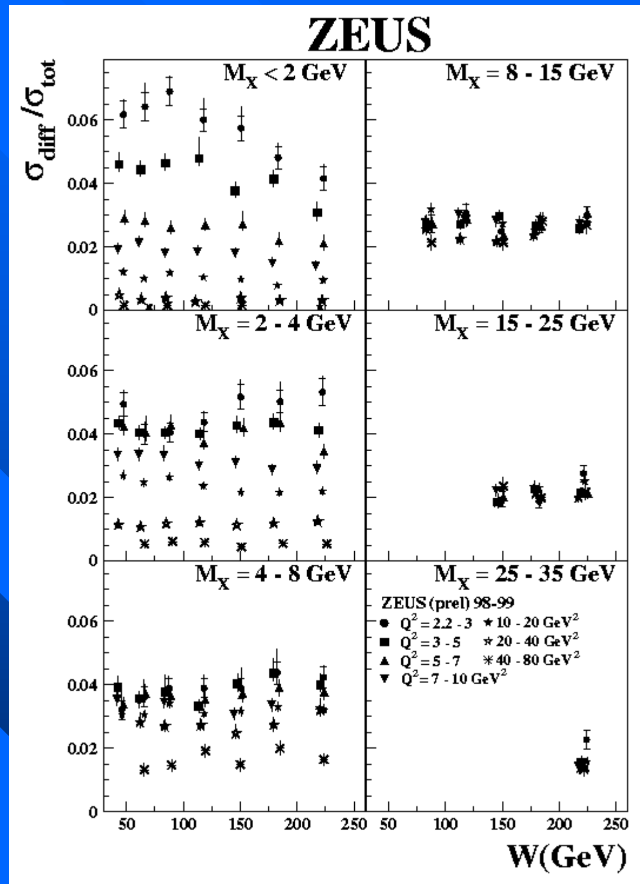


Diffractive D*



Ratios of diff/total





- little Q^2 dependence at high M_X (low β)
- strong Q^2 dependence at small M_X (high β)

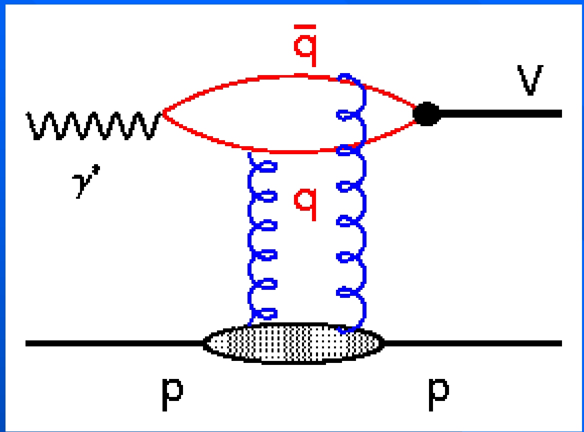
- Flat in W

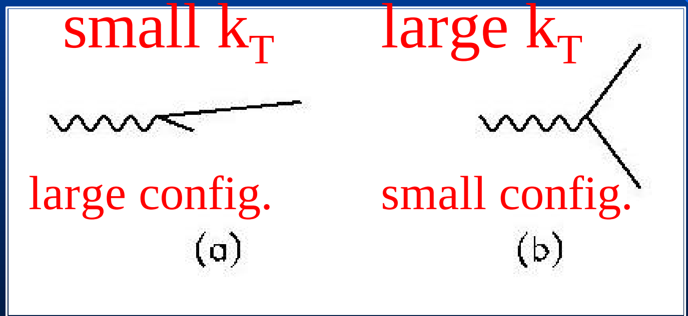
Conclusion on inclusive diffraction

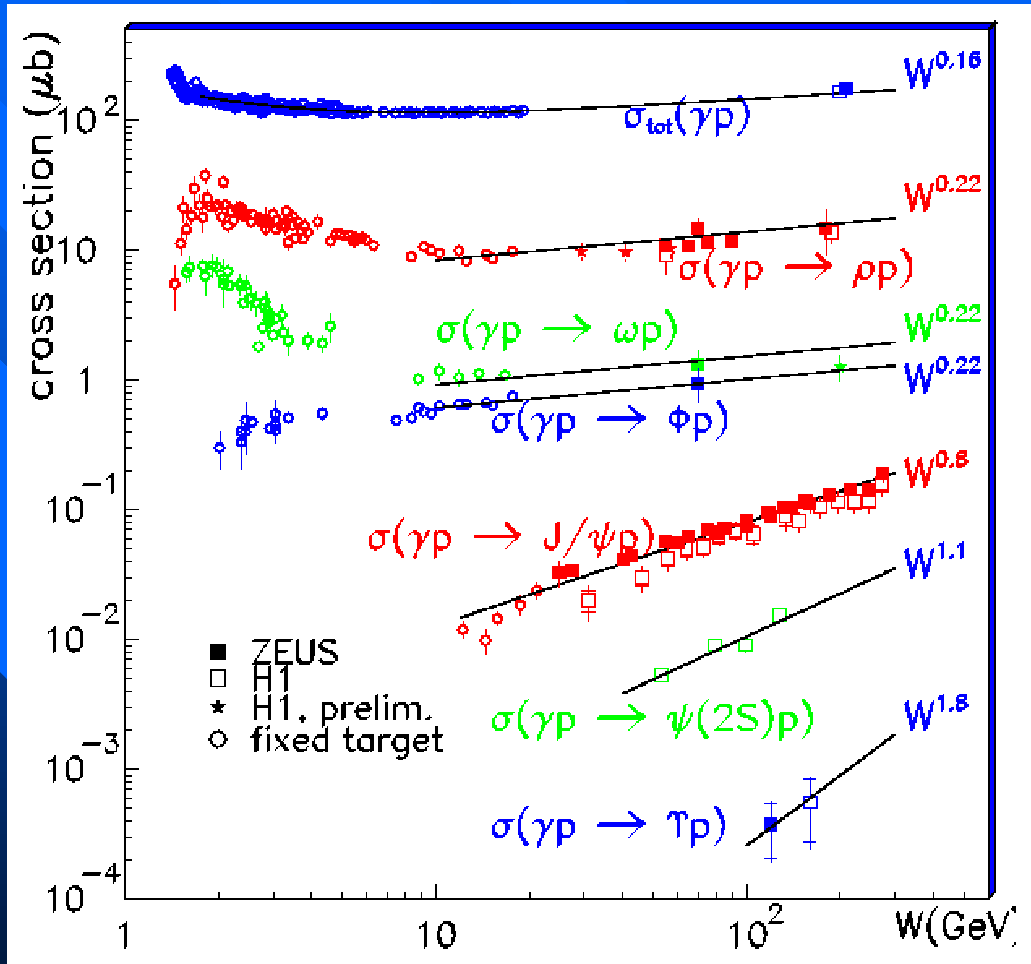
- Diffractive processes – dominated by gluons (~ 80%). May be close to the unitarity limit (P_g~0.4 at $x=10^{-3}$, $Q^2=4GeV^2$)

- Ratio of diffractive to inclusive cross section: remarkably flat over wide kinematic range.

Exclusive vector mesons



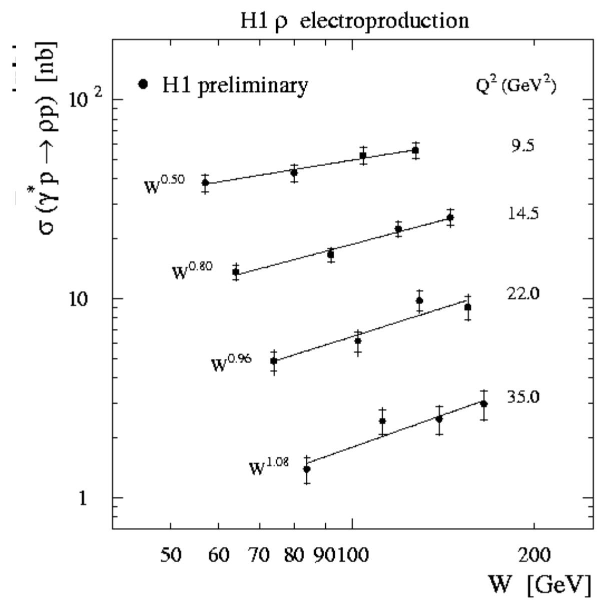


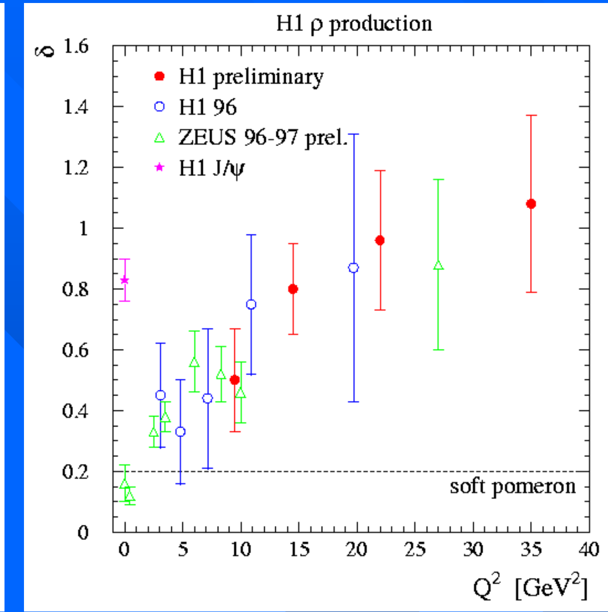


"soft" "hard"

Transition from "soft" to "hard"

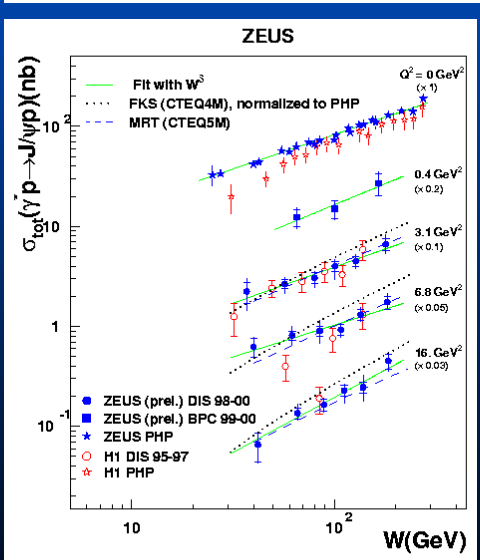
Exclusive vector mesons: σ(W)

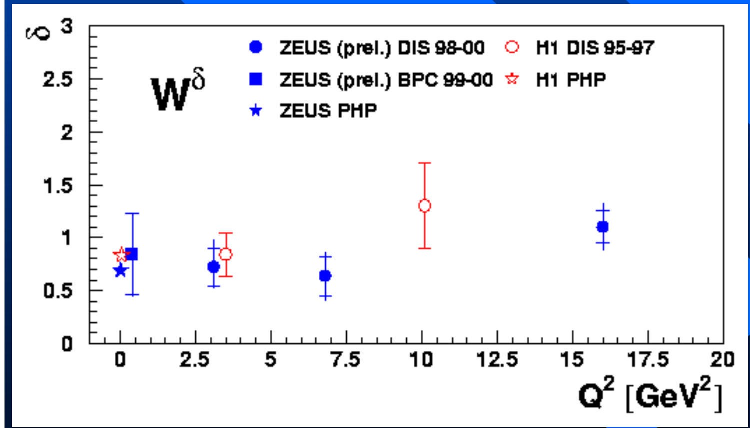




σ_ρ gets steeper with Q^2

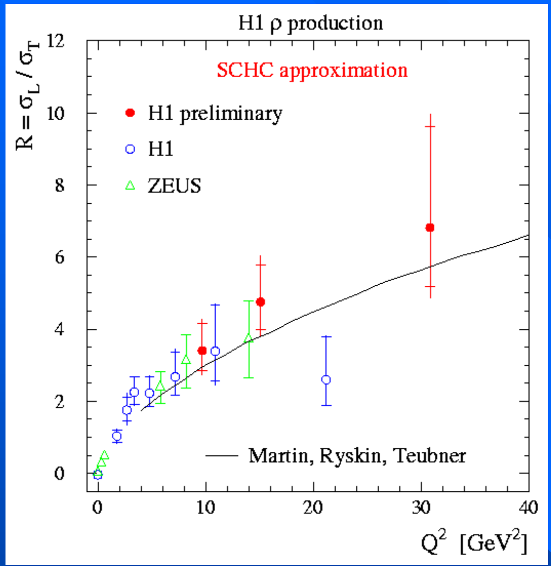
Transition from soft to hard regime

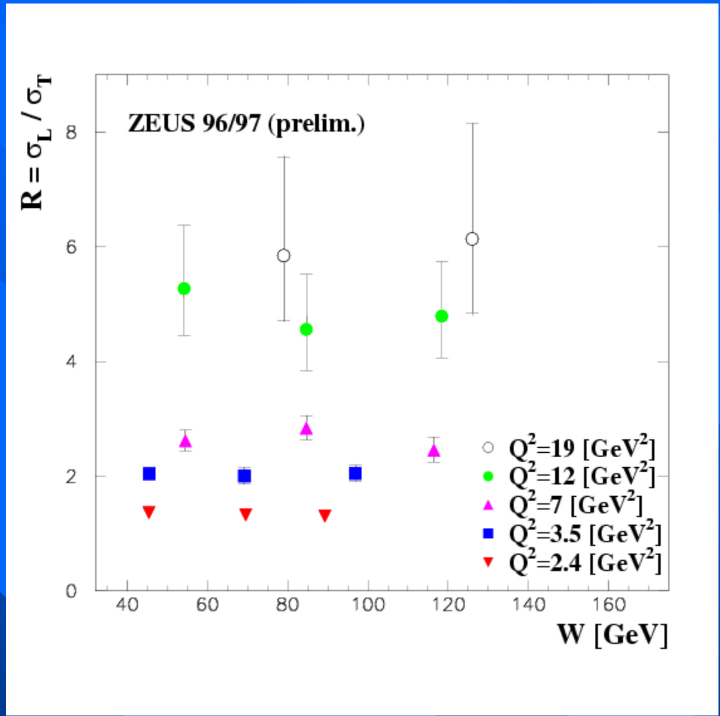


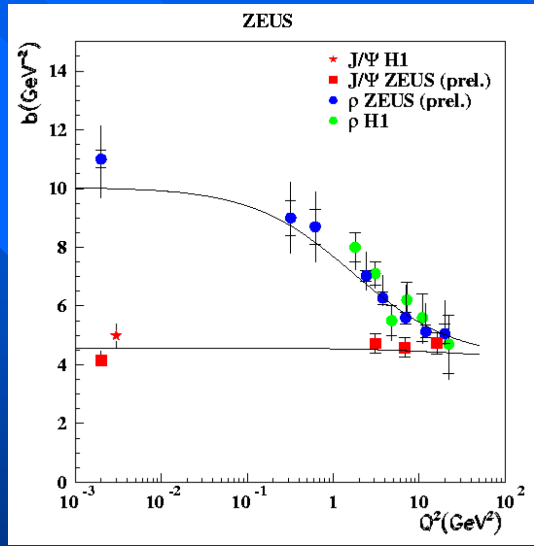


$\sigma_{J/\psi}$ steep already at $Q^2=0$

Exclusive vector mesons: sizes





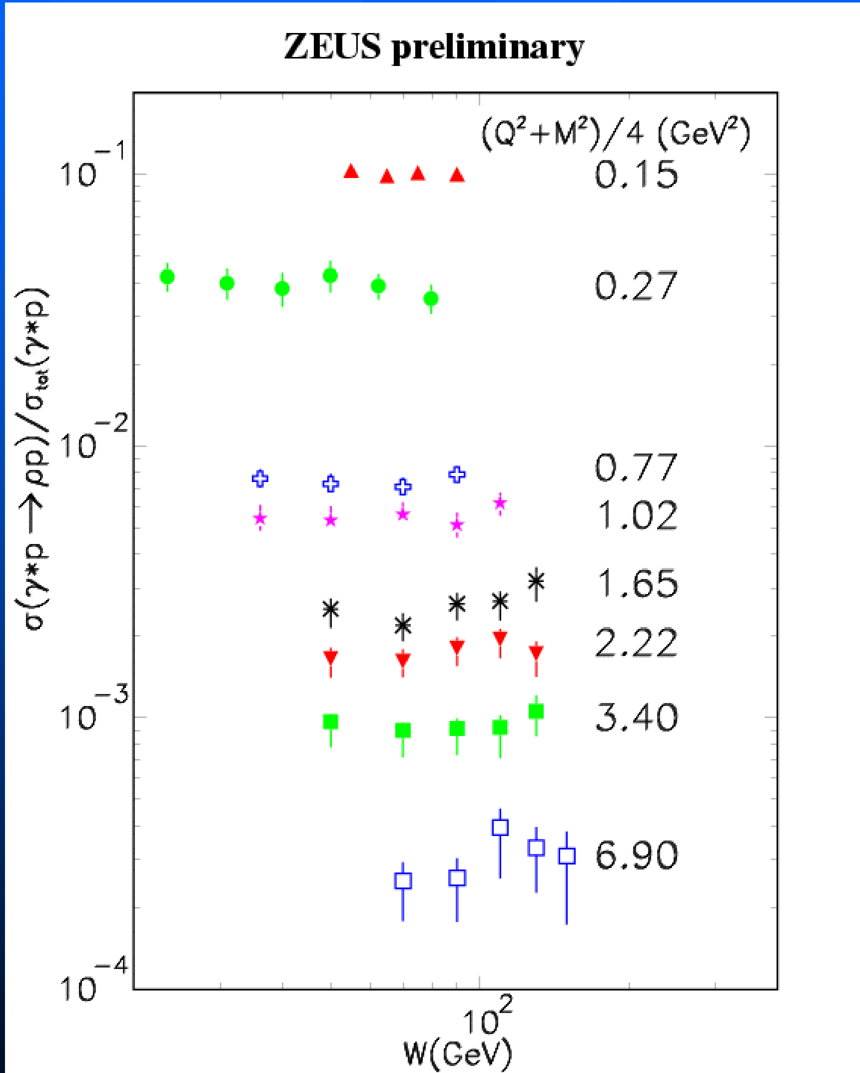


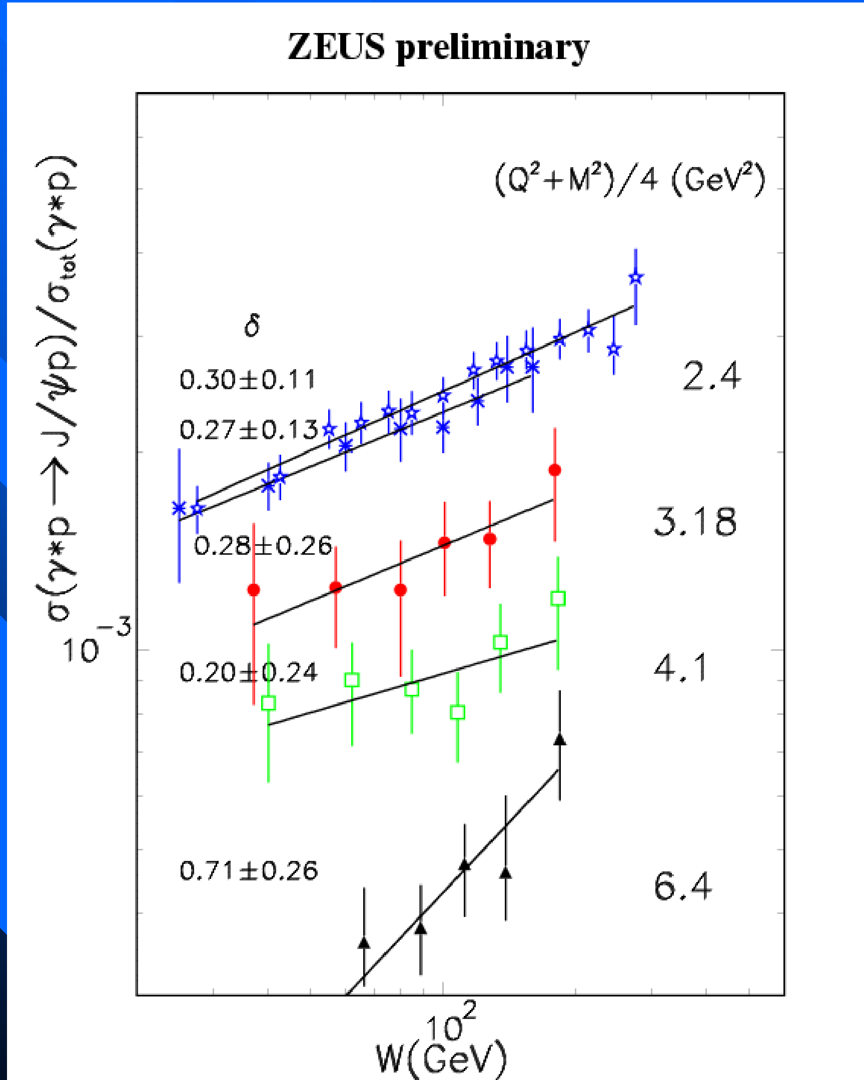
σ_L and σ_T have same W dependence

ρ becomes small with increasing Q^2

J/ψ is small already at $Q^2 = 0$

The ratio σ_V/σ_{tot}



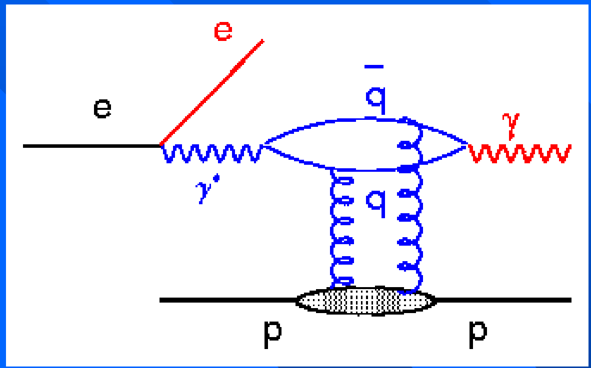


Conclusions on vector mesons

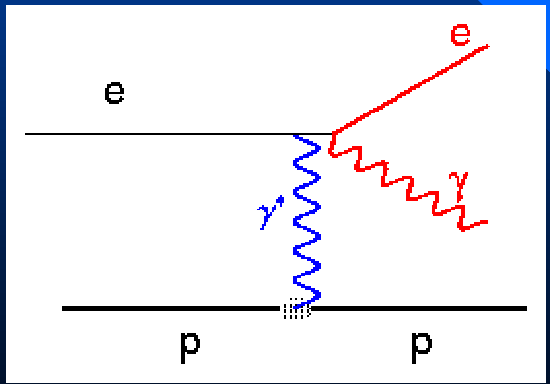
- ρ: shrinks in size with Q^2 – soft to hard transition
- large configuration of σ_T suppressed
- σ_ρ/σ_{tot} flat in W at low Q^2
- J/ψ: small object even at $Q^2=0$
- $\sigma_{J/\psi}/\sigma_{tot}$ increases with W

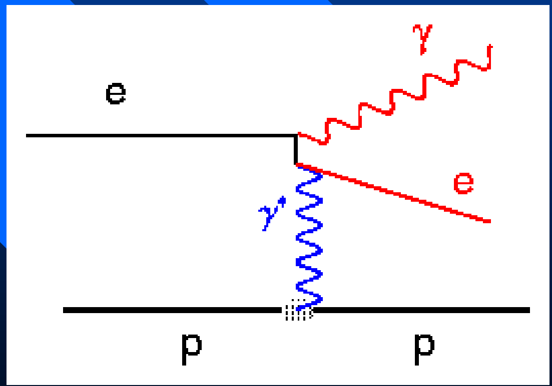
Deep Virtual Compton Scattering

Signal (QCD)→ Generalized Parton Distributions (GPD)



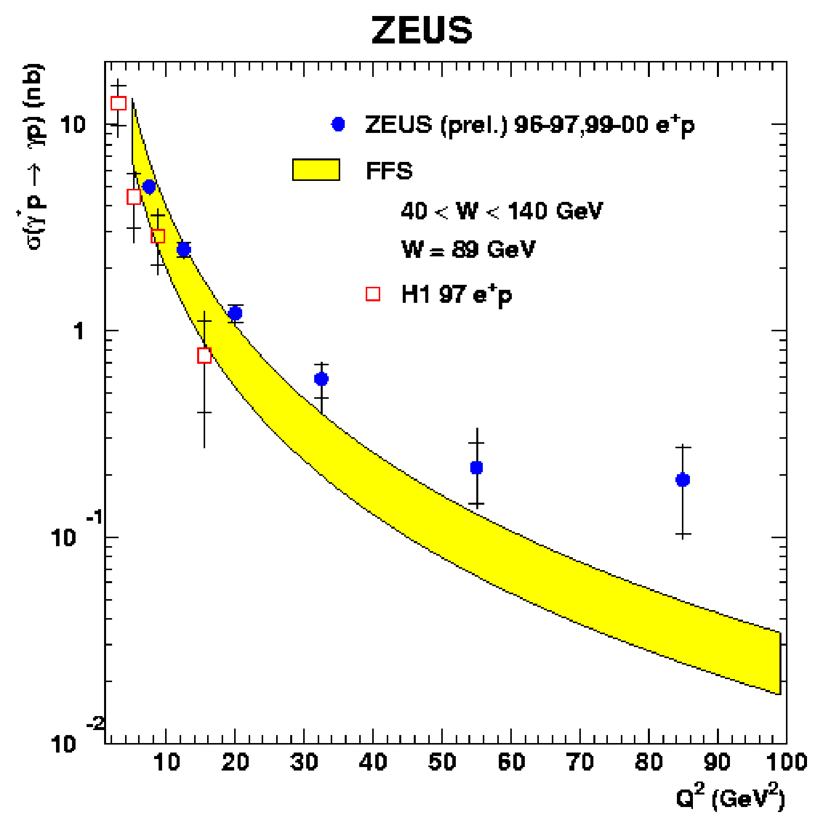
Background (QED) interfers with DVCS, thus sensitive to $Re A_{QCD}$

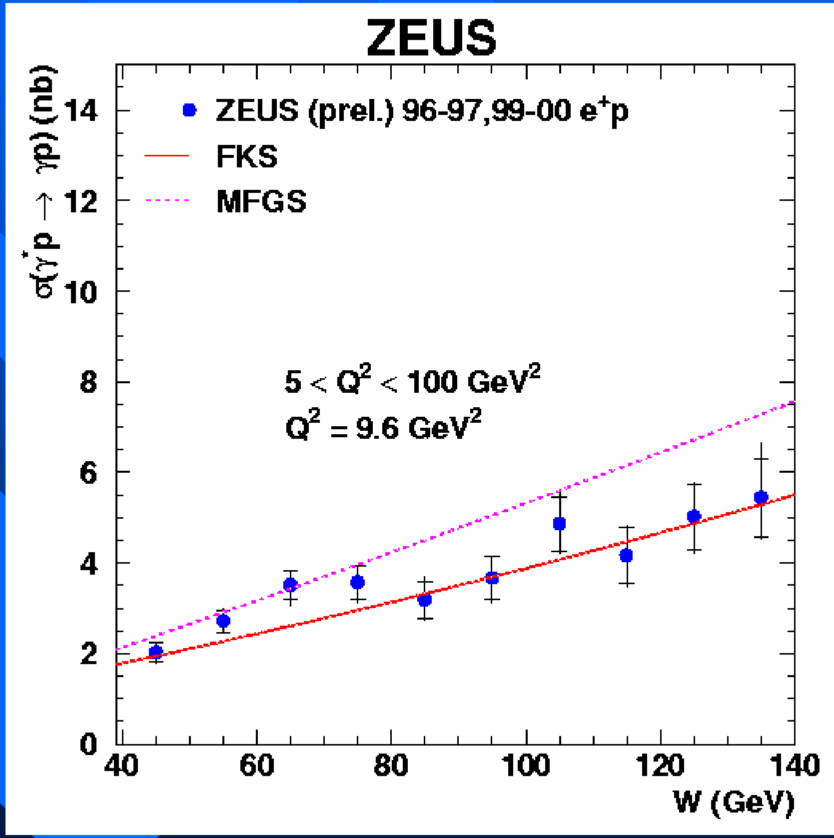




DVCS

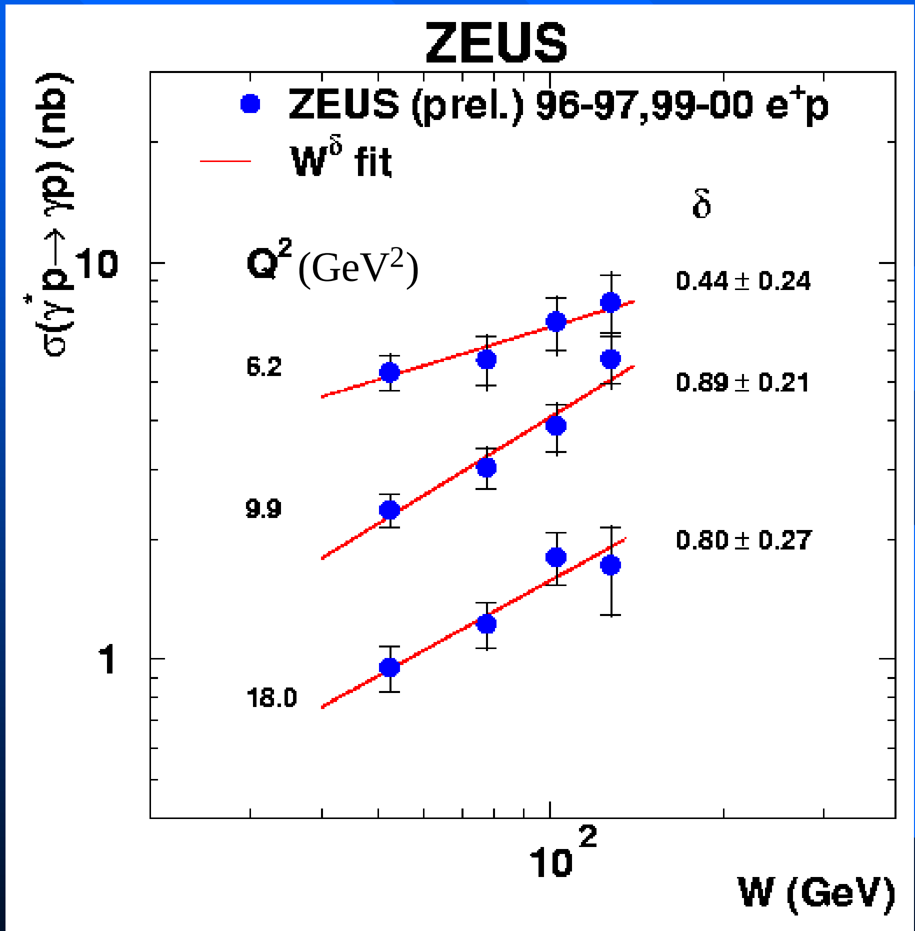
Q^2 and W dependence of σ ($\gamma^*p \longrightarrow \gamma p$)





DVCS

W dependence of $\sigma(\gamma^* p \longrightarrow \gamma p)$ for different Q^2 values



Note: if SCHC holds

γ^* is transversely pol.

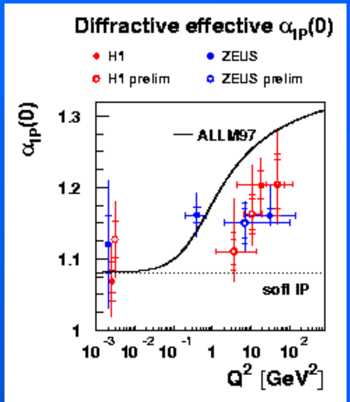
large configurations of σ_T suppressed

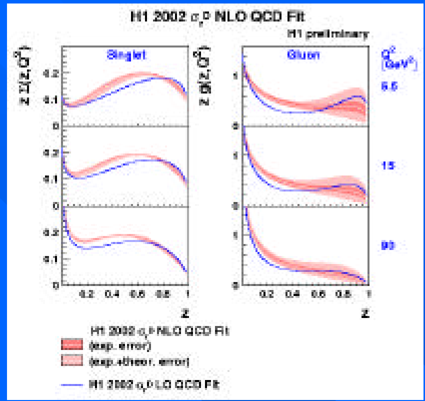
Conclusions of DVCS

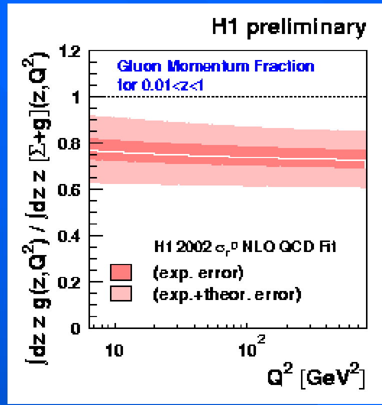
- W dependence of σ_{DVCS} increases with Q^2
- large configurations of σ_T suppressed
- clean process for obtaining GPDs

- to obtain the 3D GPDs – wait for HERA III

Summary of diffraction at HERA

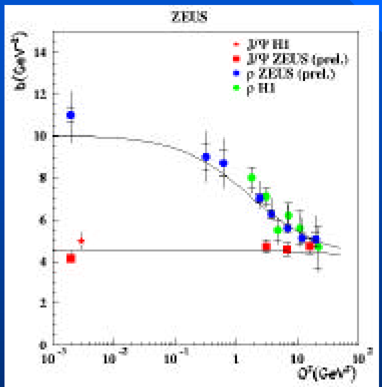


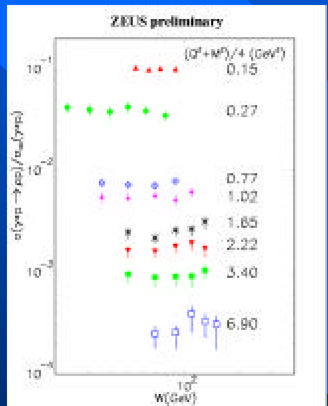


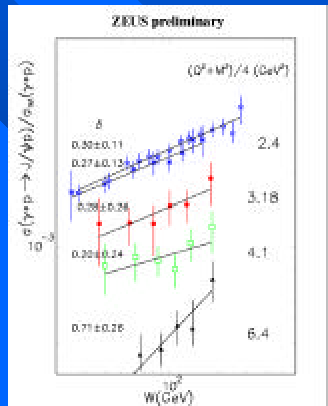


Inclusive

- Dominated by gluons
- Close to the unitarity limit

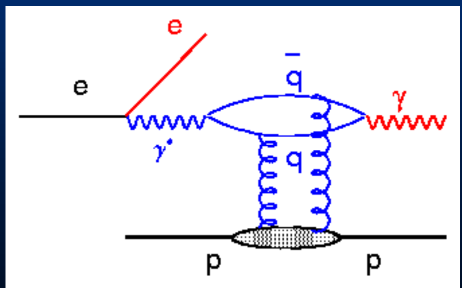


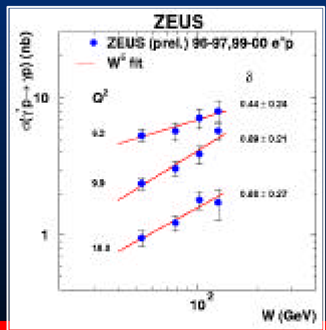




Vector mesons

- ρ size shrinks with Q^2
- large conf. of σ_T suppressed
- σ_V/σ_{tot} flat for ρ, rises for J/ψ





DVCS

- σ gets steeper with Q^2
- large conf. of σ_T suppressed
- good process for GPDs