Vector Meson Production at HERA

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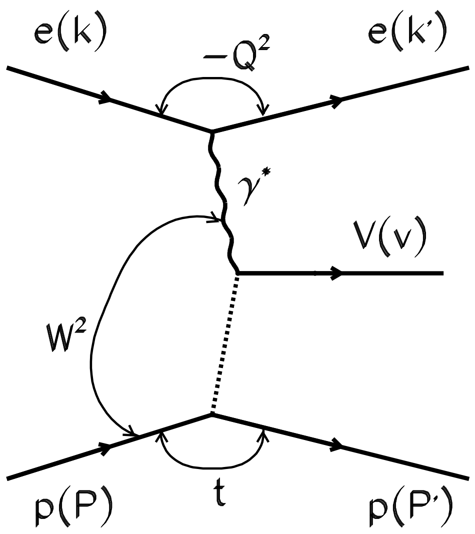
on behalf of ZEUS and H1 collaborations

Introduction
New results on ρ^0 and J/ψ mesons
Look at $\psi(2S)$ meson
Problem of the scale in vector meson production
Photoproduction of vector mesons at large $\mid t \mid$
Summary

XXXVIth Rencontres de Moriond,

QCD and High Energy Hadronic Interactions
Les Arcs, Savoie, France, March 17 - 24, 2001

Diffractive elastic vector meson electroproduction



$V = \rho, \phi, \omega, J/\psi ...$

Energy in $\gamma^* p$ CMS: $20 < W < 290\ GeV$

Virtuality of the photon: $Q^2 < 100\ GeV^2$

Square of the 4-momentum transfer: $|t| < 13\ GeV^2$

At HERA we control all these variables!

VDM: $\gamma^* p \to Vp = (\gamma^* \to V) \otimes (Vp \to Vp)$

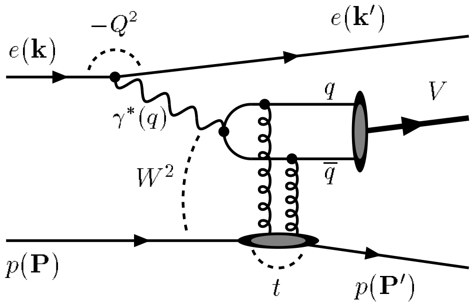
Diffractive elastic vector meson electroproduction

$Vp \to Vp$ = soft interaction $\Longrightarrow$ Pomeron exchange,

$\alpha_P(t) = \alpha_0 + \alpha' t$ = 1.08 + 0.25 t (Donnachie-Landshoff)

- $\frac{d\sigma}{dt} \sim (W^2)^{2(\alpha(t)-1)}$
- $\sigma_{Vp} \sim W^\delta, \quad \delta \simeq 0.2 \ \Rightarrow$ weak energy dependence
- S Channel Helicity Conservation

BUT: "large" Q^2 or M_V ($|t|$?) = "small" VM, hard interaction $\Rightarrow$ pQCD applicable ("Pomeron" = color singlet system of gluons):

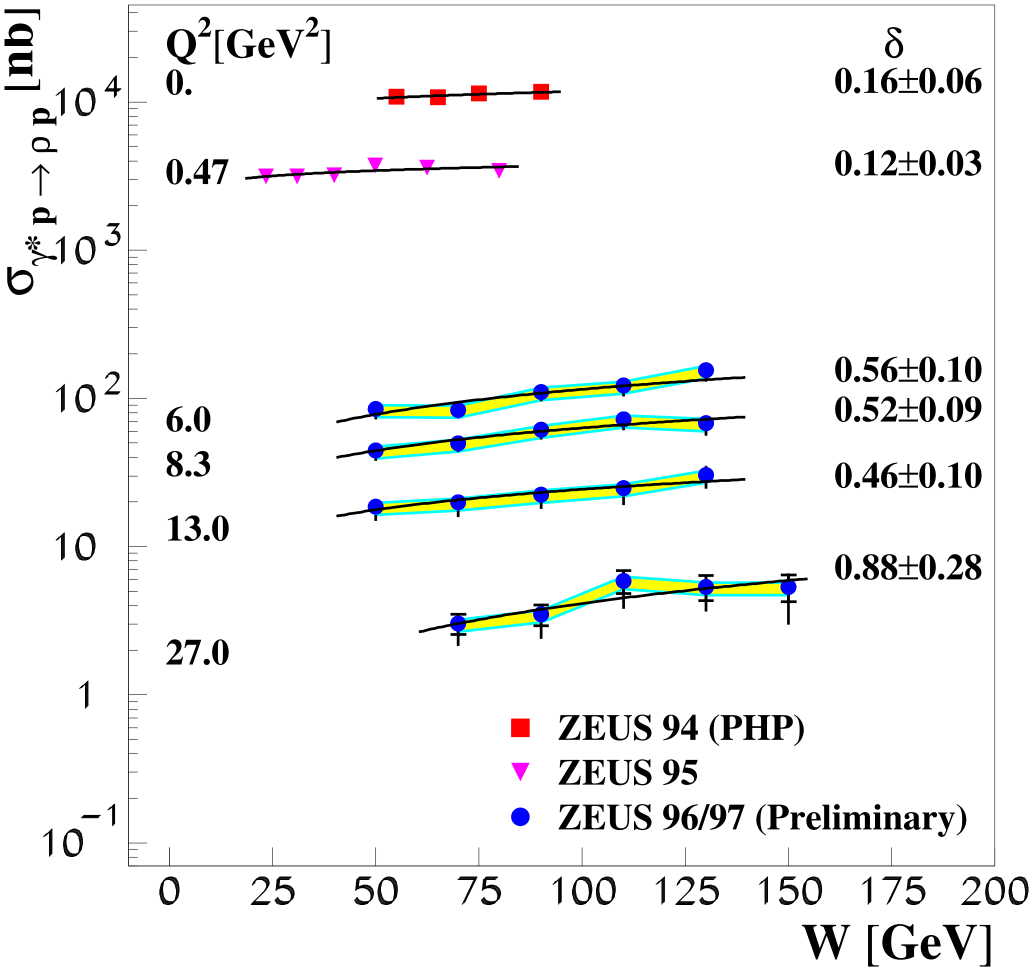


- Steeper rise of σ_V with W , ($\Longleftrightarrow$ rising gluon density in proton at large Q^2 and small x)
- possible SCHC violation...

TRANSITION between soft and hard regime - test ground of QCD!

Diffractive elastic ρ electroproduction

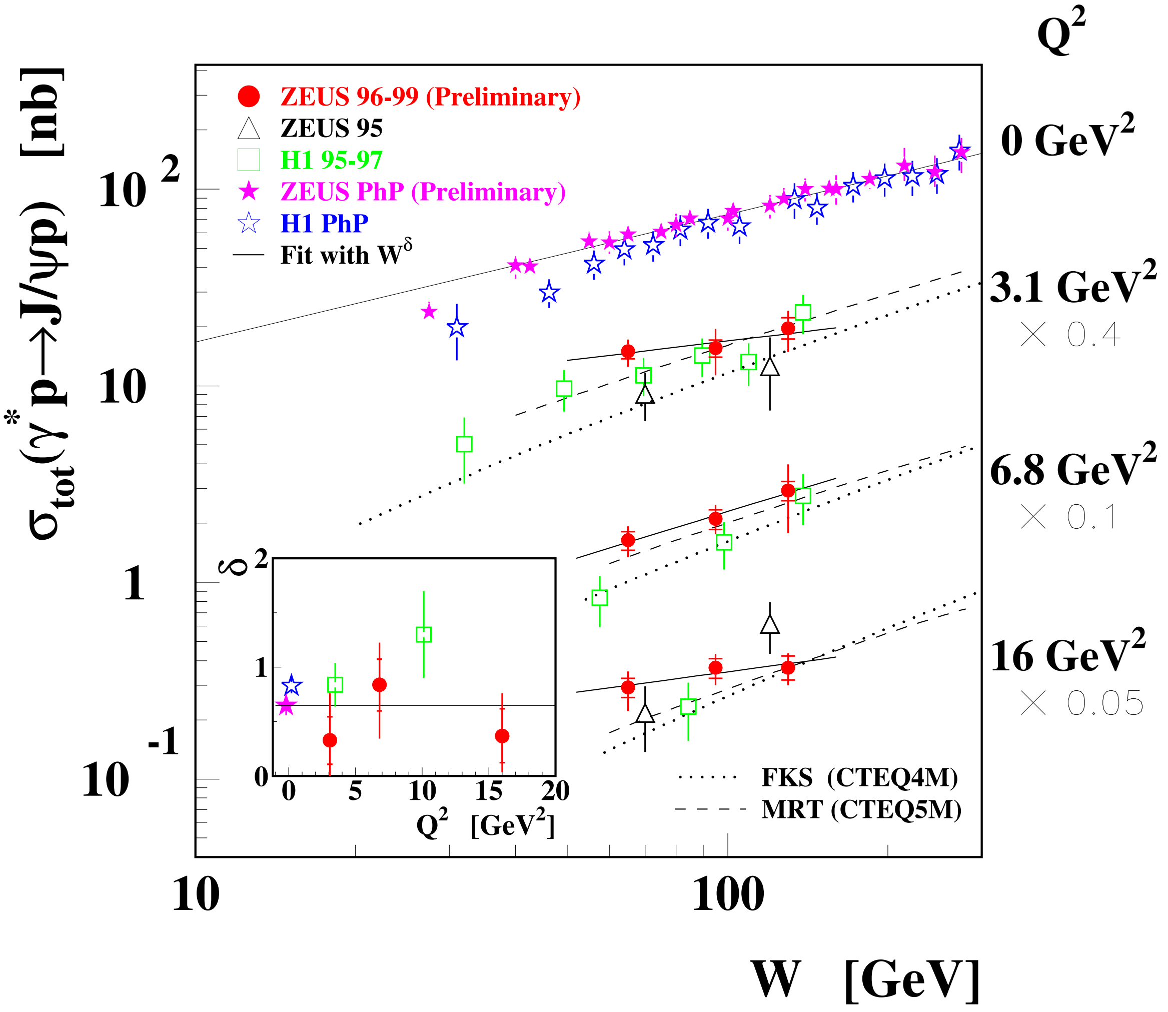
Cross section $\sim W^{\delta}$ in Q^2 intervals



- $Q^2 \simeq 0$: $\delta \simeq 0.2$, weak W dependence - soft regime
- "Large" Q^2 is hard scale : "large" δ - steeper W dependence, as expected from color singlet exchange!

Diffractive elastic J/ψ electroproduction

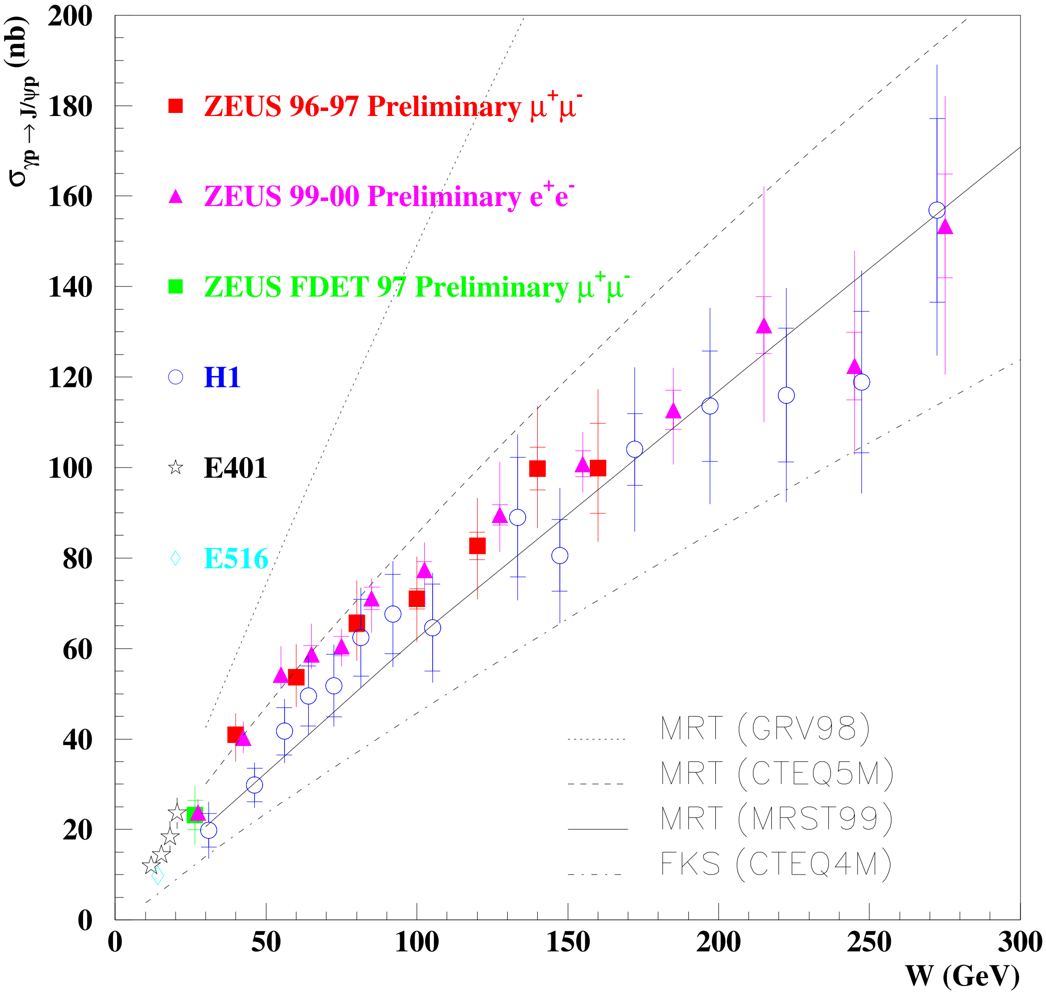
Cross section $\sim W^\delta$ in Q^2 intervals



- steep rise of cross section with W ($\delta \simeq 0.65$) does not depend on Q^2, "large" M_ψ^2 is sufficient hard scale
- pQCD models using gluon densities are $\sim$OK

Diffractive elastic J/ψ photoproduction

Cross section in function of W

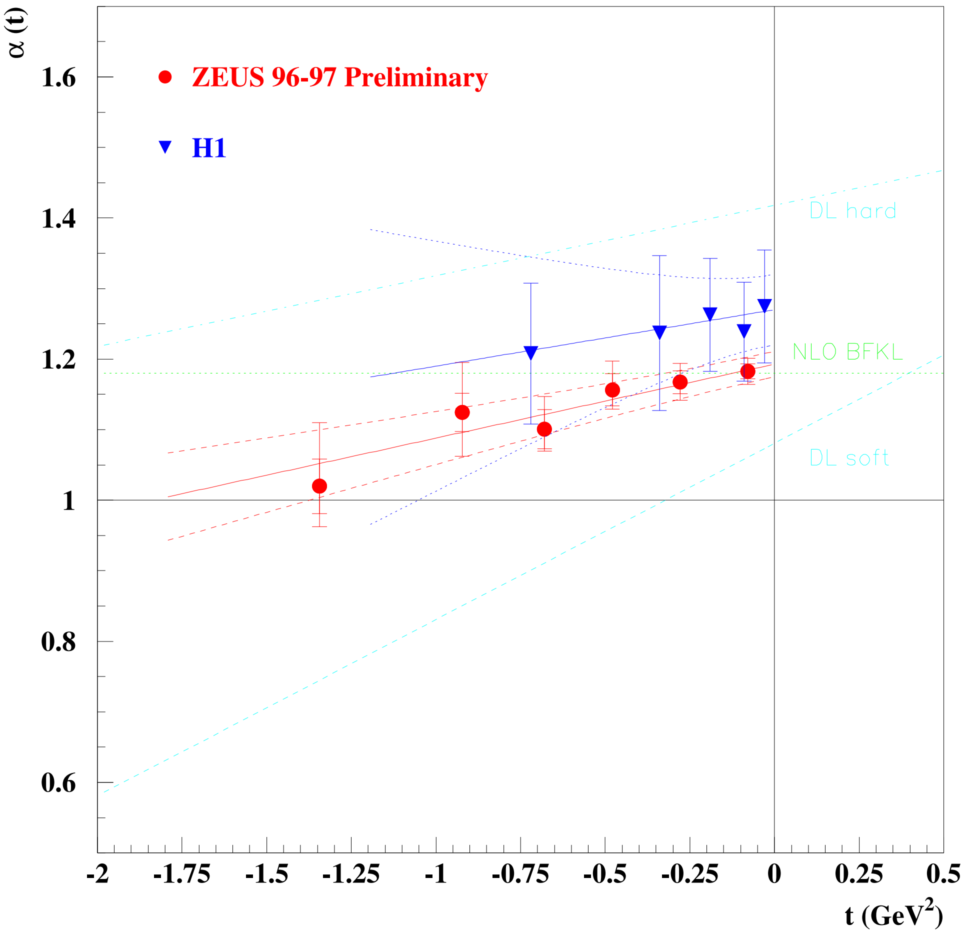


- steep rise of cross section with W: at $Q^2 = 0$ "large" M_ψ^2 is sufficient hard scale
- pQCD model with right gluon density reproduces the W- dependence

Diffractive elastic J/ψ photoproduction

The simultaneous measurement of W and t dependence

$\frac{d\sigma}{dt} \sim (W^2)^{(2\alpha(t)-2)}$ $\Rightarrow$ determination of the "Pomeron" trajectory:



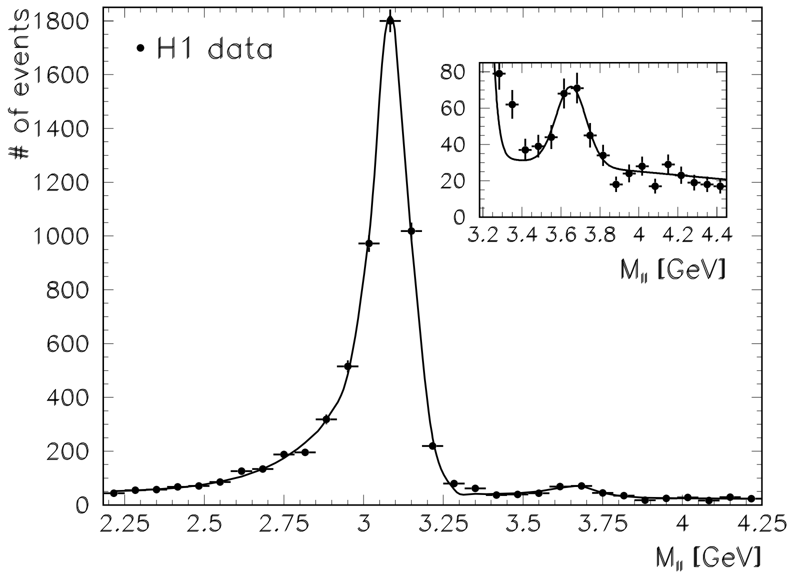
- H1: $\alpha(t) = (1.27 \pm 0.05) + (0.08 \pm 0.17)t$,

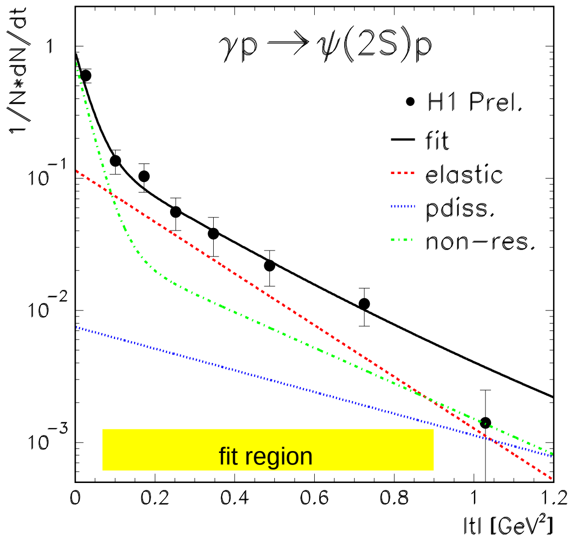
  ZEUS : $\alpha(t) = (1.193 \pm 0.011^{+0.015}_{-0.010}) + (0.105 \pm 0.024^{+0.022}_{-0.020})t$

- model with pQCD "Pomeron" describes the data

Diffractive elastic $\psi(2S)$ photoproduction

The $c\bar{c}$ radial excitation + pQCD $\Rightarrow$ $b_{\psi(2S)} \leq b_{\psi}$





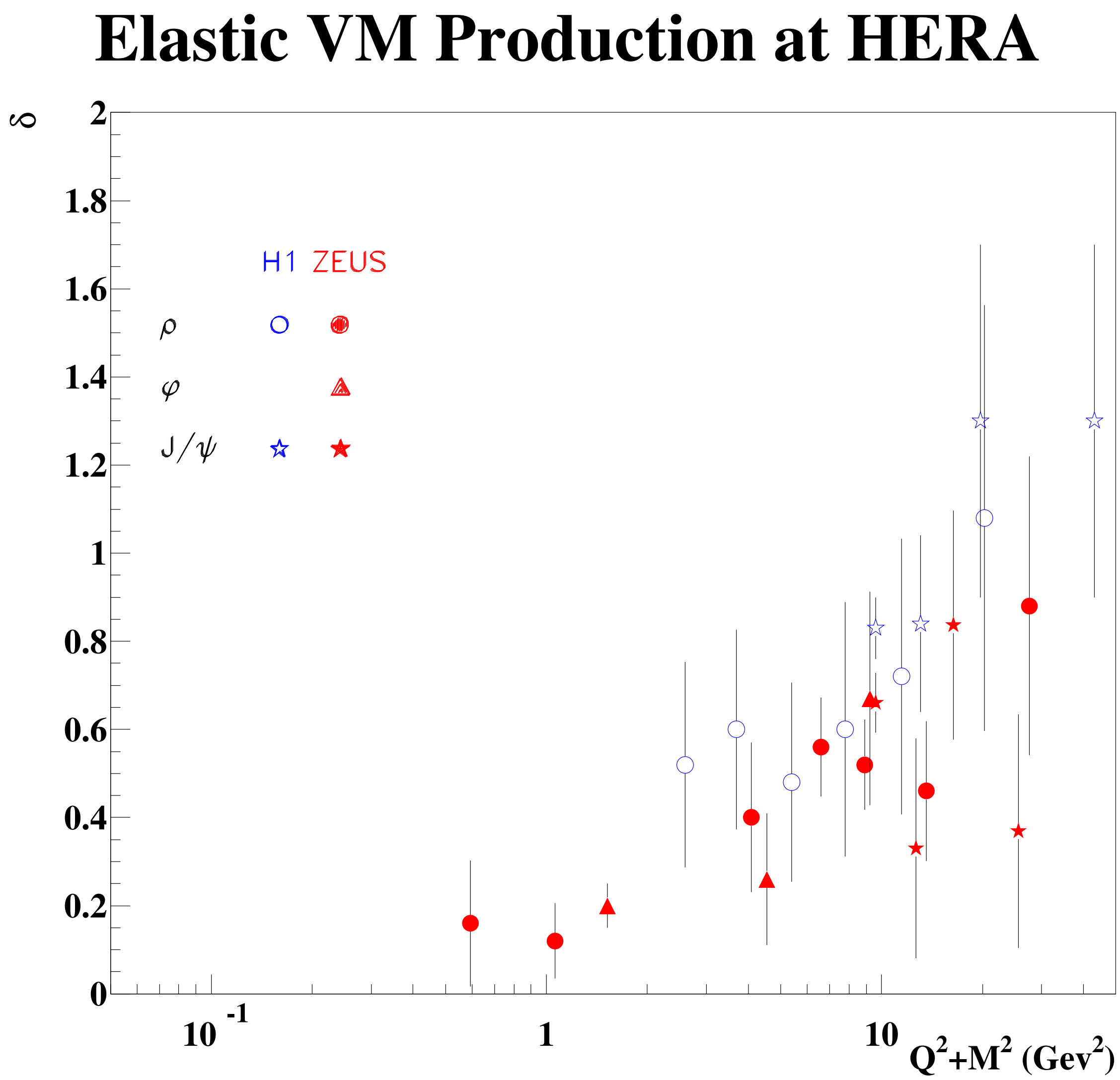
$$\psi(2S) \rightarrow \mu^+\mu^-, e^+e^-$$

$$40 < W < 150\ GeV$$

H1: $b_{\psi(2S)} = (4.5 \pm 1.2^{+1.4}_{-0.7}) GeV^{-2}$, $b_{\psi} = (4.73 \pm 0.25^{+0.30}_{-0.39}) GeV^{-2}$

Problem of the scale in vector meson production

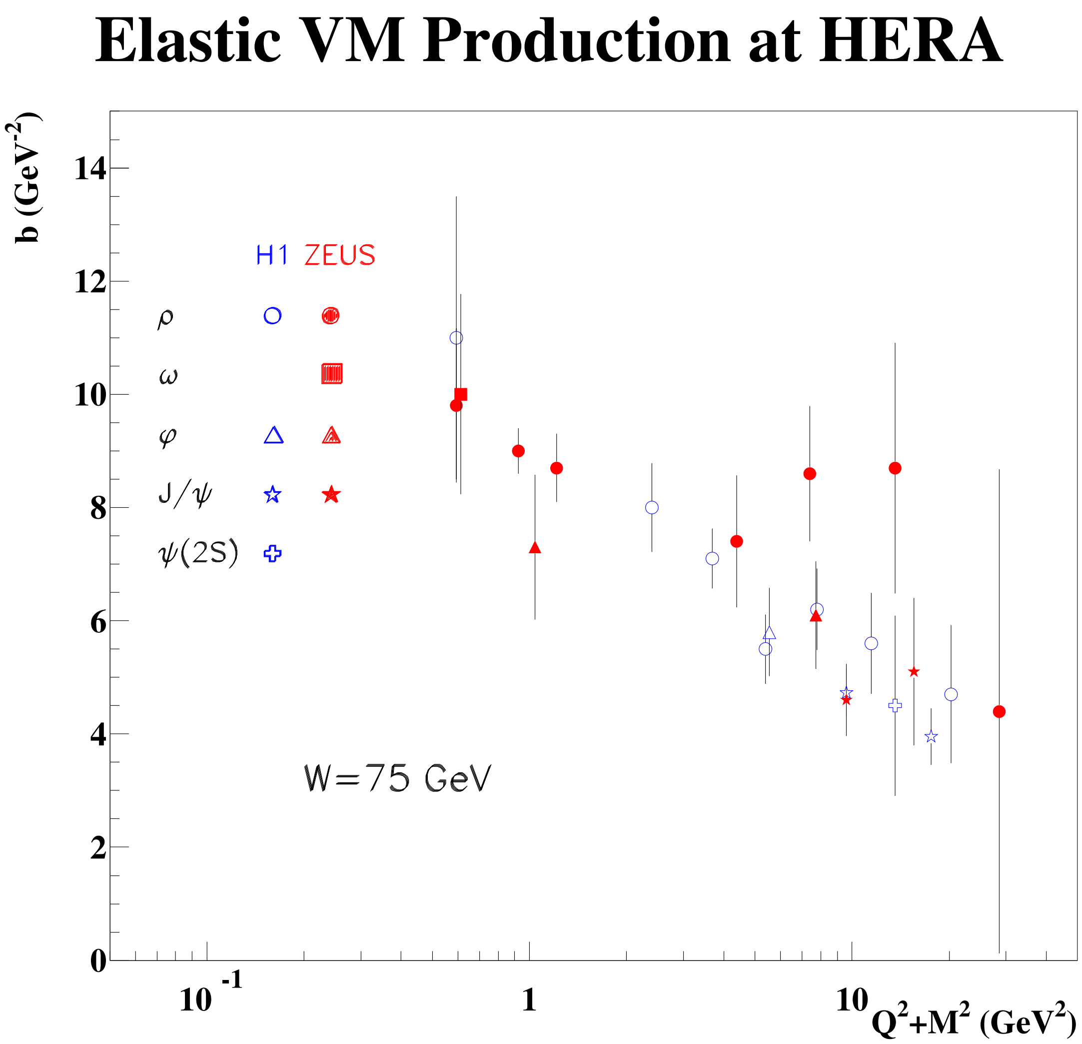
Power δ $\quad (\sigma_{Vp} \sim W^{\delta})$ vs $\;Q^2 + M^2$



- $\sim$ “universal” δ dependence on $\;Q^2 + M^2$
- the harder interaction - the steeper W - dependence

Problem of the scale in vector meson production

Slope b of the differential cross section ($\frac{d\sigma}{dt} \sim e^{-bt}$) $\sim$ radius of the interaction.



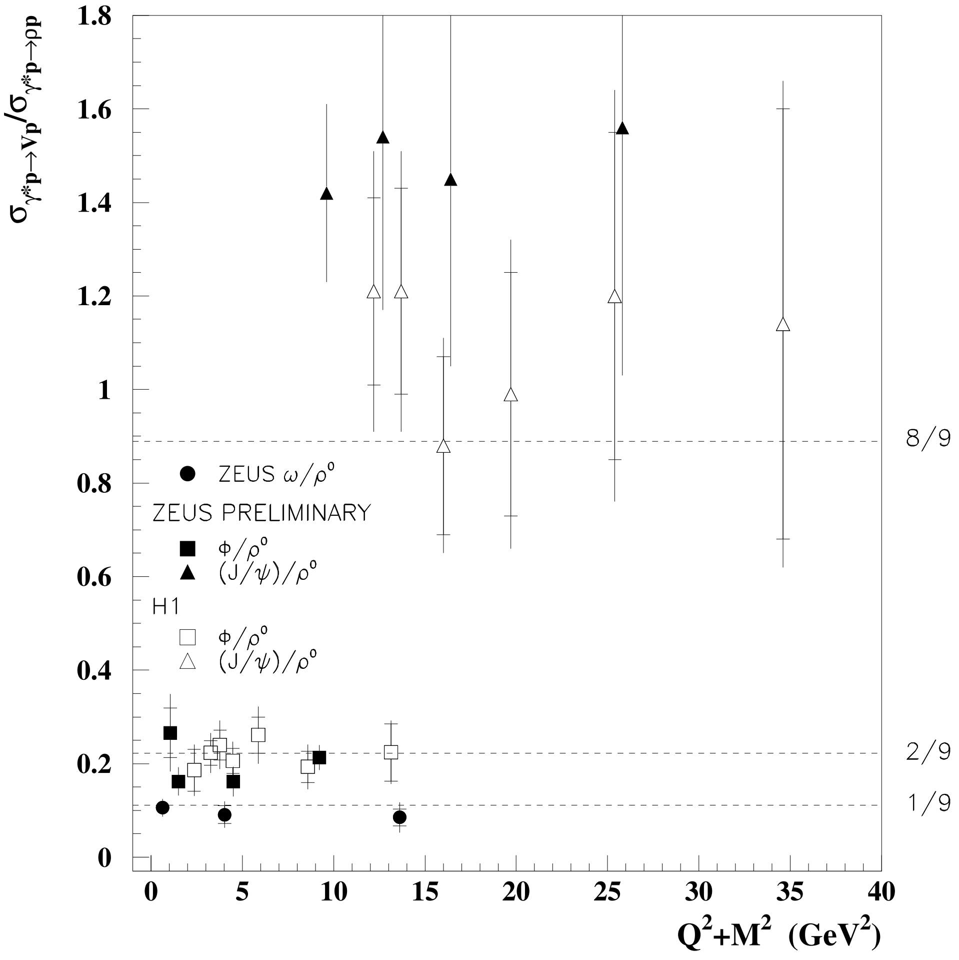
- The larger $Q^2 + M^2$ ("harder" interaction) the smaller its size

Problem of the scale in vector meson production

VM quark composition + flavour independence: cross section ratios

$\omega : \phi : J/\psi : \rho \;=\; 1:2:8:9$ - in function of $Q^2 + M^2$

Elastic VM production at HERA

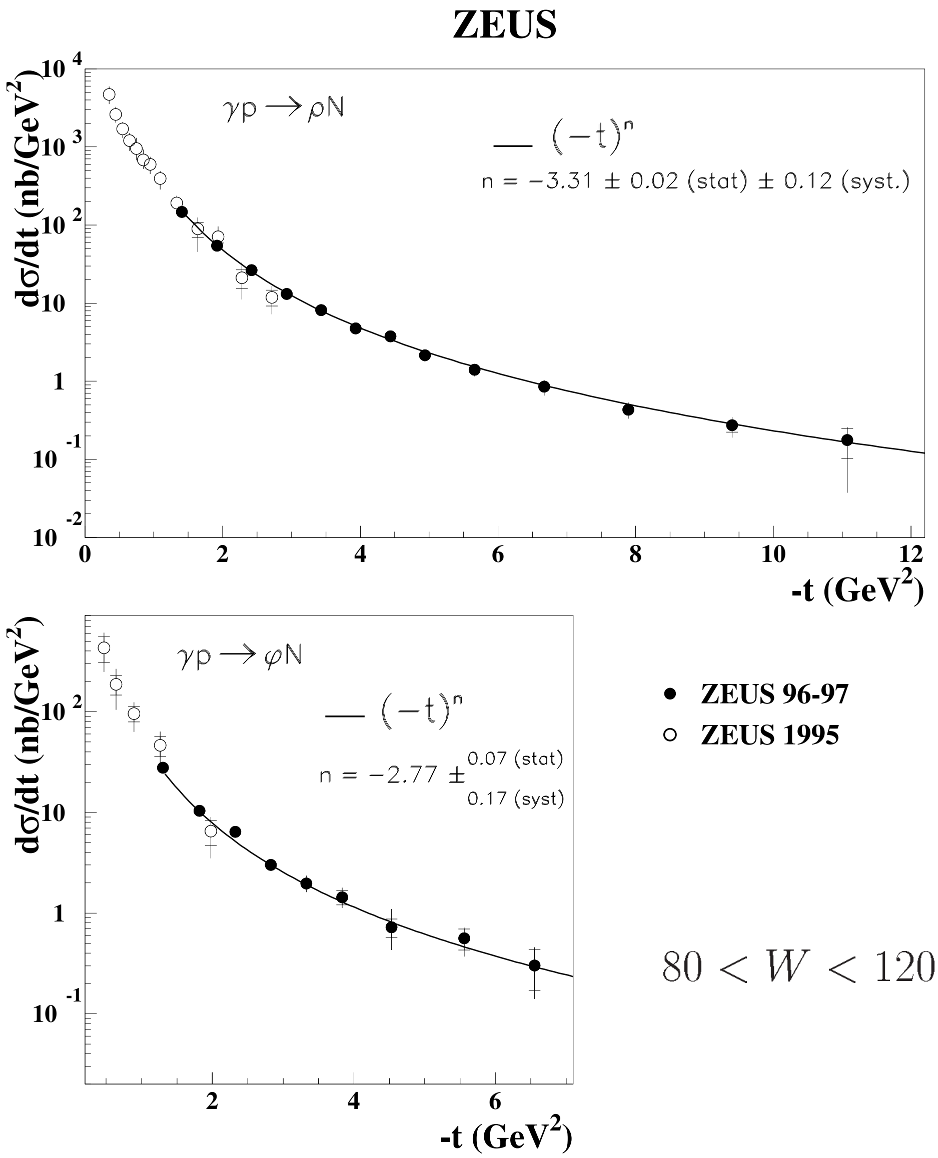


- Ratios are constant $\Rightarrow$ Q^2+M^2 seems to be convenient scale...
- What about $|\, t \,|$?

Diffractive vector meson photoproduction at large $\mid t \mid$

Does large $\mid t \mid$ provide a hard scale and justify pQCD application?

Cross section $\frac{d\sigma}{dt}(\gamma p \to VN)$

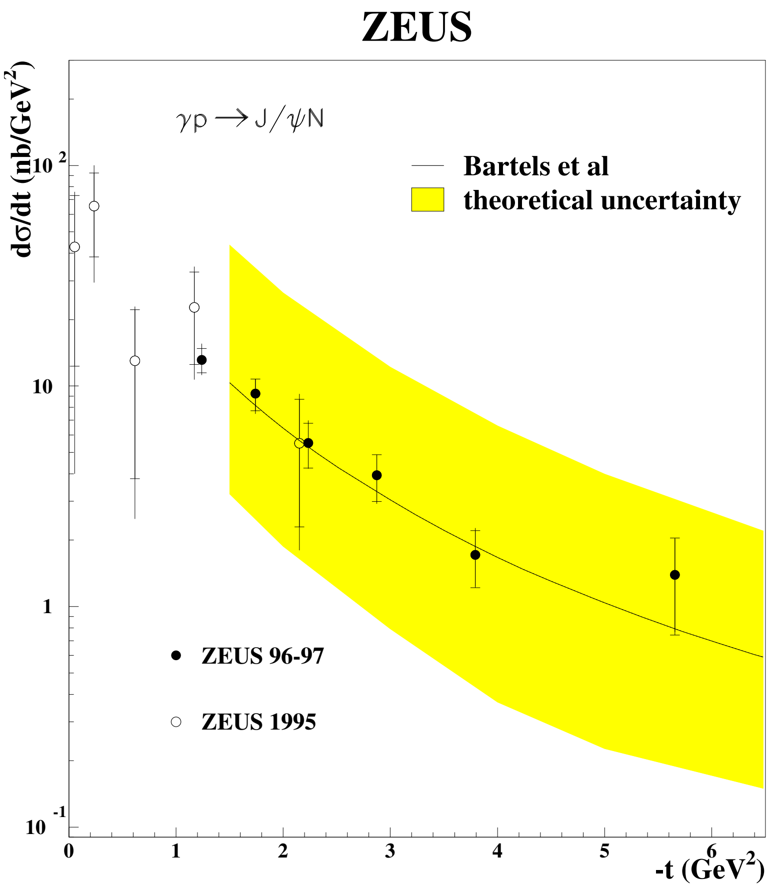


$80 < W < 120\ GeV$

- VM photoproduction at large $\mid t \mid$ is proton-dissociative!
- $\frac{d\sigma}{dt} \sim (-t)^n$ - consistent with pQCD expectation

Diffractive vector meson photoproduction at large $| t |$

Cross section $\frac{d\sigma}{dt}(\gamma p \to J/\psi N)$



- The heavier VM the smaller power $|n|$ $\left(\frac{d\sigma}{dt} \sim (-t)^n\right)$:

$$\rho : \quad n = -3.31 \pm 0.02(stat.) \pm 0.12(syst.)$$

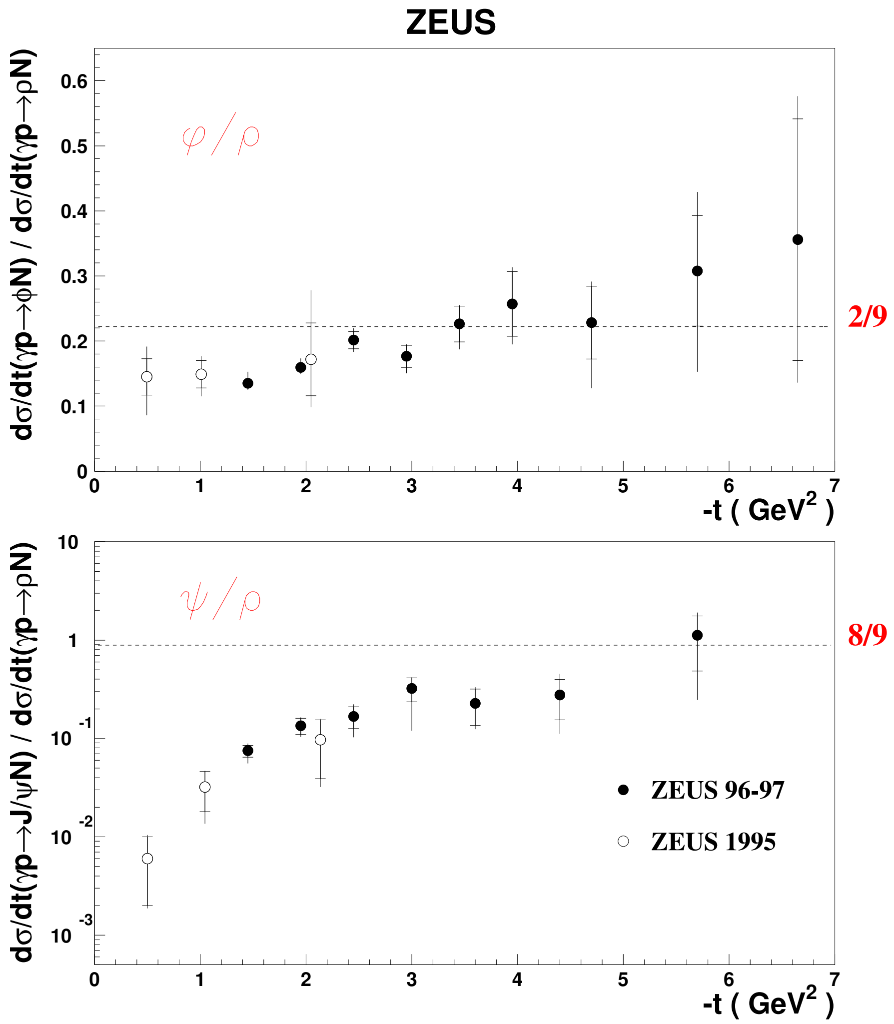
$$\phi : \quad n = -2.77 \pm 0.07(stat.) \pm 0.17(syst.)$$

$$J/\psi : \quad n = -1.7 \pm 0.2(stat.) \pm 0.2(syst.)$$

- Model with pQCD "Pomeron" coupling to single parton in the proton describes the J/ψ data!

Diffractive vector meson photoproduction at large $\mid t \mid$

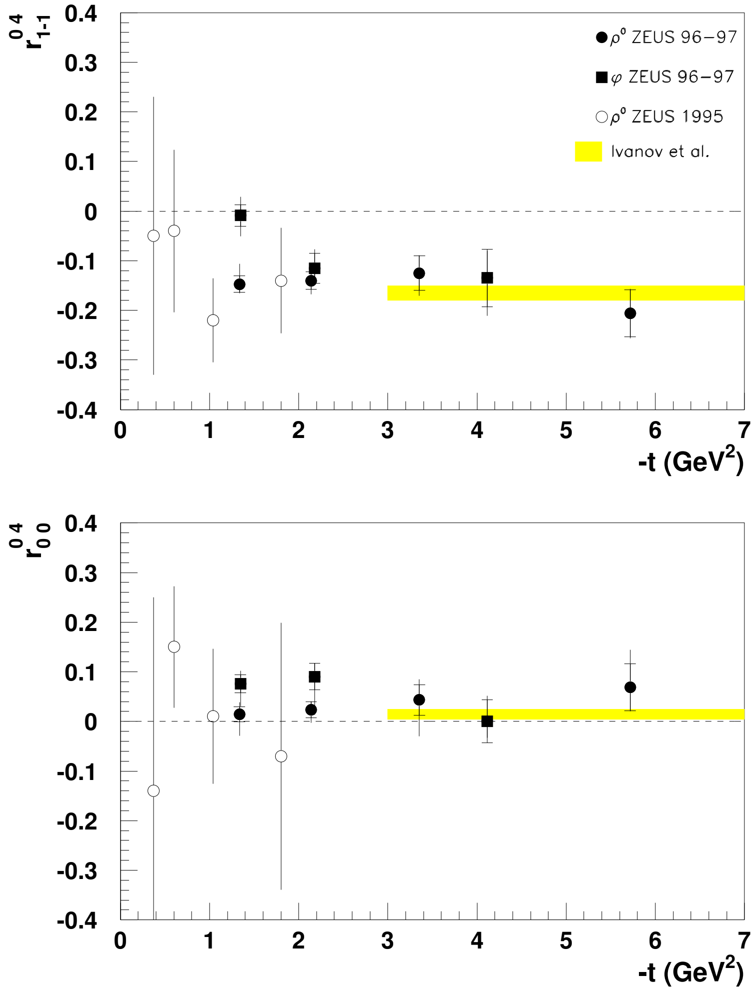
Cross section ratios



- with increasing $\mid t \mid$ both ratios aproach "asymptotic" limits but ψ/ρ much slower then ϕ/ρ...
- $\mid t \mid$ is hard scale ...?

Diffractive vector meson photoproduction at large $| t |$

VM decay products angular distributions $\Rightarrow$ spin density matrix elements r^{04}_{00} $\sim$ single helicity flip contribution and r^{04}_{1-1} $\sim$ double helicity flip contribution. If SCHC holds - they should be zero !



- Non zero double helicity flip contribution $\Rightarrow$ SCHC violation, as predicted by pQCD based model...

SUMMARY

- The statistics and quality of the data enable multi-variable analysis
- Production of heavy VM shows expected features of a short distance (hard) process (M_V^2 being the hard scale)
- For light VM the virtuality of γ^* controls the transition between soft ($Q^2 \simeq 0$) and hard ("large" Q^2) limits of strong interaction
- Evidence that also $\mid t \mid$ provides hard scale
- At HERA one can control all these variables simultaneously
- Production of vector mesons: non-perturbative - perturbative QCD playground...