

Diffractive VM Production at HERA

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On behalf of the H1 and ZEUS Collaborations

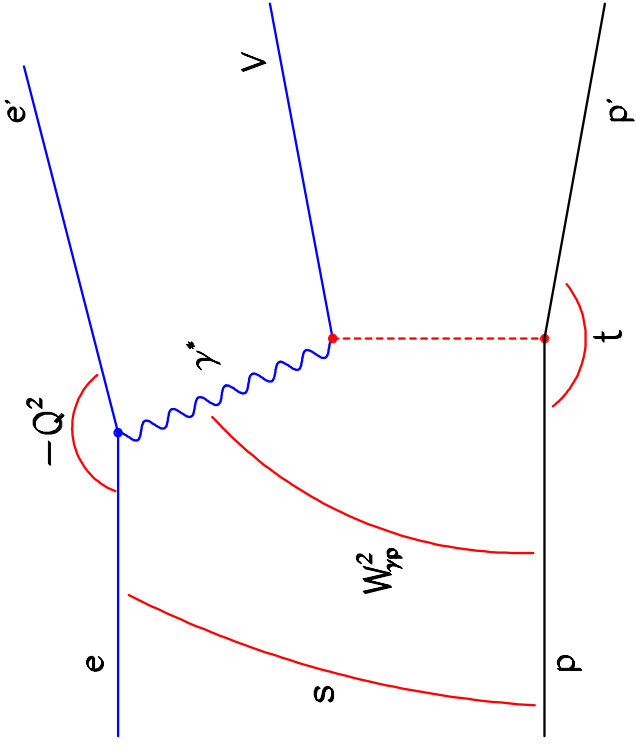
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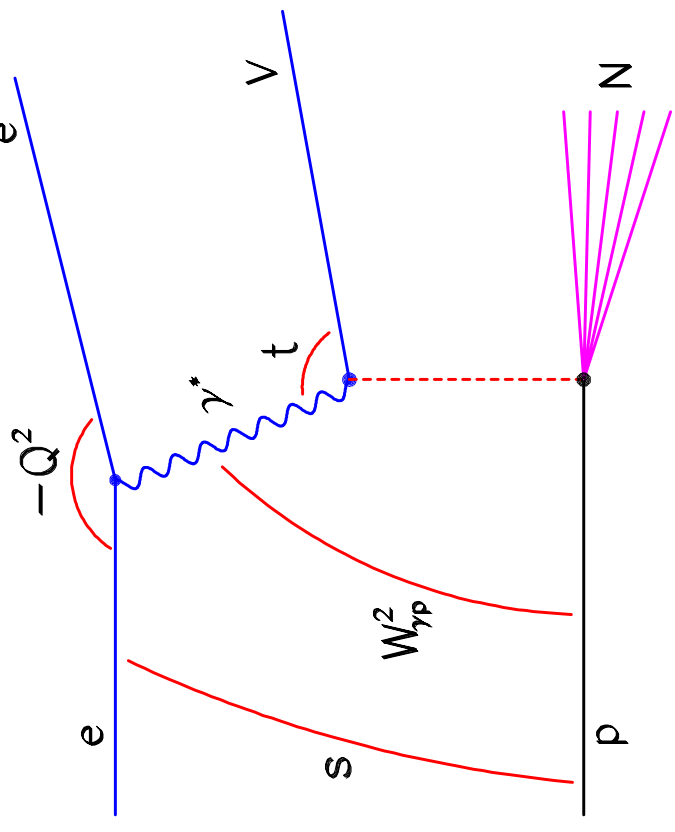


- Introduction.
- New Physics Results.
 - Electroproduction of Rho
 - Photoproduction of J/Psi and Psi'
 - Electroproduction of J/Psi
 - Photoproduction of VM at high $|t|$
- Considerations on the scale of the interaction in VM production.
- Conclusions.

Elastic VM (dominates at $|t| < 1 \text{ GeV}^2$)



VM with Proton Dissociation ($|t| > 1 \text{ GeV}^2$)



$$s = (p + e)^2 = 4E_e E_p$$

$$W_{\gamma p}^2 = (p + q)^2$$

$$Q^2 = -q^2 = -(e - e')^2$$

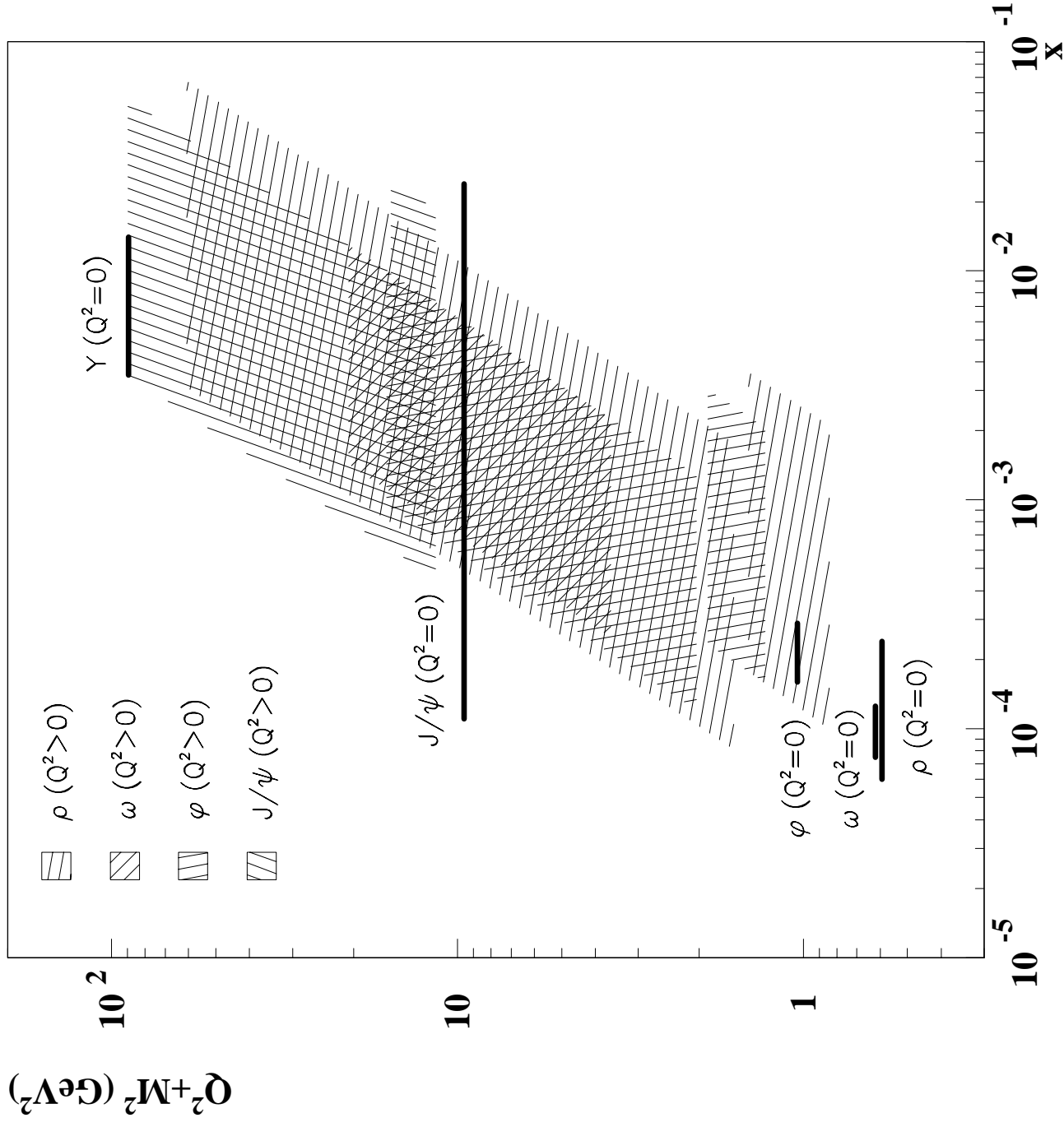
$$t = (p - p')^2$$

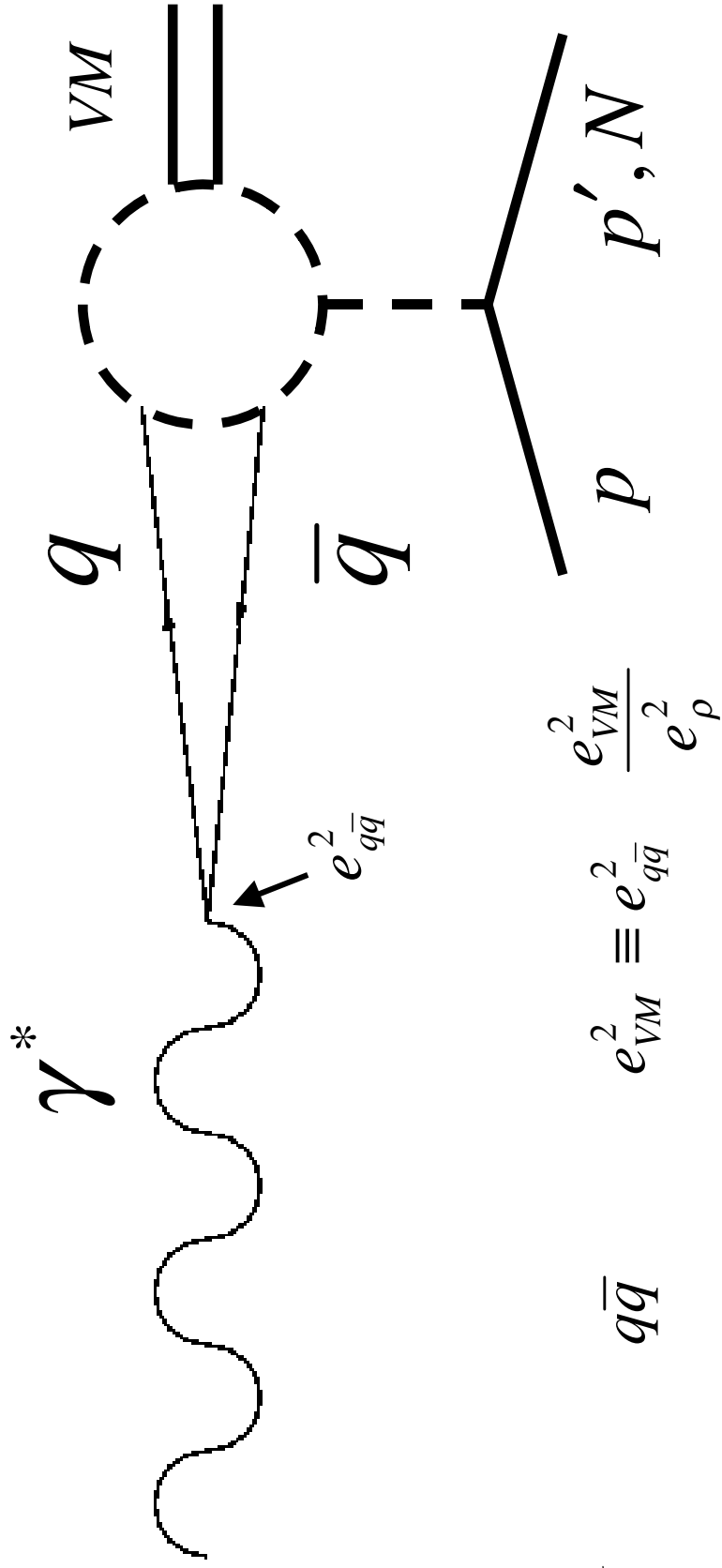
$$x = \frac{Q^2 + M_V^2}{W_{\gamma p}^2}$$

Measure Rho, Phi, J/Psi in
Photoproduction with $|t| < 12 \text{ GeV}^2$

- What is the scale of the interaction?
- Is $|t|$ providing scale on the same footing as Q^2 in M^2 ?
- Observe the interplay between soft and hard physics

Elastic VM Production at HERA

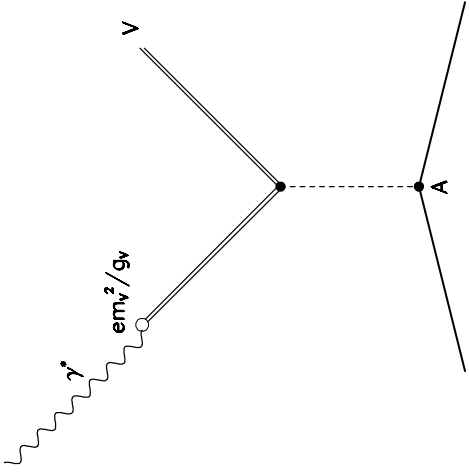




How does the interaction change the SU(4) ratios?

VM	$q\bar{q}$	$e^2_{VM} \equiv e^2_{q\bar{q}}$	$\frac{e^2_{VM}}{e^2_p}$
ρ	$\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d})$	1/2	1
ω	$\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})$	1/18	1/9
ϕ	$s\bar{s}$	1/9	2/9
J/ψ	$c\bar{c}$	4/9	8/9
Y	$b\bar{b}$	1/9	2/9

Non-Perturbative approach



Regge Theory + Vector Dominance

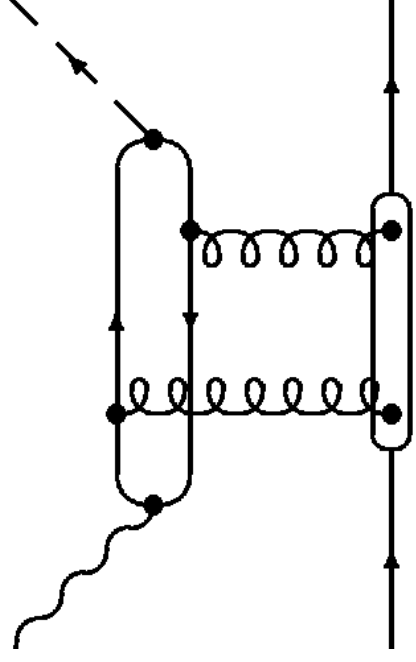
- Exchange of *soft P* trajectory:

$$\alpha_p(t) = \alpha_p(0) + \alpha'_p t = 1.08 + 0.25t$$
- Shallow rise of the cross section with W:

$$\sigma(W) \propto W^{0.22}$$
- Q^2 Dependence:

$$\sigma(Q^2) \propto \frac{1}{(Q^2 + M^2)^2} \quad R = \frac{\sigma_L}{\sigma_T} \propto \frac{Q^2}{M^2}$$
- Steep dependence of cross section with $|t|$ and strong shrinkage

Perturbative approach



At enough big Q^2 , M^2 or $|t|$ p. QCD is applicable

- Colorless exchange as gluon ladders
- Steep increase of cross section with W

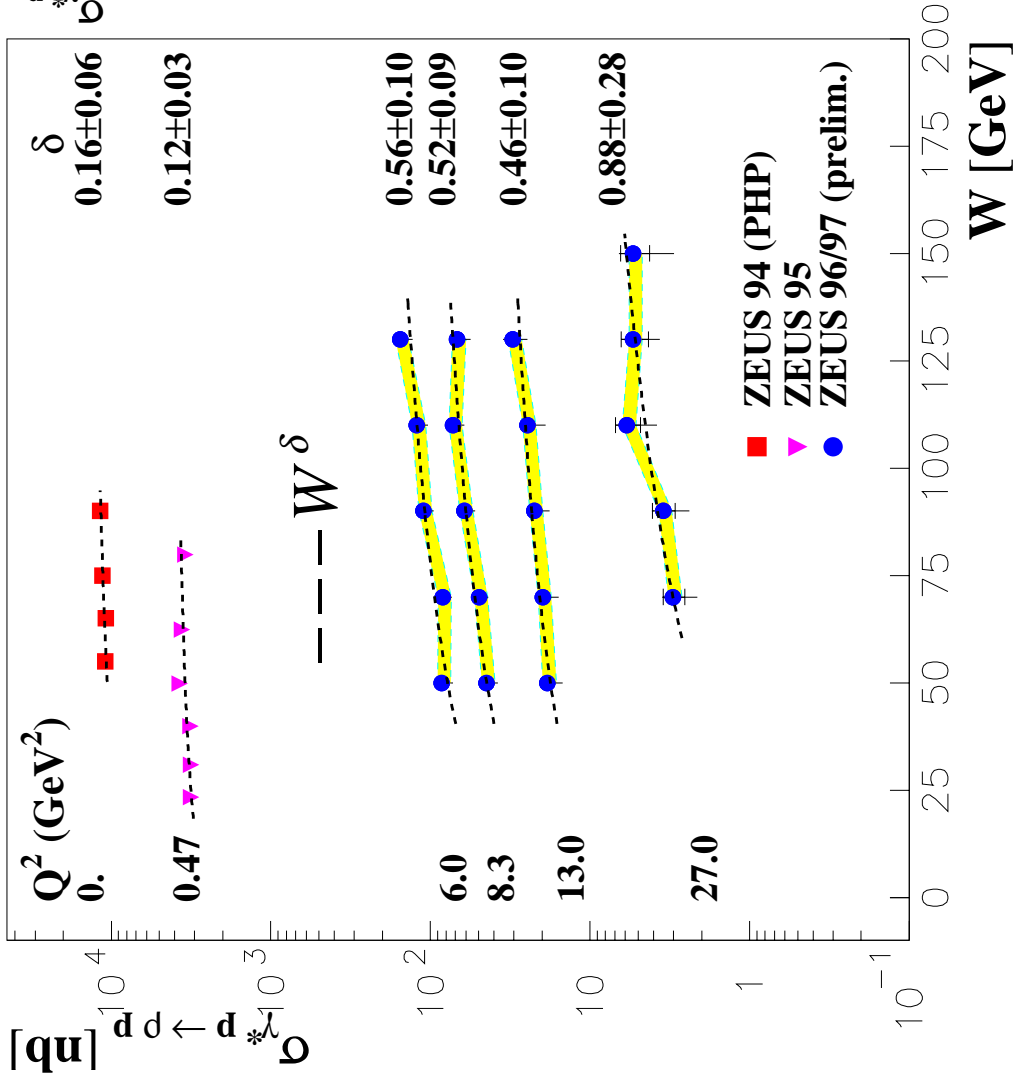
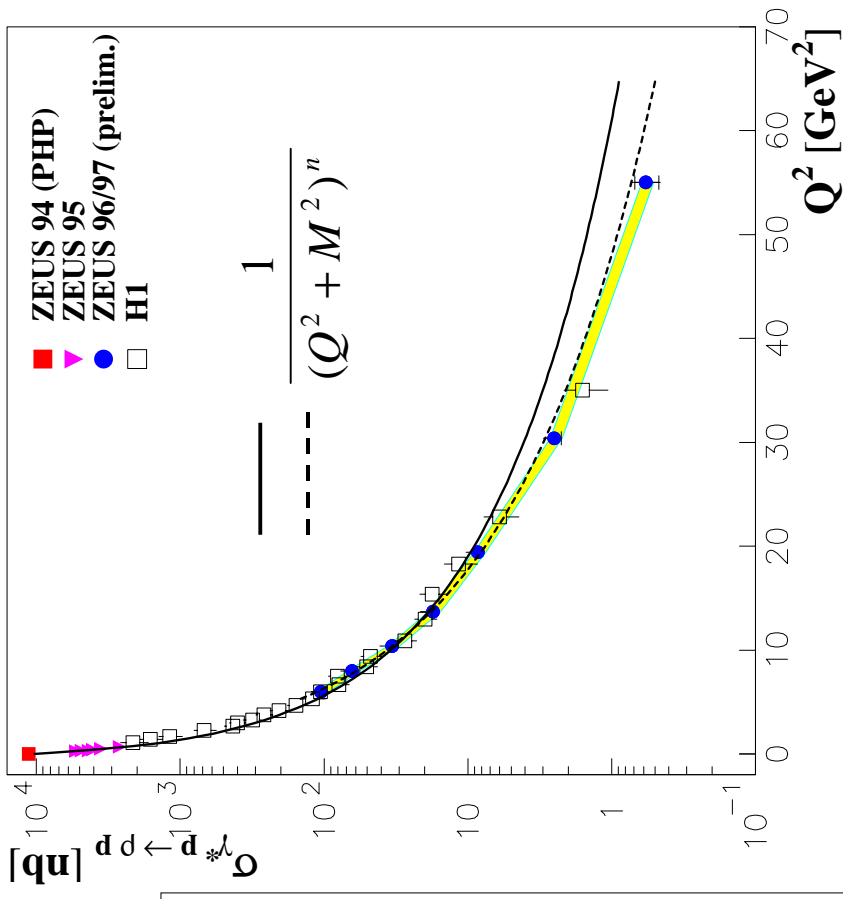
$$\sigma(W) \propto [\alpha_s(\bar{q}^2) x g(x, \bar{q}^2)]^2 \quad \bar{q}^2 = \frac{Q^2 + M^2}{4} \quad x = \frac{Q^2 + M^2}{W^2}$$
- Weaker dependence of cross section with $|t|$ and no shrinkage
- Expect:

$$R = \frac{\sigma_L}{\sigma_T} \uparrow W, Q^2$$

Electroproduction of Rho

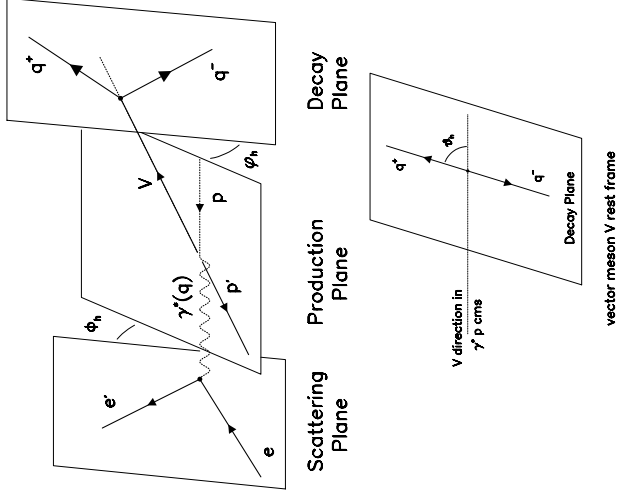
(Abstract #880, ZEUS Preliminary)

- 37 pb^{-1} of data taken in 96-97
- $5 < Q^2 < 50 \text{ GeV}^2$
- $32 < W < 160 \text{ GeV}$
- 7500 events



- Steepness of rise of the cross section with W grows with Q^2
- $1/(Q^2+M^2)^n$ does not fit all Q^2 range

γp center of mass system



SCHC breaking is small

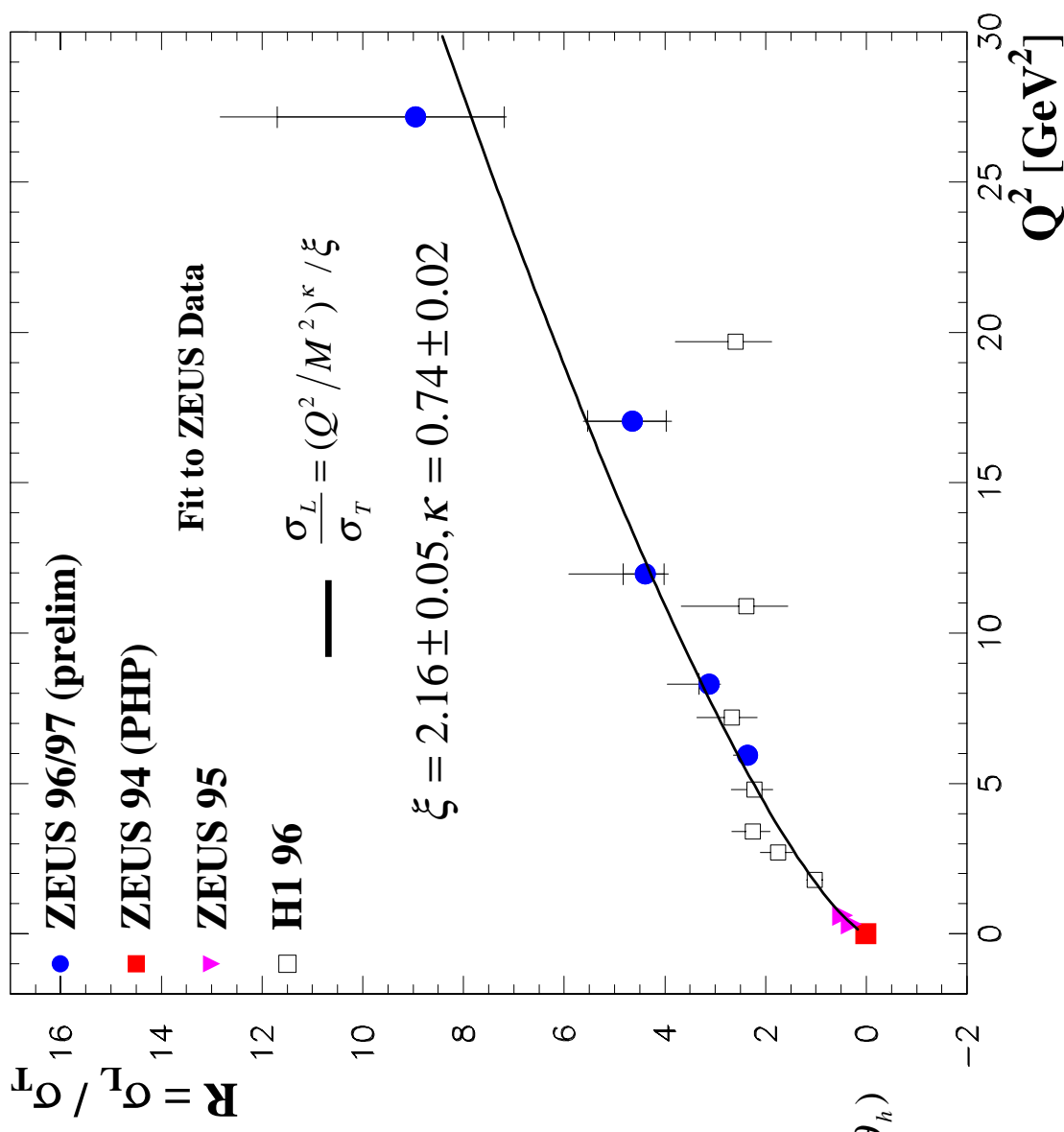
$$r_{00}^{04} \gg \Delta \approx 0.08$$

$$R = \frac{1}{\epsilon} \frac{r_{00}^{04} - \Delta^2}{1 - (r_{00}^{04} - \Delta^2)} \approx \frac{r_{00}^{04}}{1 - r_{00}^{04}}$$

$$w(\cos(\theta_h)) = \frac{3}{8\pi} (1 - r_{00}^{04}) + (3r_{00}^{04} - 1) \cos(\theta_h)$$

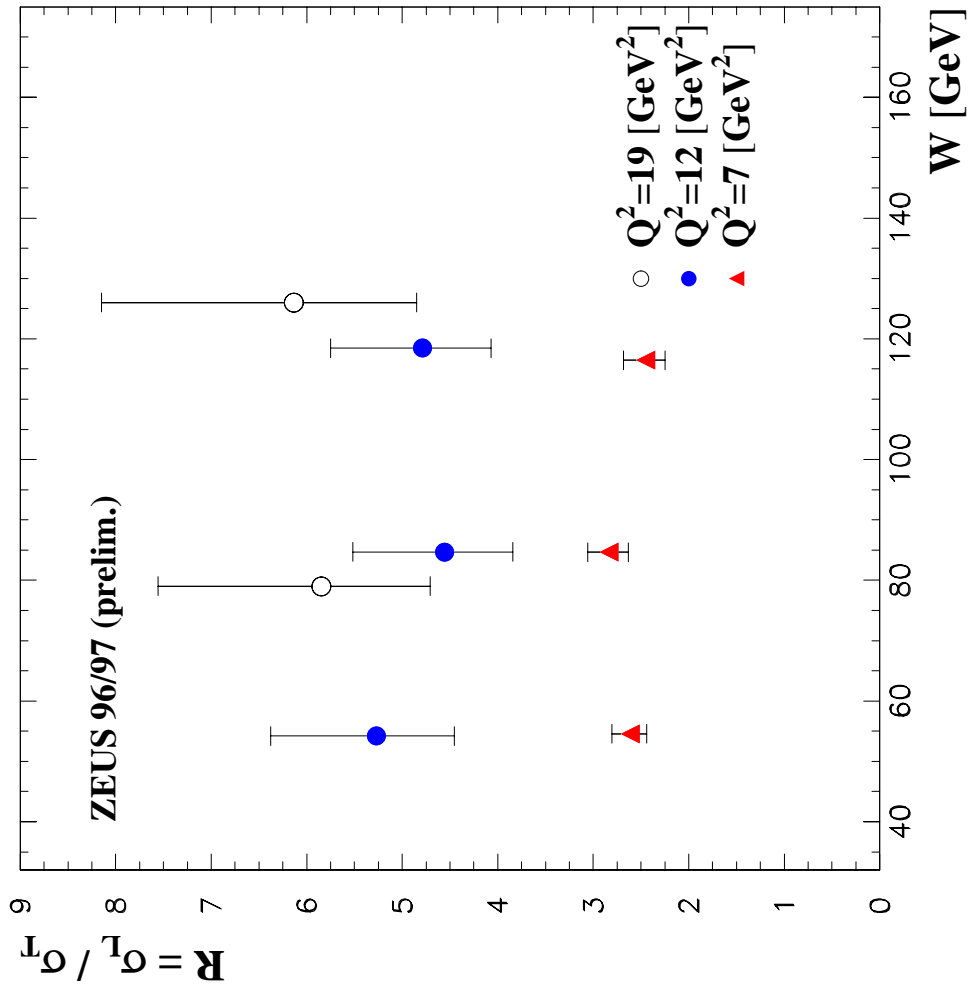
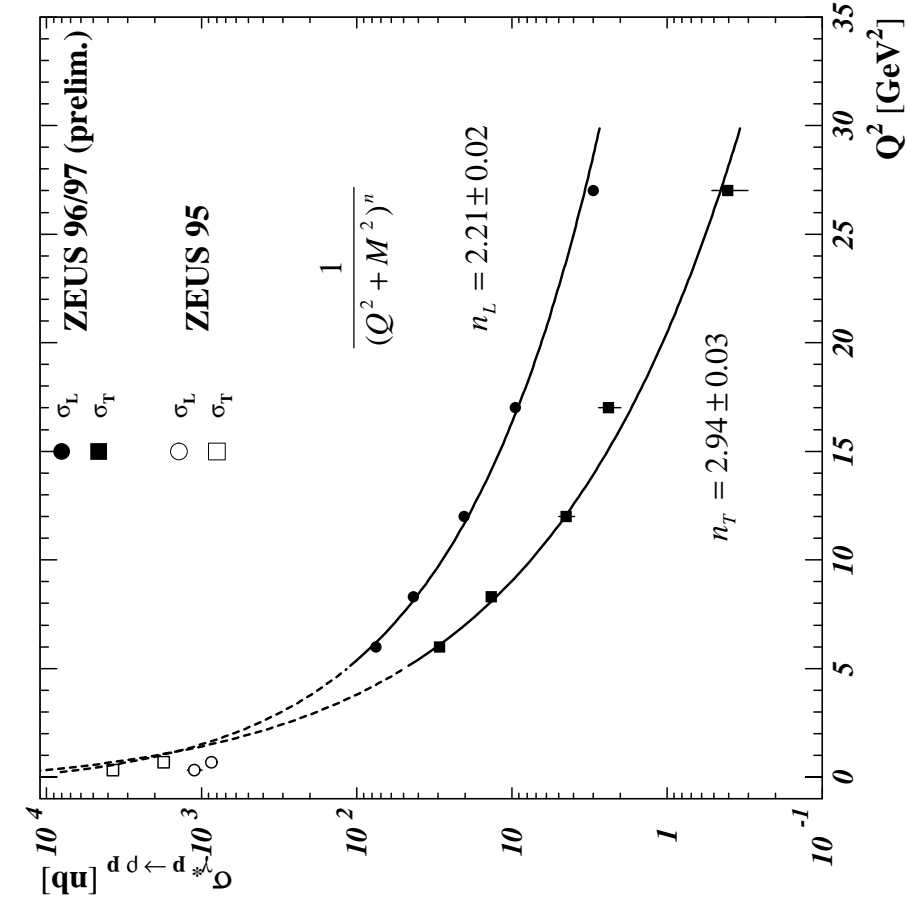
Electroproduction of Rho (Cont.)
(Abstract #880, ZEUS Preliminary)

R keeps growing with Q^2 !!



Transverse and longitudinal cross sections are extracted

R does not depend on W !



Photoproduction of J/Psi

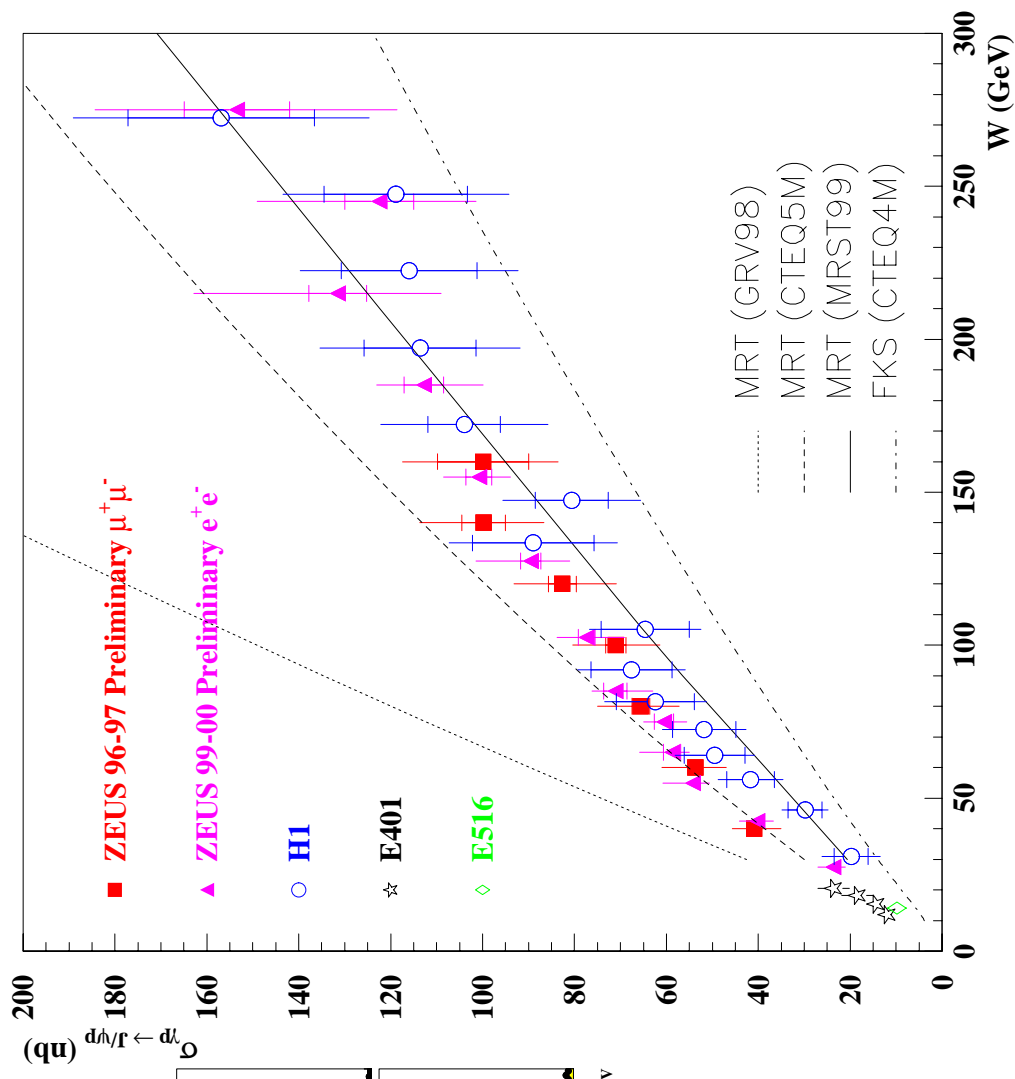
(Abstract #878, ZEUS Preliminary)

•48 pb-1 of data taken in 99-00

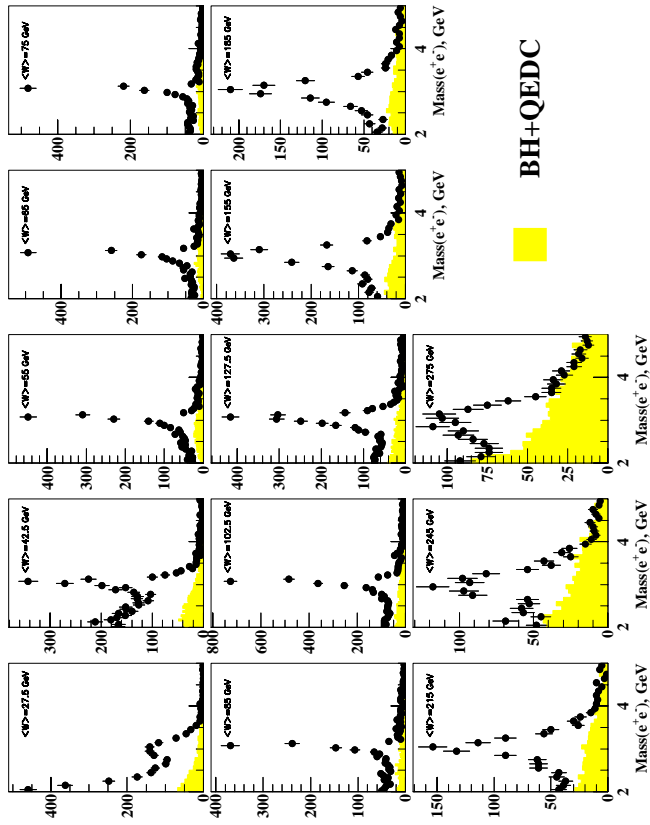
•Extension of W through combined use of tracking and CAL: $20 < W < 290$ GeV

•21000 candidates

Steep rise of cross section with W



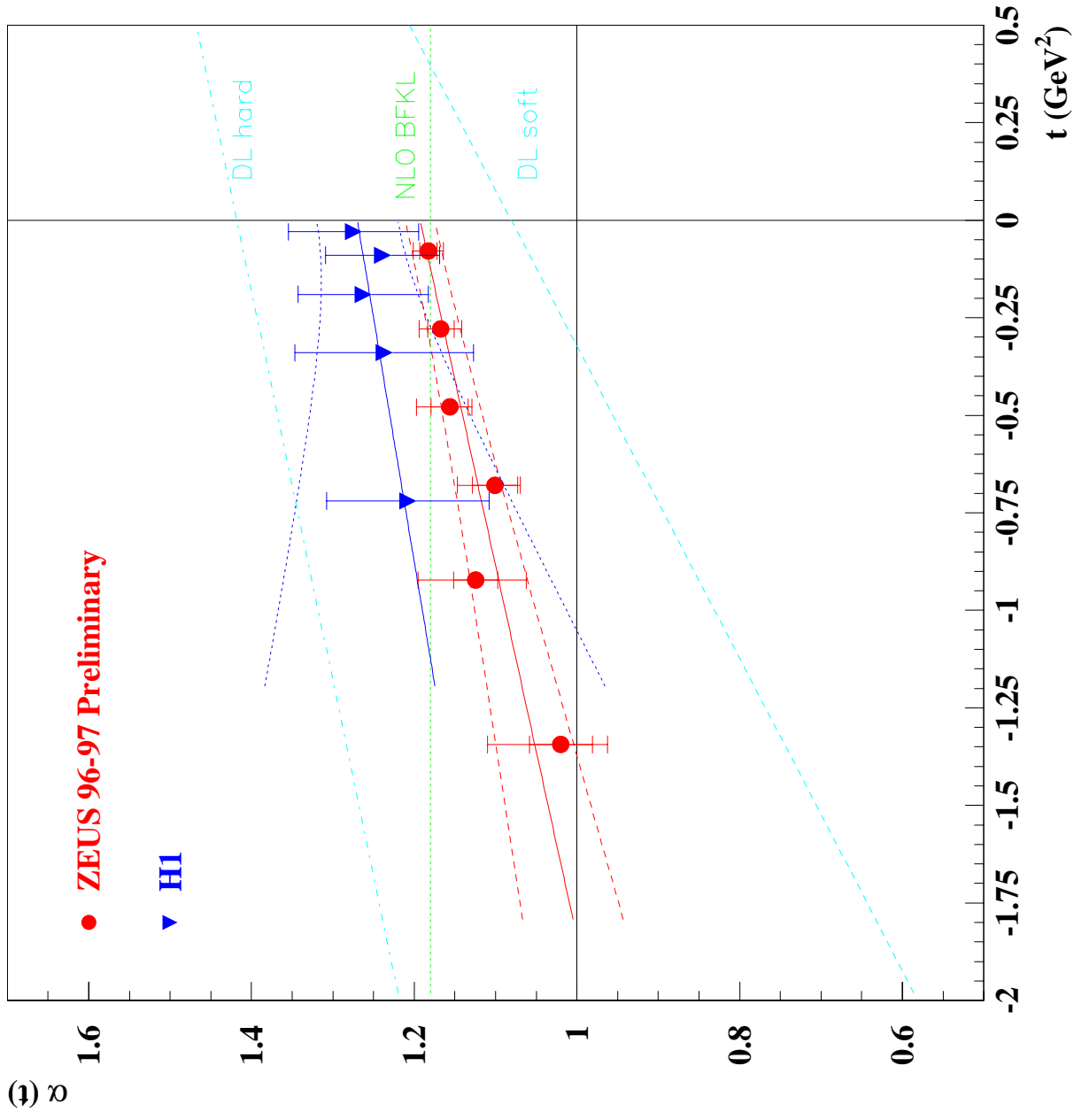
ZEUS 99-00 Preliminary



$$\frac{d\sigma}{dt} = F(t)(W^2)^{2\alpha_P(t)-2}$$

Photoproduction of J/Psi (Cont.)

(Abstract #878, ZEUS Preliminary)



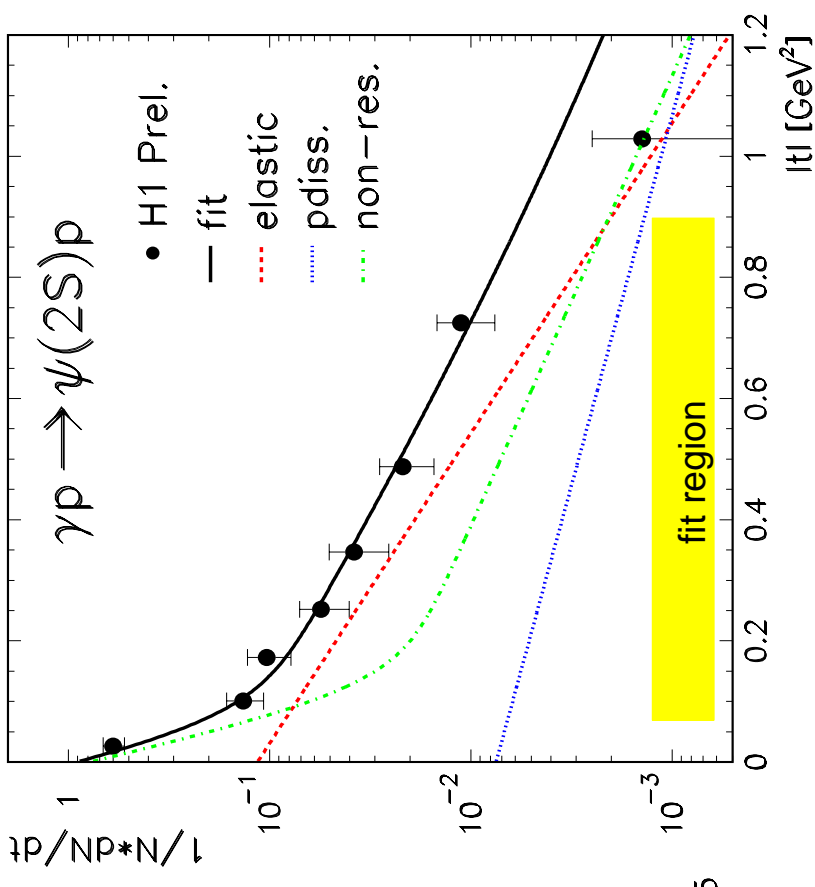
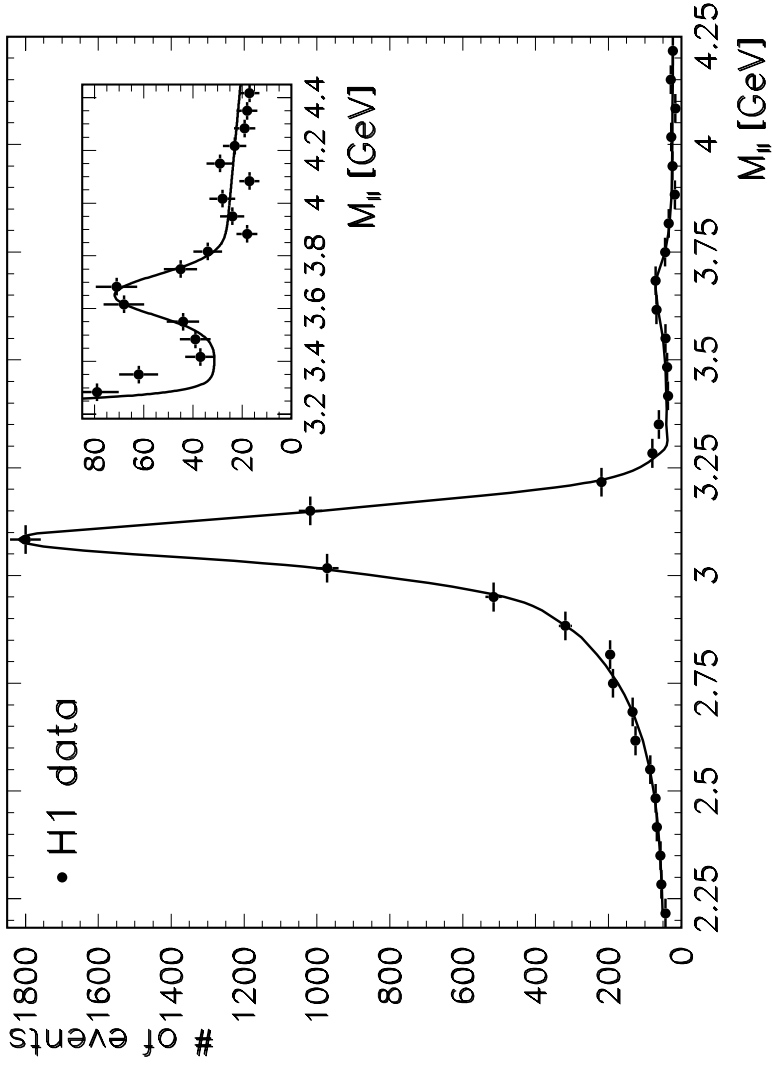
Photoproduction of $\Psi(2S)$

(Abstract #987 985, H1 Preliminary)

- 38 pb⁻¹ taken during 1996-1999
- 40 < W < 150 GeV

$$b_{\Psi(2S)} = (4.5 \pm 1.2^{+1.4}_{-0.7}) \text{GeV}^{-2}$$

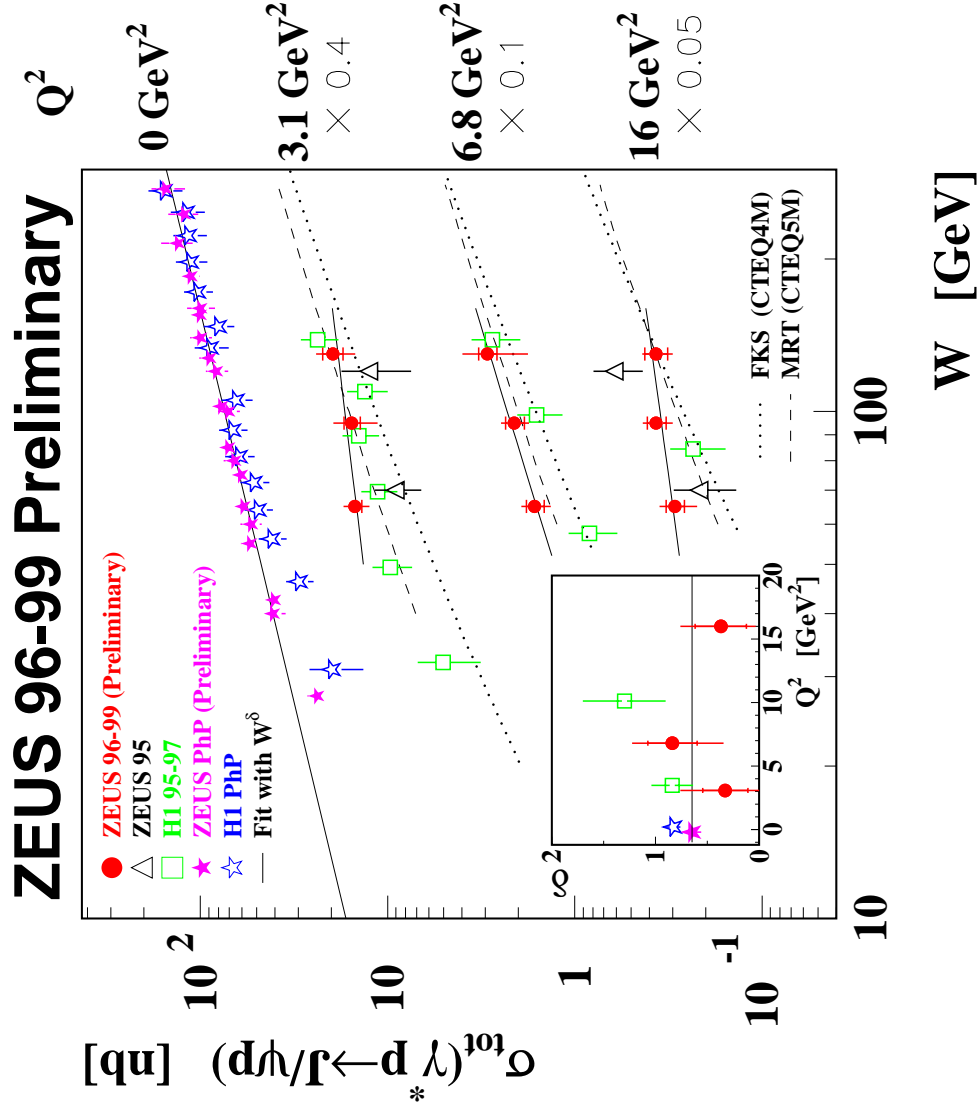
$$b_{J/\Psi} = (4.73 \pm 0.25^{+0.3}_{-0.39}) \text{GeV}^{-2}$$



Electroproduction of J/Psi

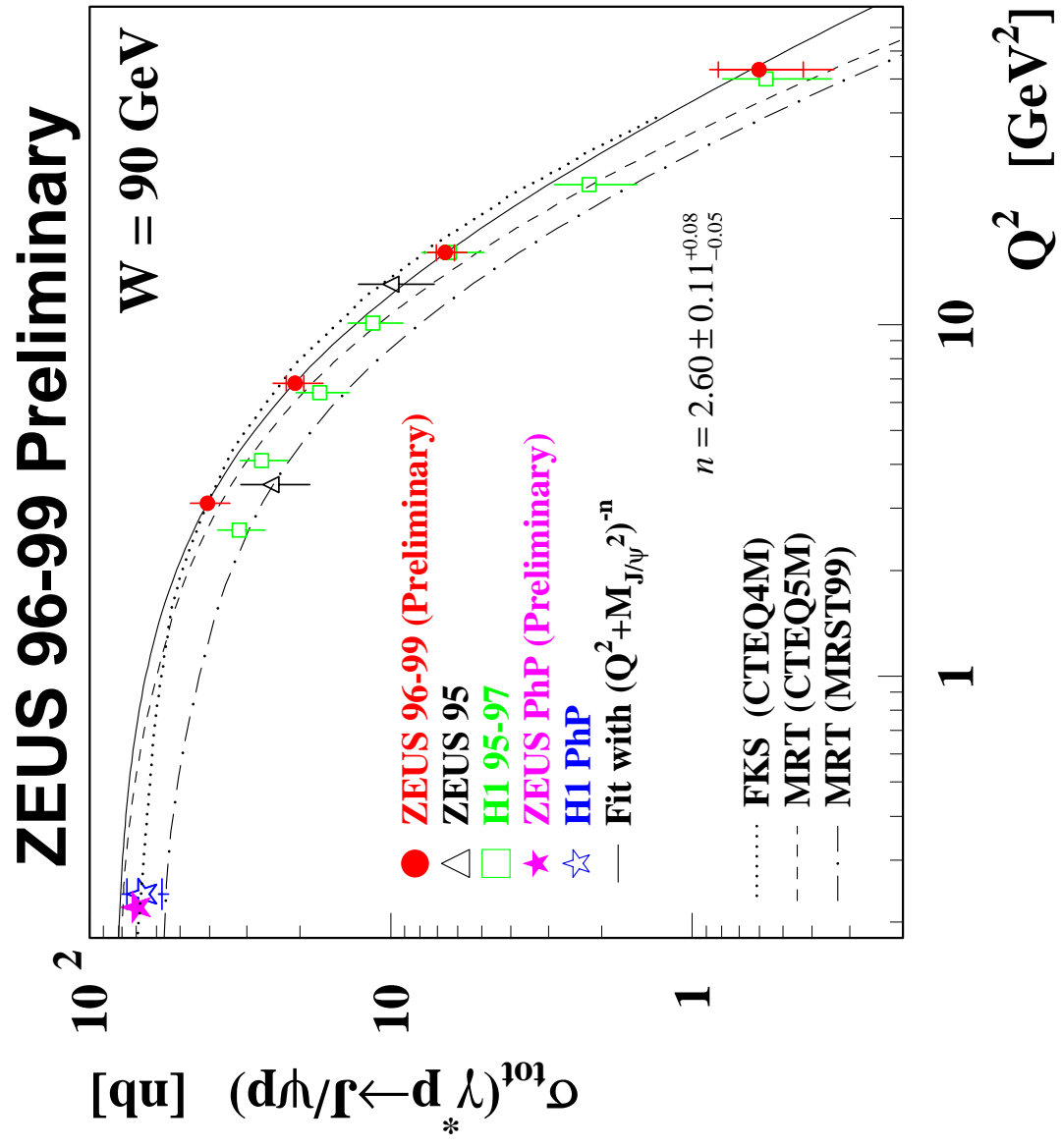
(Abstract #879, ZEUS Preliminary)

- 75 pb⁻¹ taken during 96-99 (Compared to 6pb⁻¹ for previous analysis)
- 50 < W < 150 GeV
- 2 < Q² < 100 GeV²
- 1000 candidates



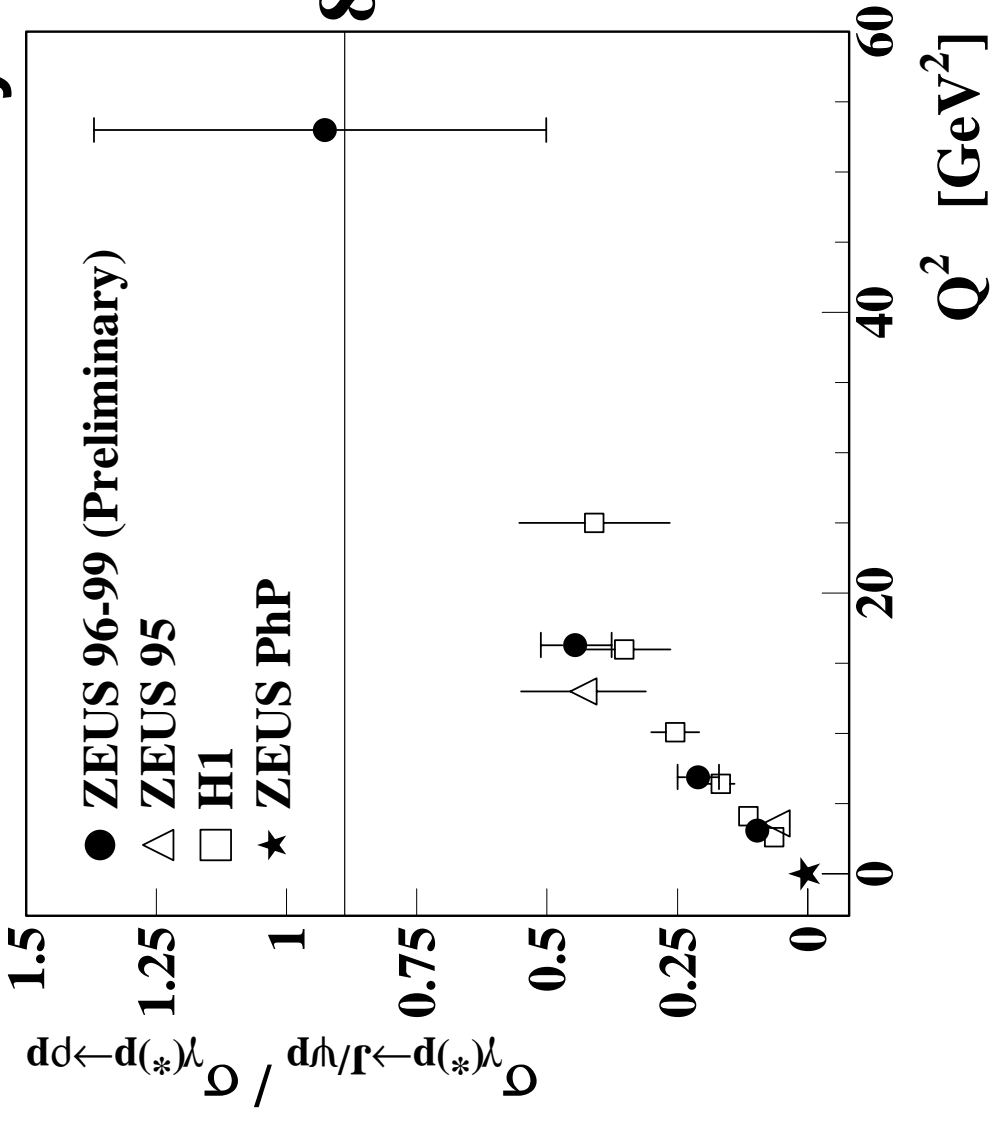
Electroproduction of J/Psi (Cont.)

(Abstract #879, ZEUS Preliminary)



Cross section ratio rises with Q^2

ZEUS 96-99 Preliminary



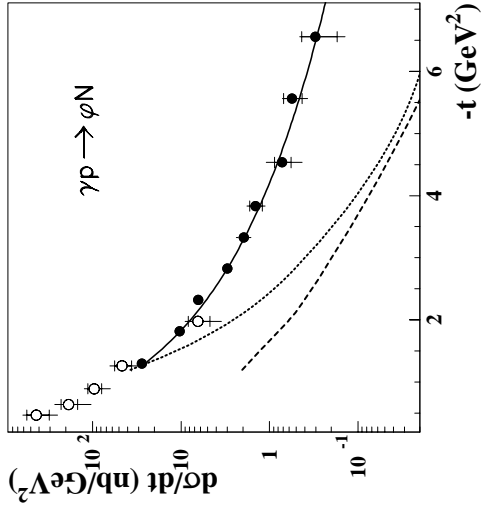
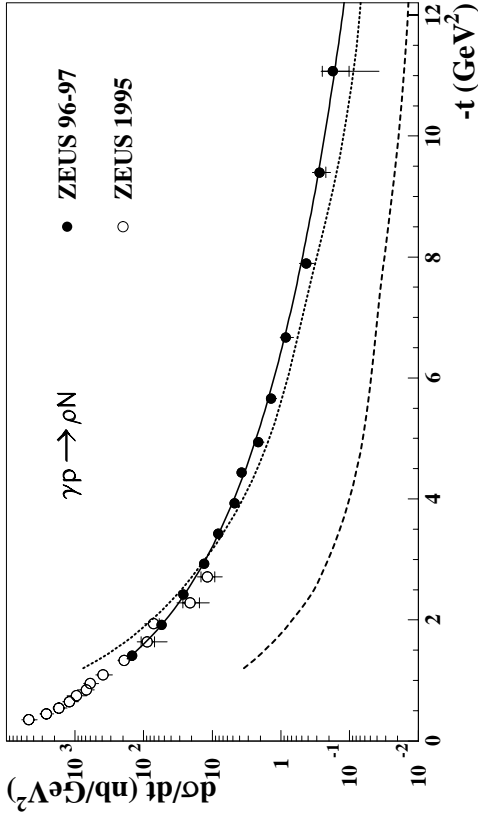
Proton dissociative VM production at High $|t|$

(Abstract #884, ZEUS preliminary)

- 24 pb⁻¹ taken during 96-97 (3 fold increase w.r.t. previous preliminary)
- Tag scattered electron at $W = 100$ GeV
- $|t| < 12$ GeV²

- pQCD is well below Rho and Phi data
- pQCD calculations describe J/Psi

ZEUS 96 - 97 Preliminary



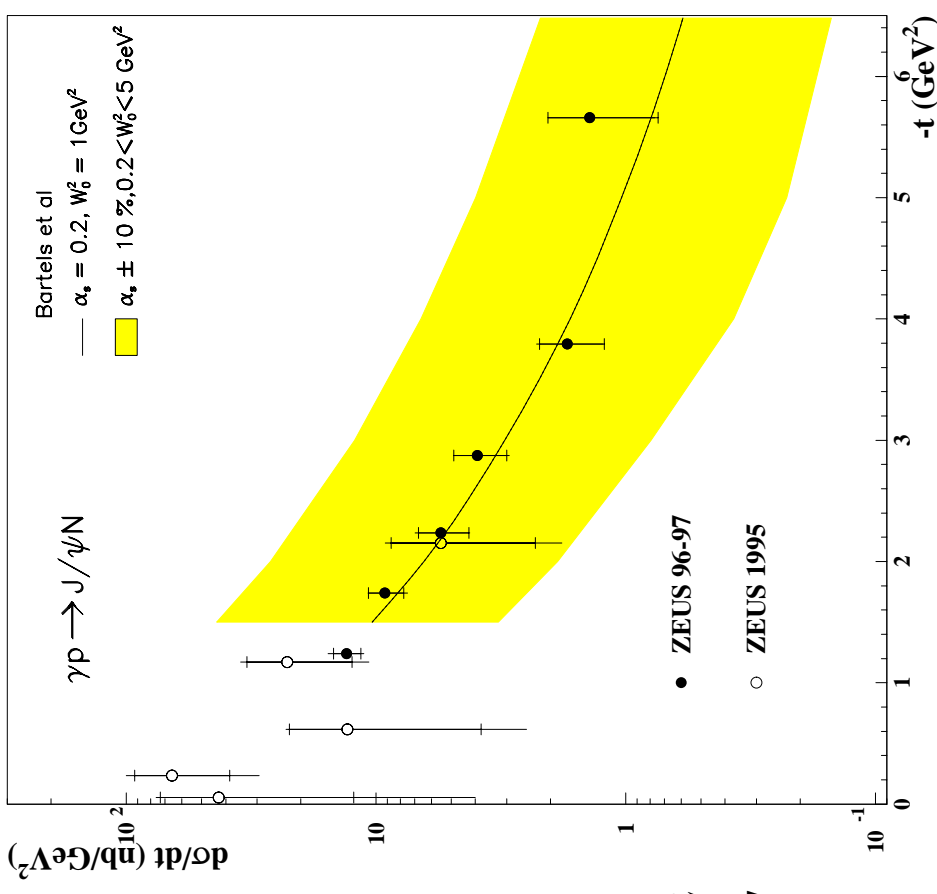
$$\frac{d\sigma}{d|t|} \propto |t|^{-n}$$

$$n_\rho = 3.31 \pm 0.02 \pm 0.12$$

$$n_\phi = 2.77 \pm 0.07 \pm 0.17$$

$$n_{J/\psi} = 1.7 \pm 0.2 \pm 0.2$$

ZEUS 96-97 Preliminary

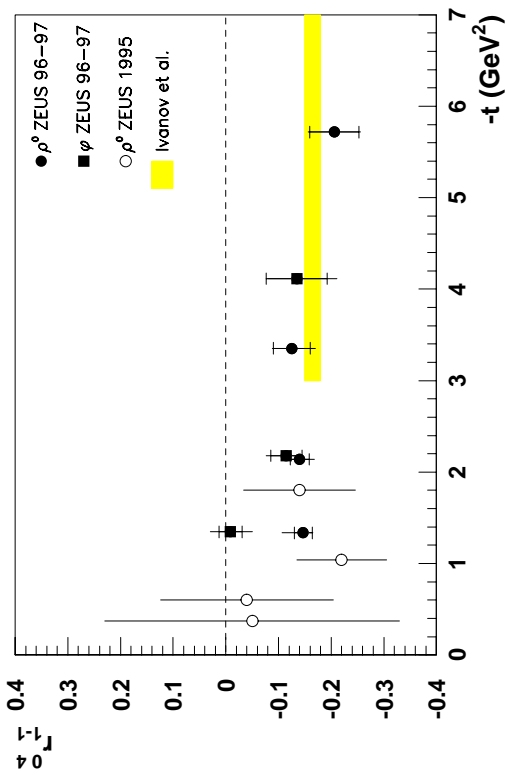
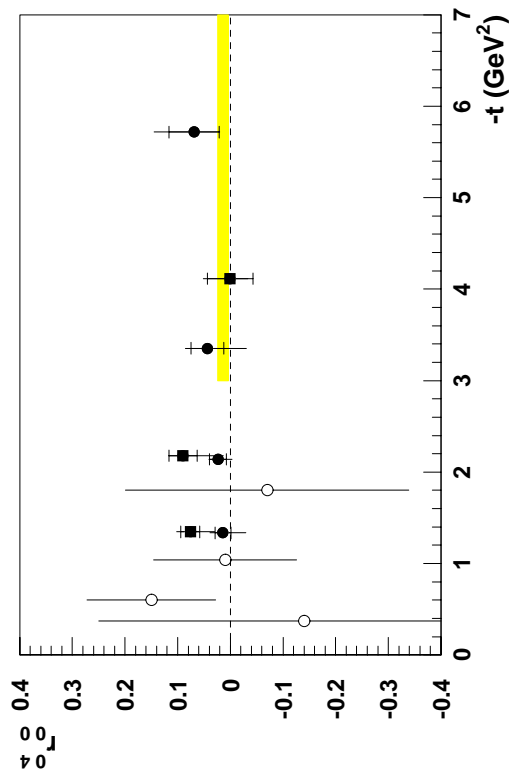


Proton dissociative VM production at High $|t|$ (Cont.)

(Abstract #884, ZEUS preliminary)

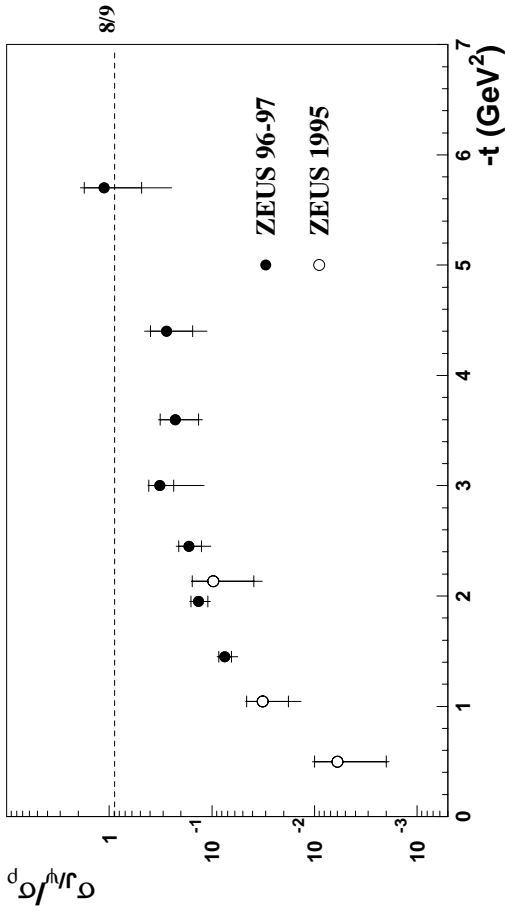
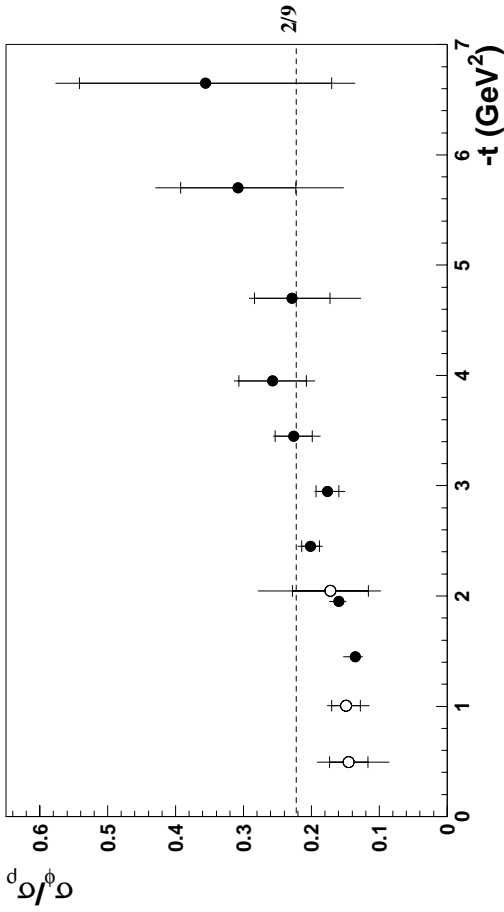
SCHC breaking, consistent with pQCD

ZEUS 96-97 Preliminary

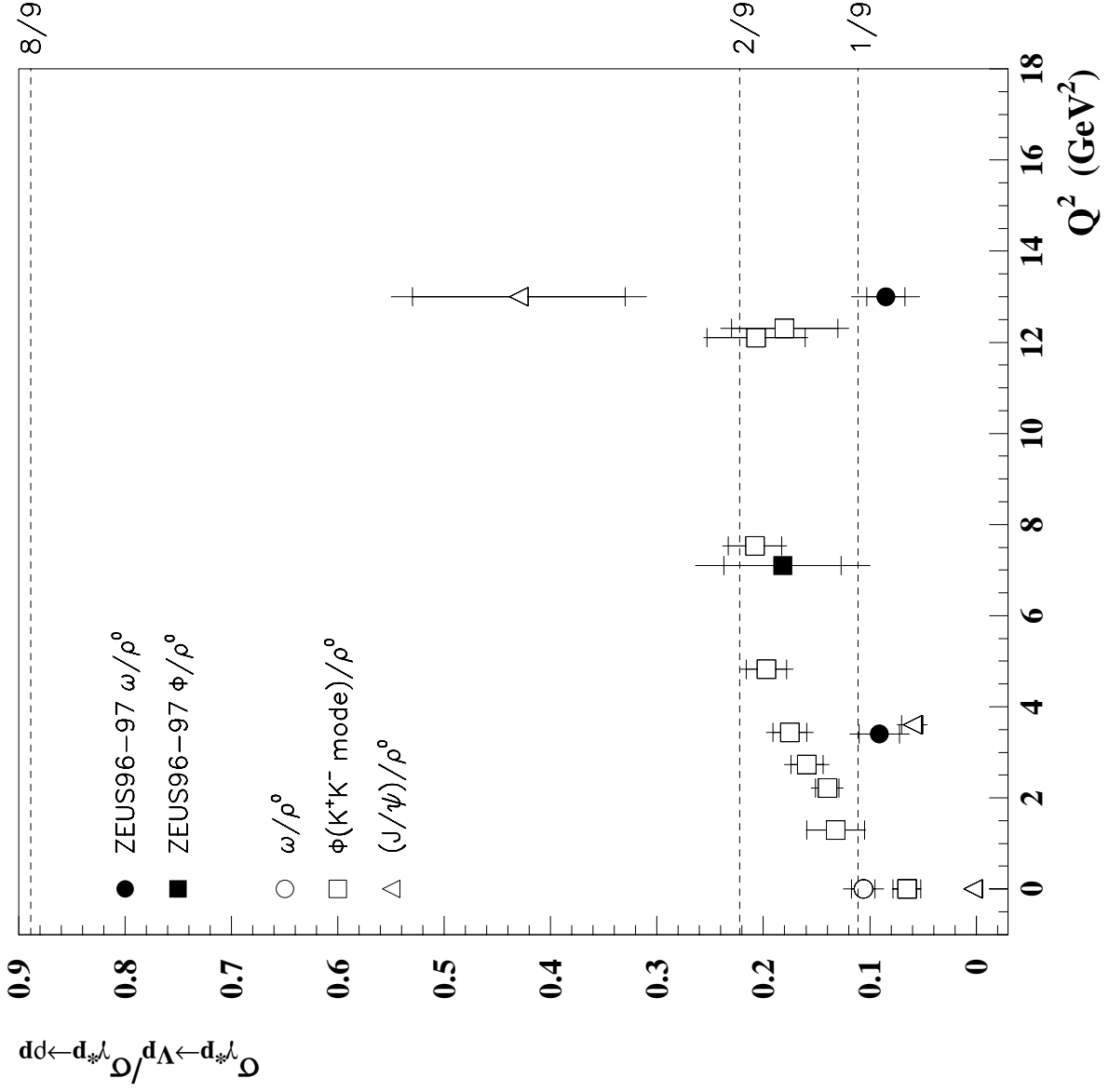


- Ratio Φ/ρ approaches $SU(4)$ at $|t|=3-4 \text{ GeV}^2$
- Ratio $J/\psi/\rho$ is suppressed

ZEUS 96 - 97 Preliminary

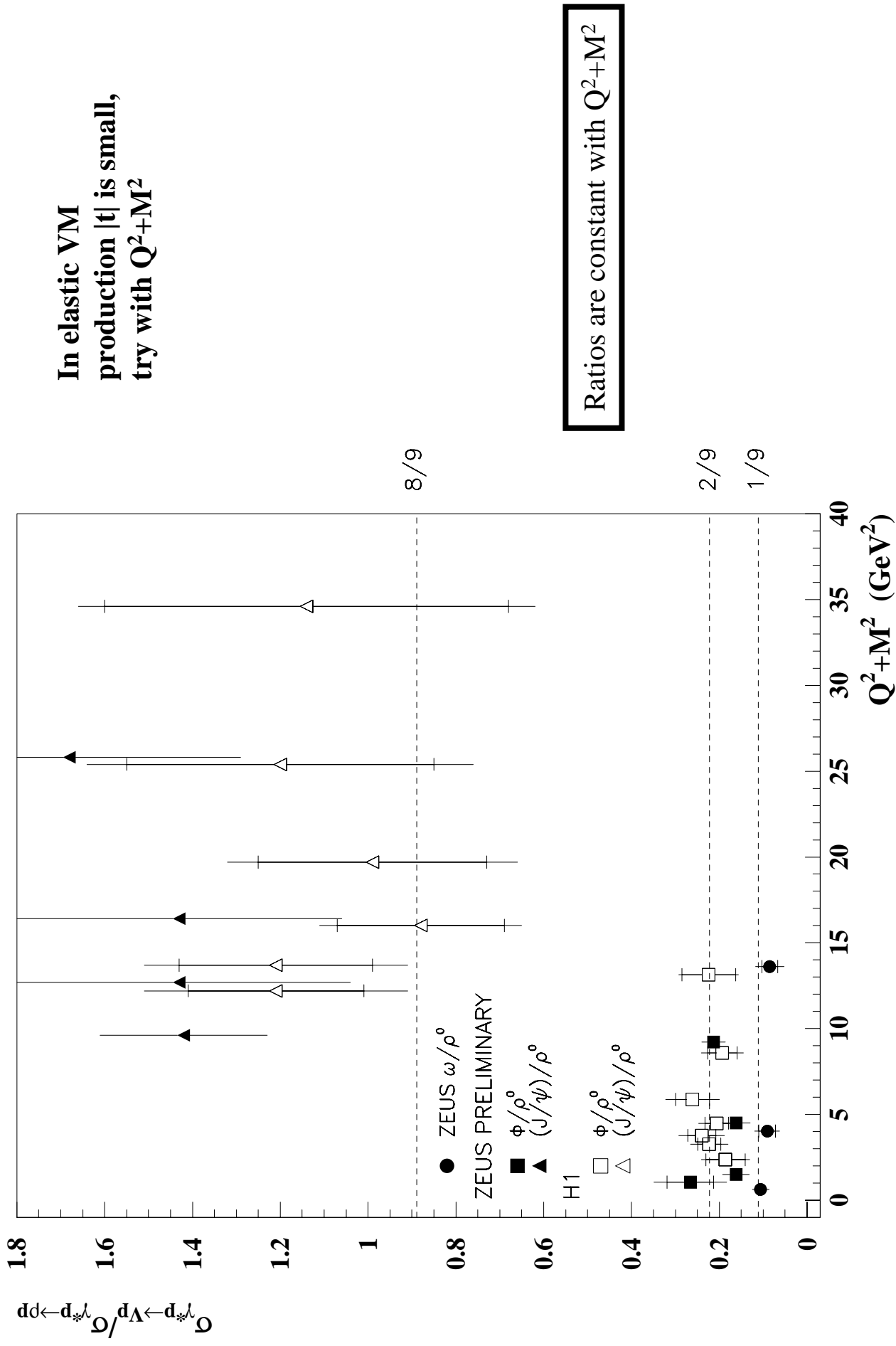


ZEUS 1996 - 1997



VM production at HERA
 show that $|t|$, Q^2 are not
 universal scales

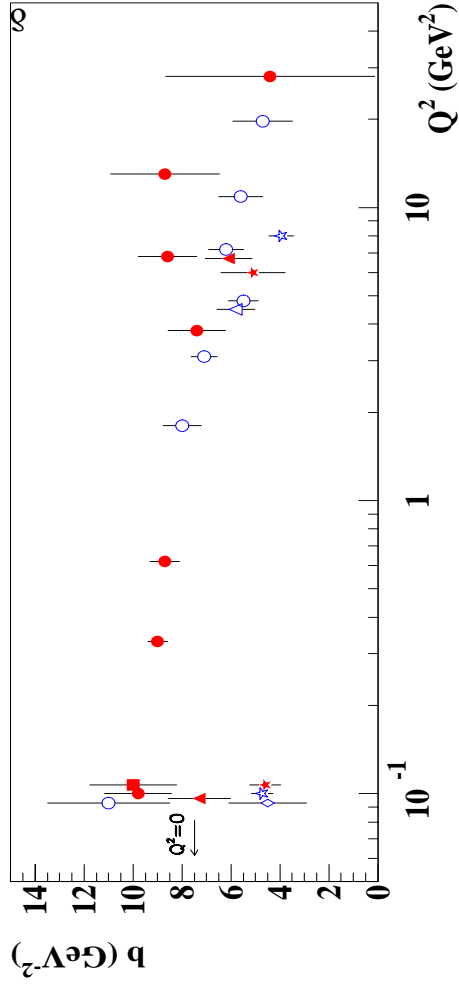
Elastic VM production at HERA



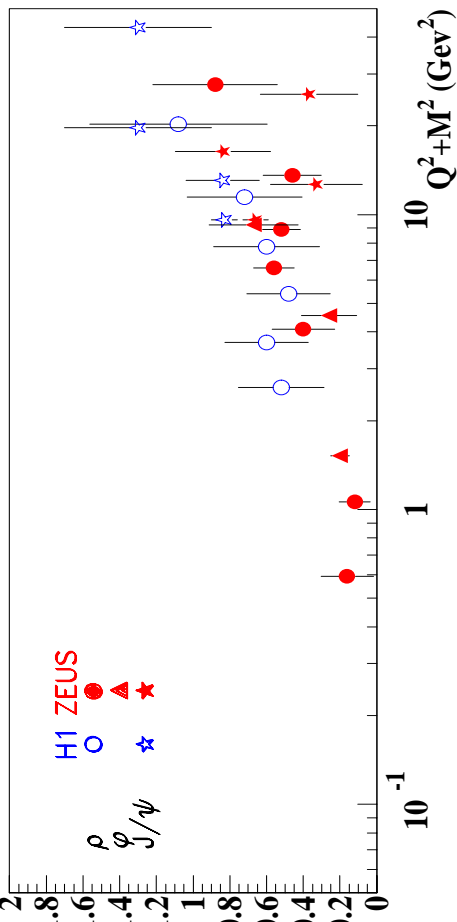
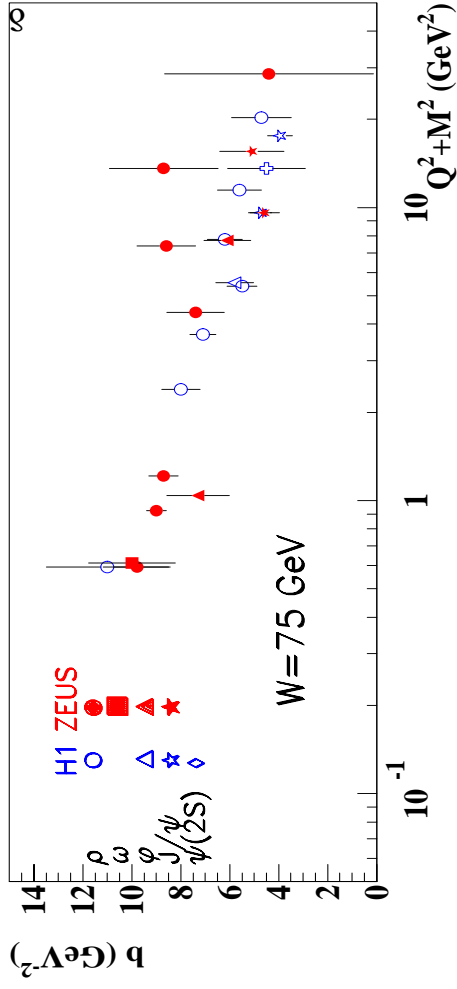
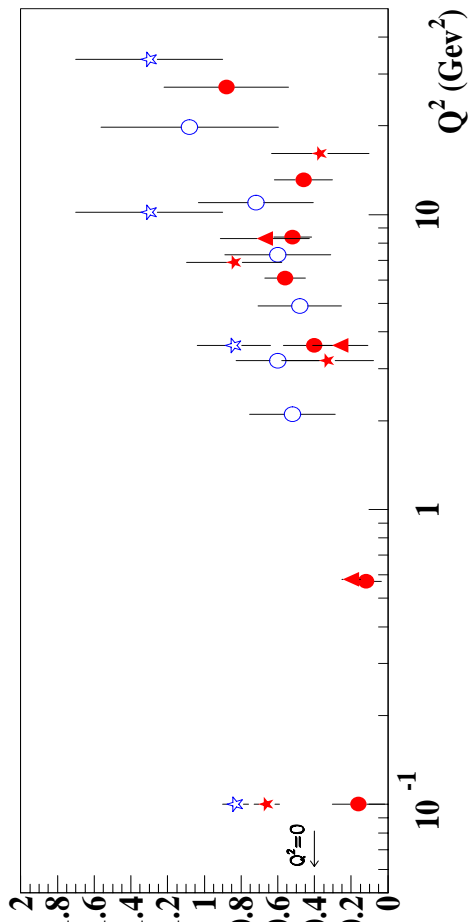
$$\frac{d\sigma}{d|t|} \propto e^{-b|t|}$$

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

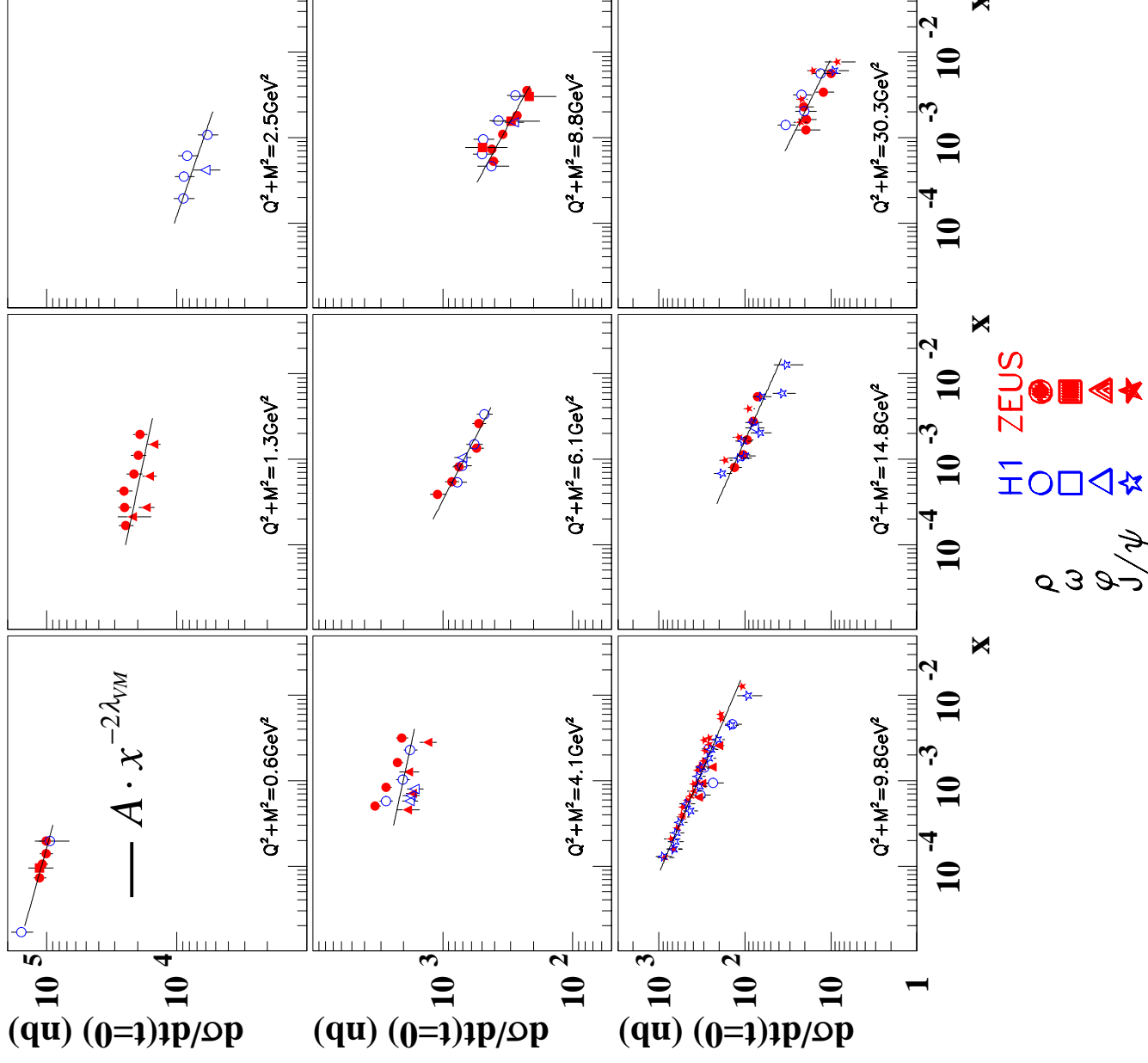
Elastic VM Production at HERA



Elastic VM Production at HERA



Elastic VM Production at HERA



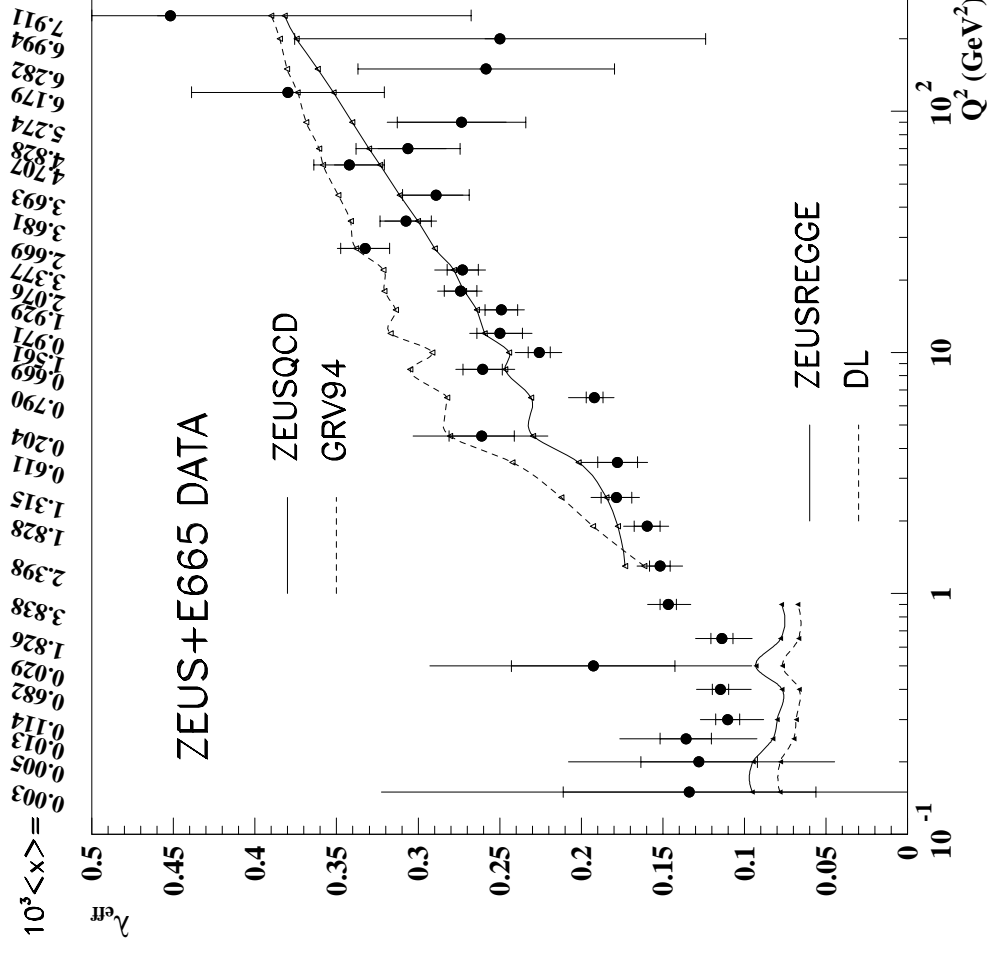
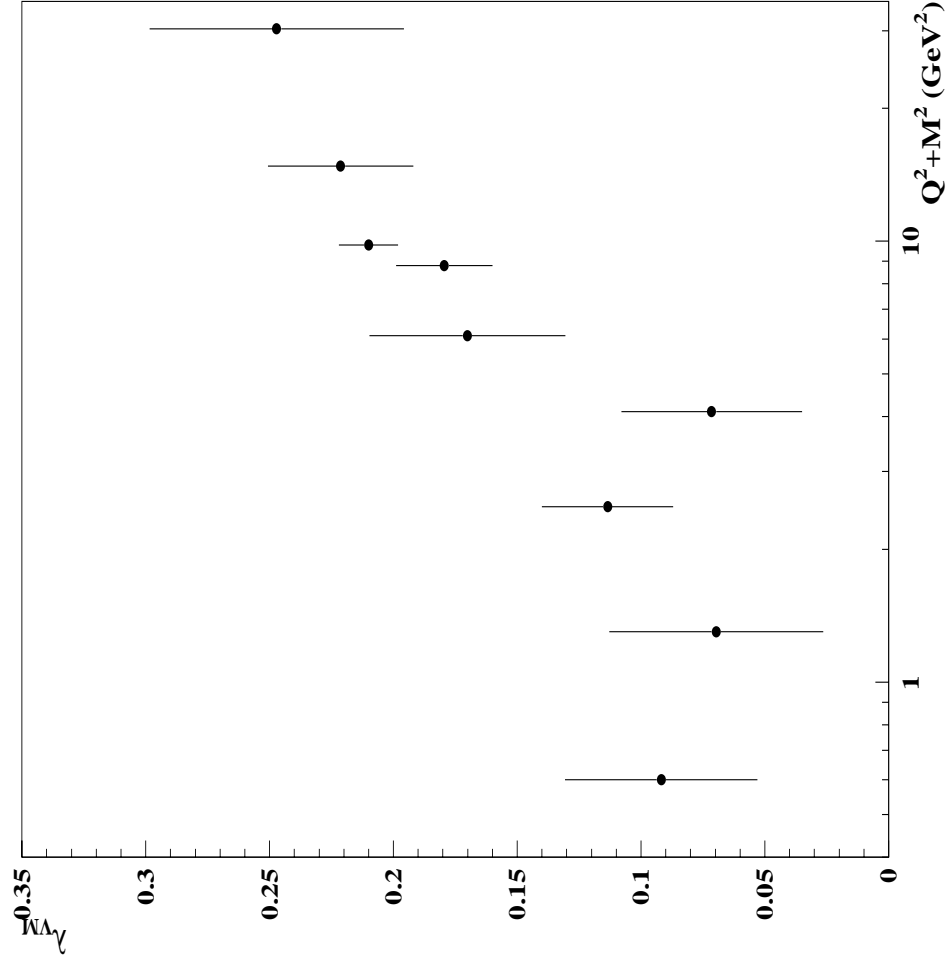
$$\left. \frac{d\sigma}{dt} \right|_{t=0} = \sigma \cdot b \cdot \left(\frac{e_p^2}{e_{VM}^2} \right)$$

Cross sections scale with Q^2+M^2

Similar x dependence to inclusive

ZEUS 1995

Elastic VM Production at HERA



Conclusions

- New preliminary results for various VM have been shown with 5-10 increase in statistics
- Rho in electron production shows increase of steepness in the cross section as Q^2 rises. R grows with Q^2 and does not depend on W. The Q^2 dependence cannot be fit by $1/(Q^2+M^2)^n$
- The cross section of the J/Psi in photoproduction has a steep W dependence. Shrinkage is small
- $b_{\psi(2S)} \approx b_{J/\psi}$, supported by pQCD against naïve expectation.
- The electroproduction of J/Psi shows steep rise of the cross section with W which does not depend on Q^2 . The ratio of the J/Psi to Rho cross section grows with Q^2 .
- Photoproduction of Rho, Phi, J/Psi at high $|t|$ has been measured. pQCD well below Rho and Phi, consistent J/Psi. Break down of SCHC consistent with pQCD calculations.
- All data available on elastic VM production has been compiled
- Cross section ratios grow with Q^2 but constant with Q^2+M^2
- Data suggest that VM production scales with Q^2+M^2