Diffractive VM Production at HERA

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On behalf of the H1 and ZEUS Collaborations
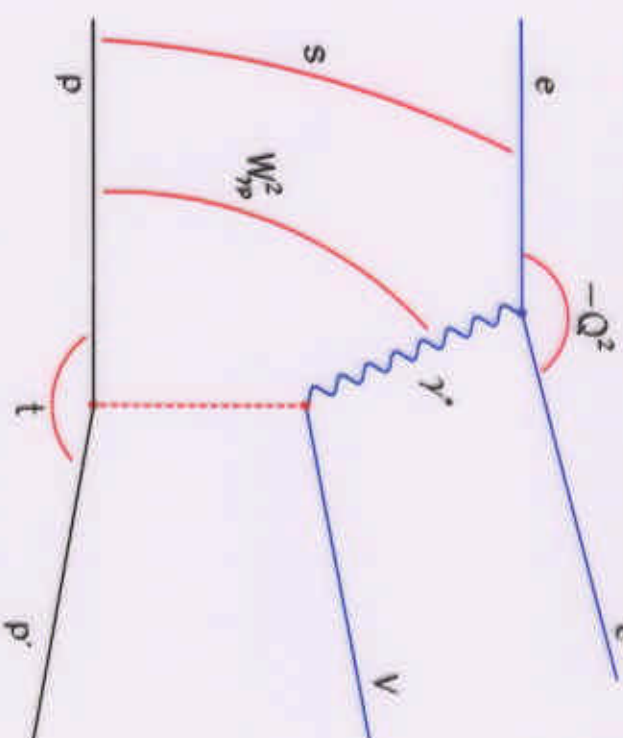
XXXth International Conference on High Energy Physics

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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.

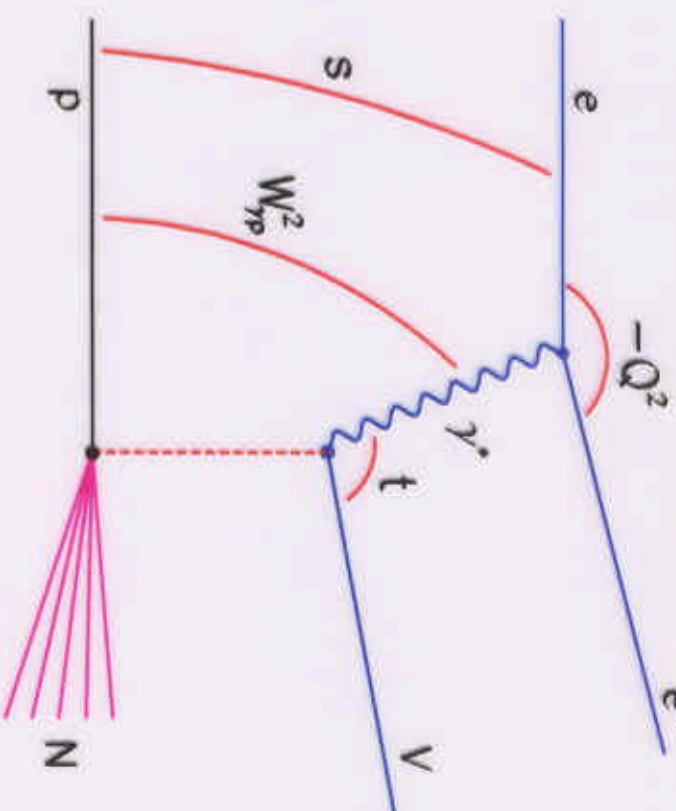Elastic VM (dominates at |t|<1GeV²)

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

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

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

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

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

VM with Proton Dissociation (|t|>1GeV²)
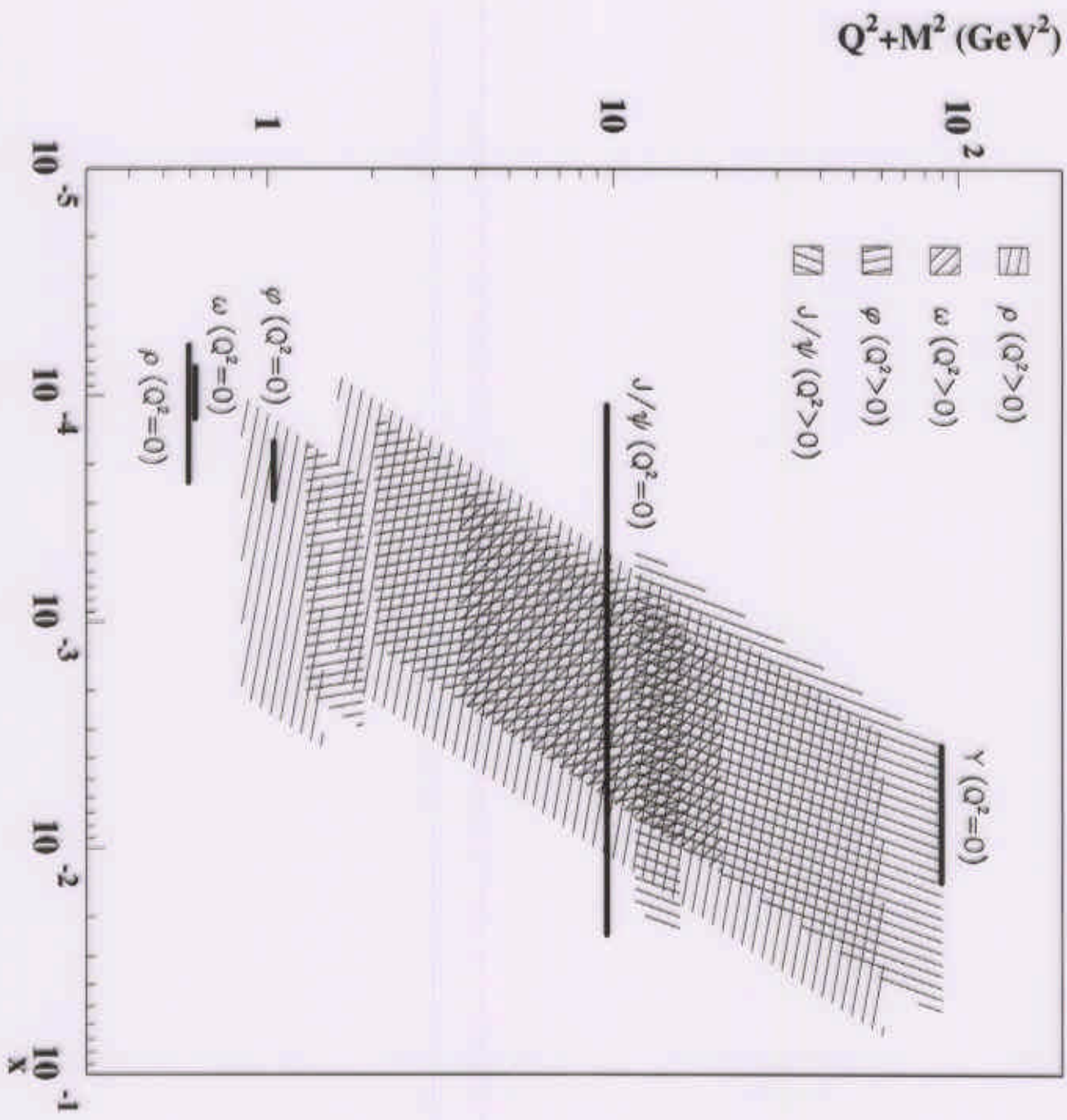

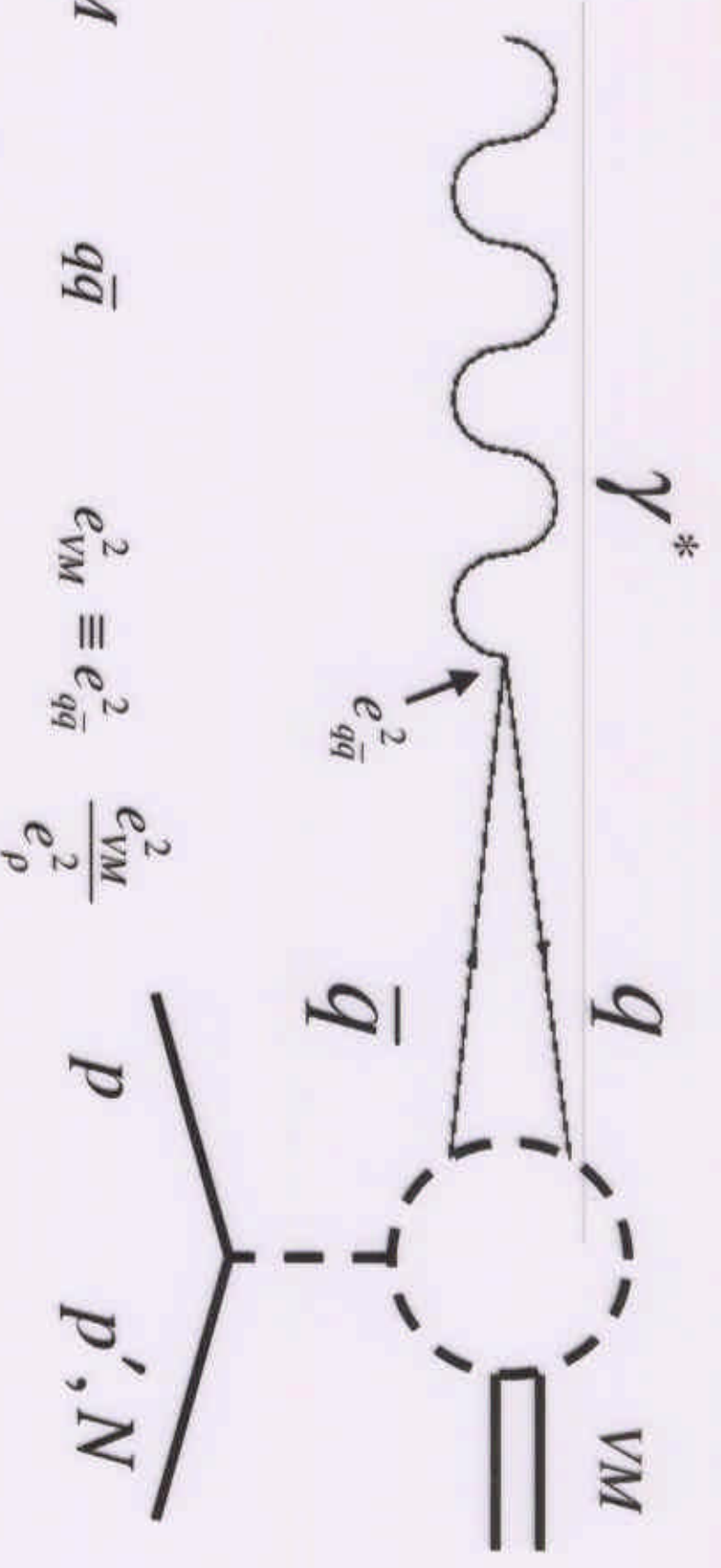Measure Rho, Phi, J/Psi in
Photoproduction with |t|<12 GeV²

• What is the scale of the interaction?
• Is |t| providing scale on the same
footing as Q² in M²?
• Observe the interplay between soft
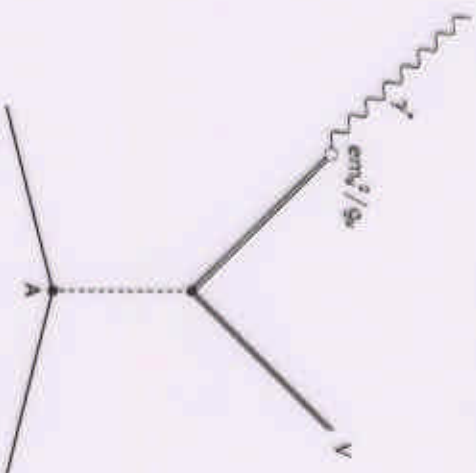and hard physics

Elastic VM Production at HERA

$Q^2 + M^2$ (GeV^2)

Legend:
- ρ ($Q^2 > 0$)
- ω ($Q^2 > 0$)
- φ ($Q^2 > 0$)
- J/ψ ($Q^2 > 0$)

φ ($Q^2 = 0$)
ω ($Q^2 = 0$)
ρ ($Q^2 = 0$)

J/ψ ($Q^2 = 0$)

Υ ($Q^2 = 0$)

x

$$\gamma^* \quad q \qquad \qquad VM$$

$$e^2_{q\bar{q}} \qquad \bar{q}$$

$$p \qquad p', N$$

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

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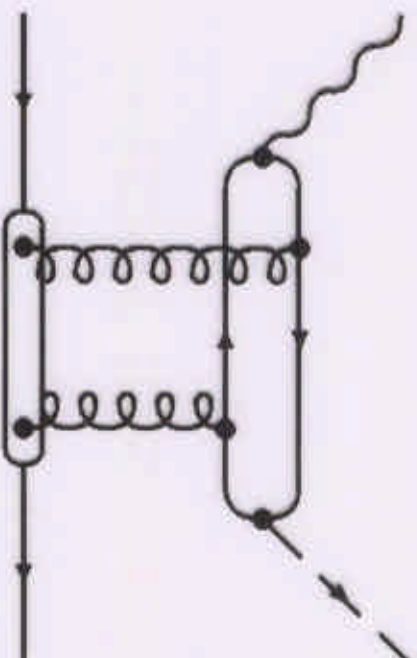the SU(4) ratios?

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:

$$\sigma(Q^2) \propto \frac{1}{(Q^2 + M^2)^2} \qquad R = \frac{\sigma_L}{\sigma_T} \propto \frac{Q^2}{M^2}$$

- Steep dependence of cross section with |t| and strong shrinkage
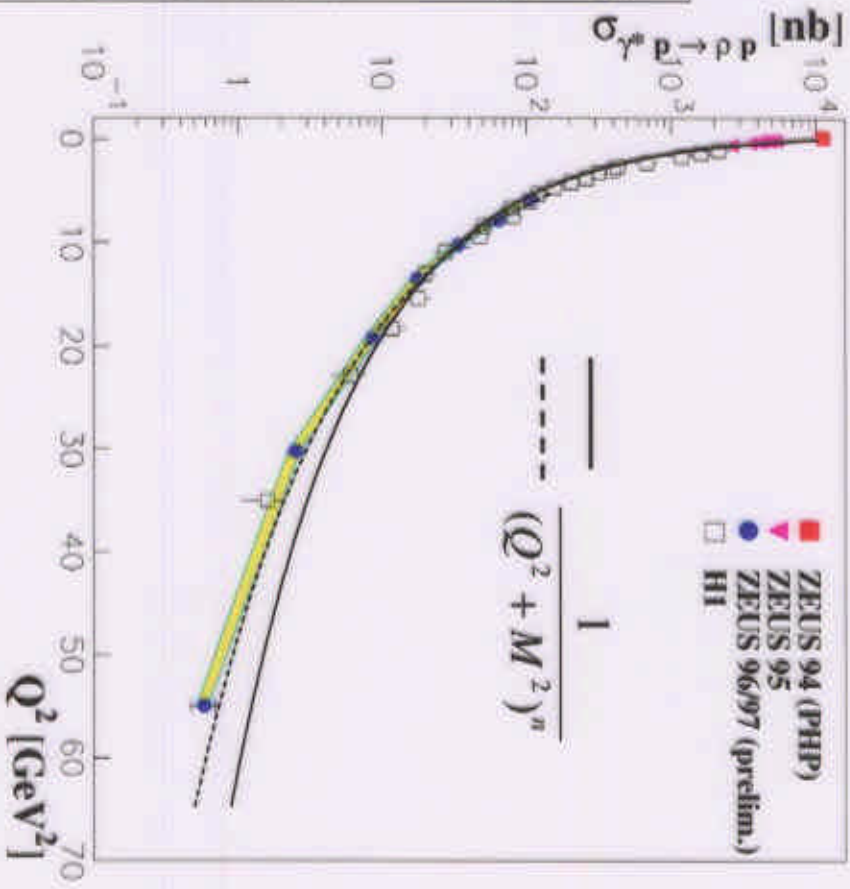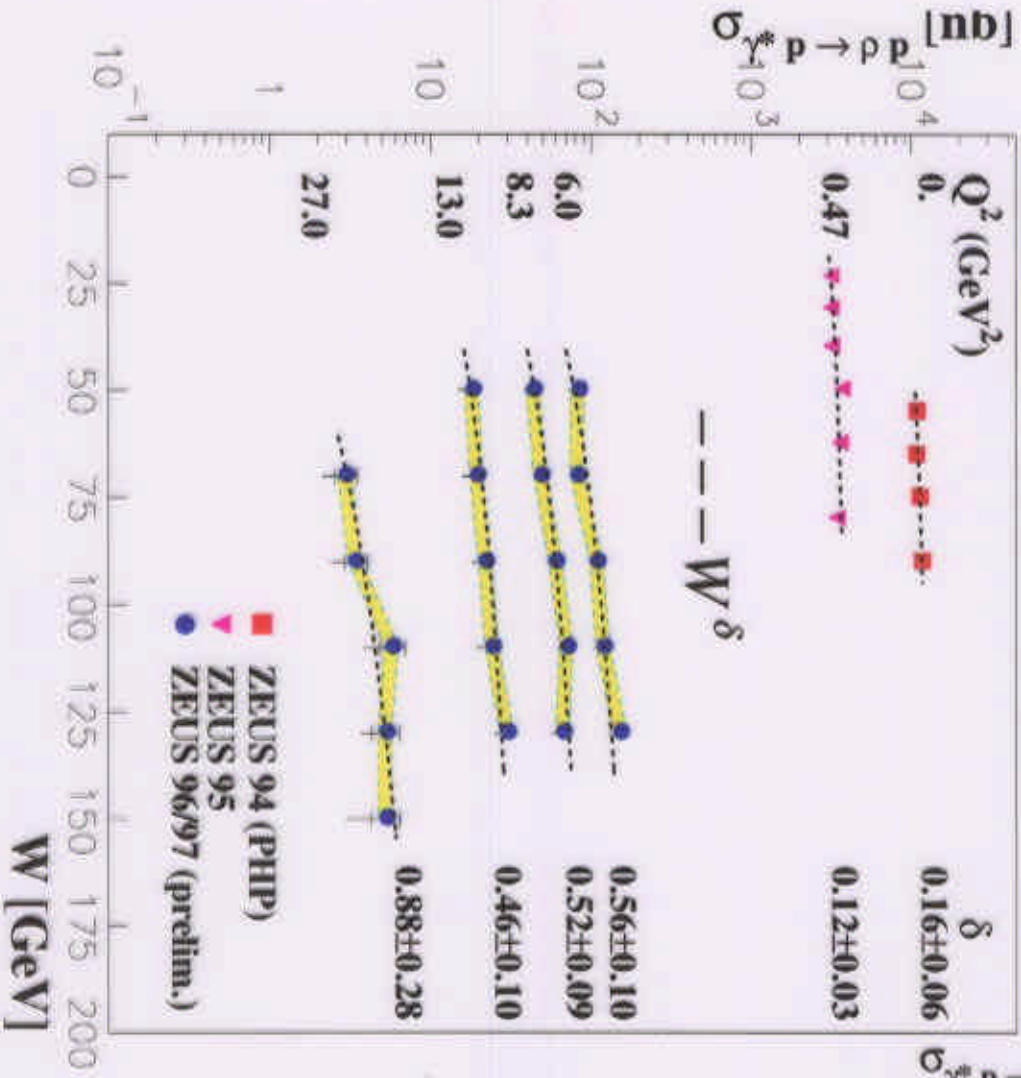
Perturbative approach

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

$$\sigma(W) \propto |\alpha_s(\bar{q}^2) x g(x, \bar{q}^2)|^2 \qquad \bar{q}^2 = \frac{Q^2 + M^2}{4} \qquad x = \frac{Q^2 + M^2}{W^2}$$

- Weaker dependence of cross section with |t| and no shrinkage
- Expect:

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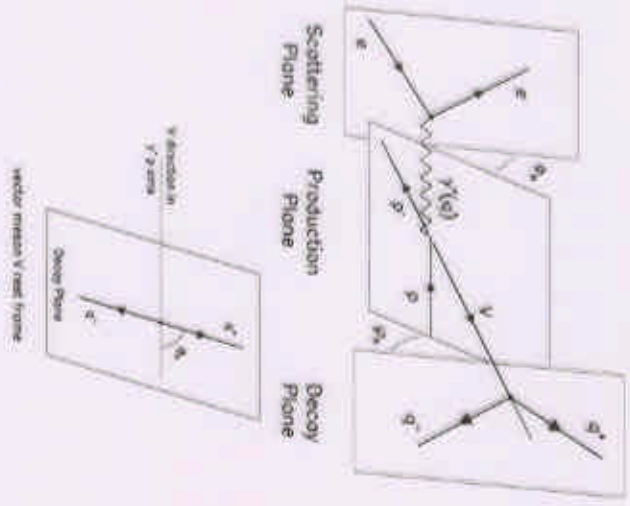
Electroproduction of Rho

(Abstract #880, ZEUS Preliminary)

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

γ*p center of mass system

Scattering Plane   Production Plane   Decay Plane
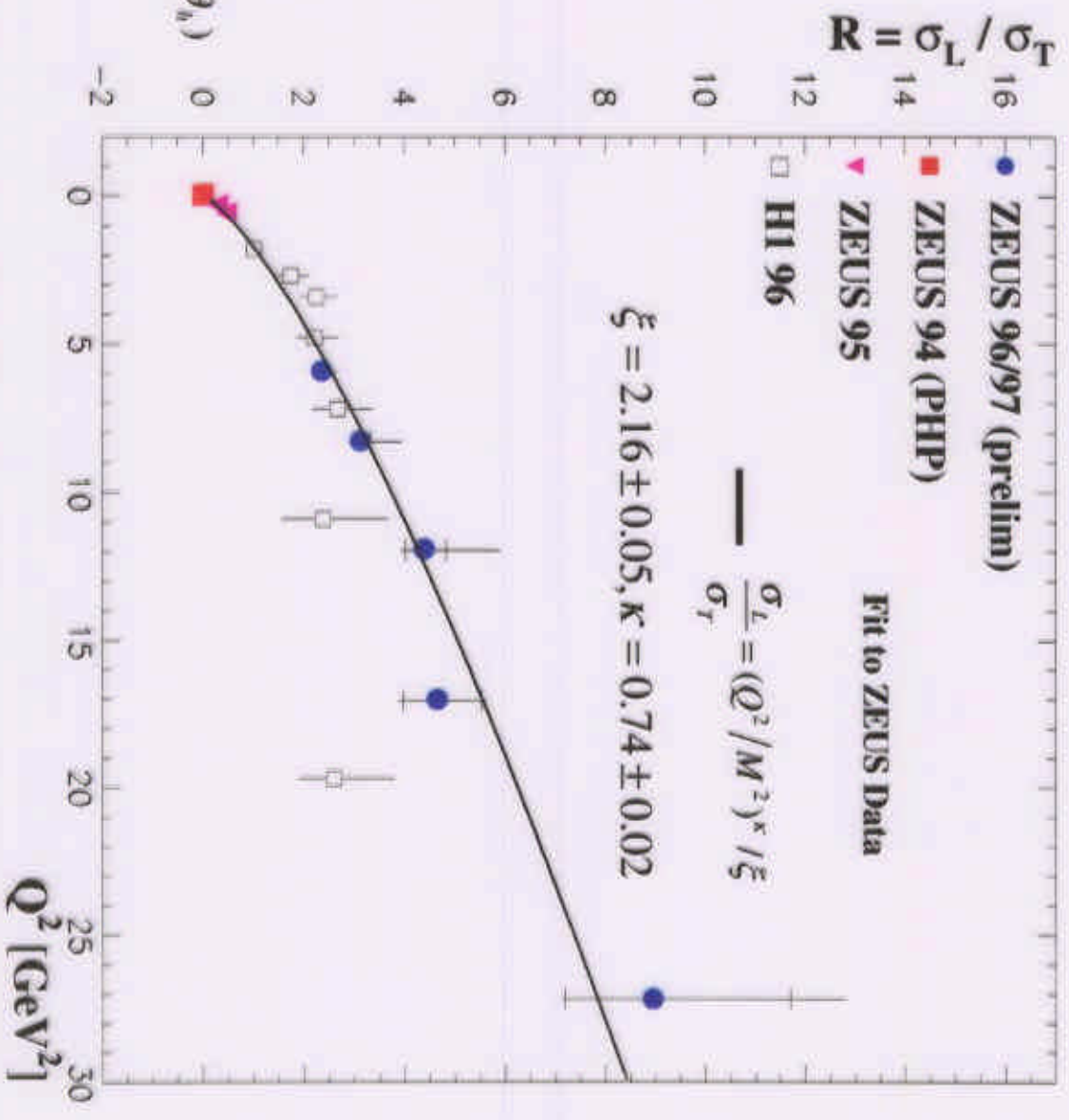
SCHC breaking is small

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

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

$$W(\cos(\theta_h)) = \frac{3}{8\pi}(1 - r_{00}^{04}) + (3r_{00}^{04} - 1)\cos(\theta_h))$$
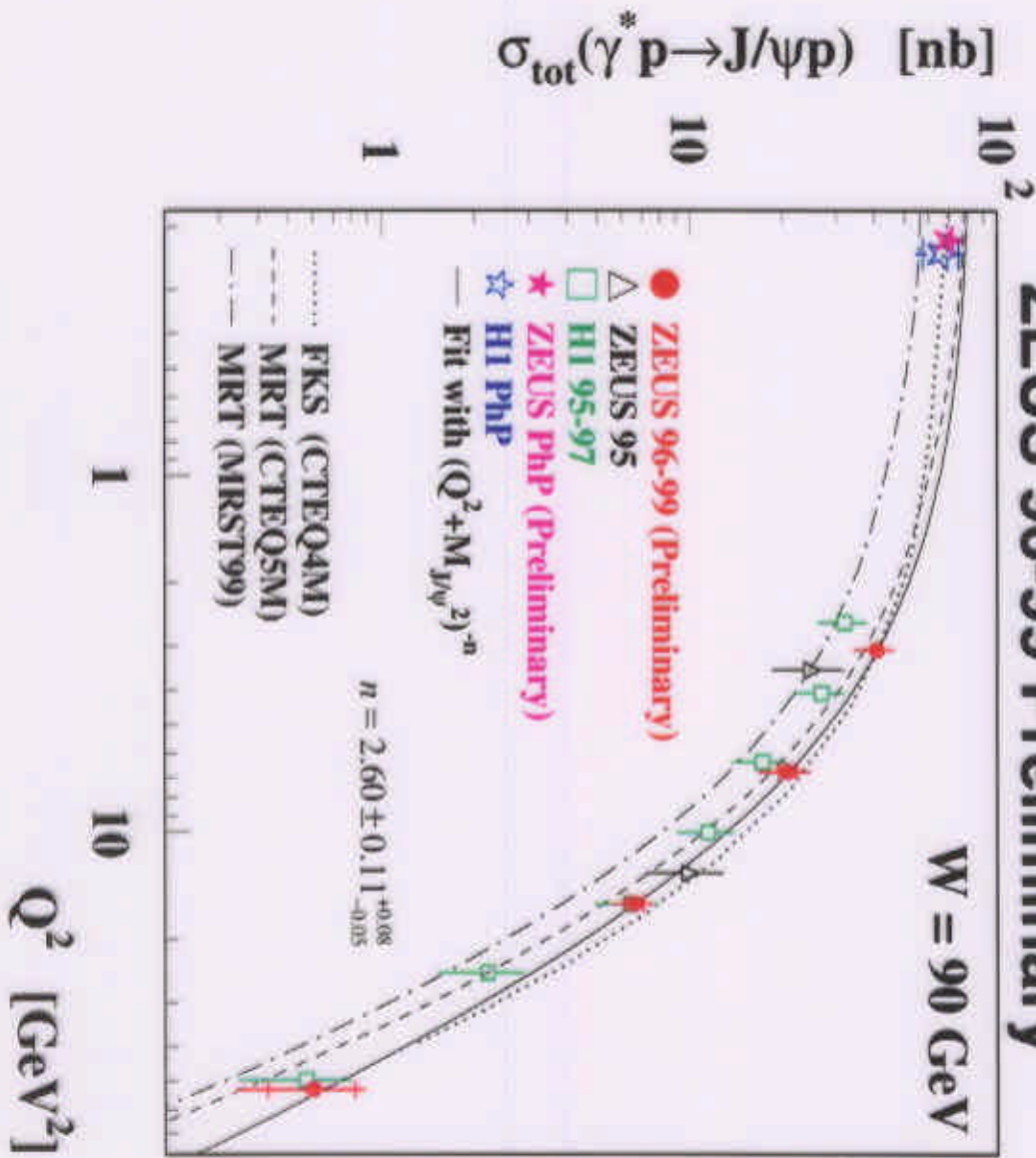
R keeps growing with Q²!!!

$$R = \sigma_L / \sigma_T$$

- ● ZEUS 96/97 (prelim)
- ■ ZEUS 94 (PHP)
- ◄ ZEUS 95
- □ H1 96

Fit to ZEUS Data

$$\frac{\sigma_L}{\sigma_T} = (Q^2/M^2)^\kappa / \xi$$

$$\xi = 2.16 \pm 0.05, \kappa = 0.74 \pm 0.02$$

Q² [GeV²]

ZEUS 96-99 Preliminary

$\sigma_{tot}(\gamma^* p \rightarrow J/\psi p)$ [nb]

10^2

10

1

W = 90 GeV

ZEUS 96-99 (Preliminary)
ZEUS 95
H1 95-97
ZEUS PhP (Preliminary)
H1 PhP
Fit with $(Q^2 + M_{J/\psi}^2)^{-n}$

$n = 2.60 \pm 0.11^{+0.08}_{-0.05}$
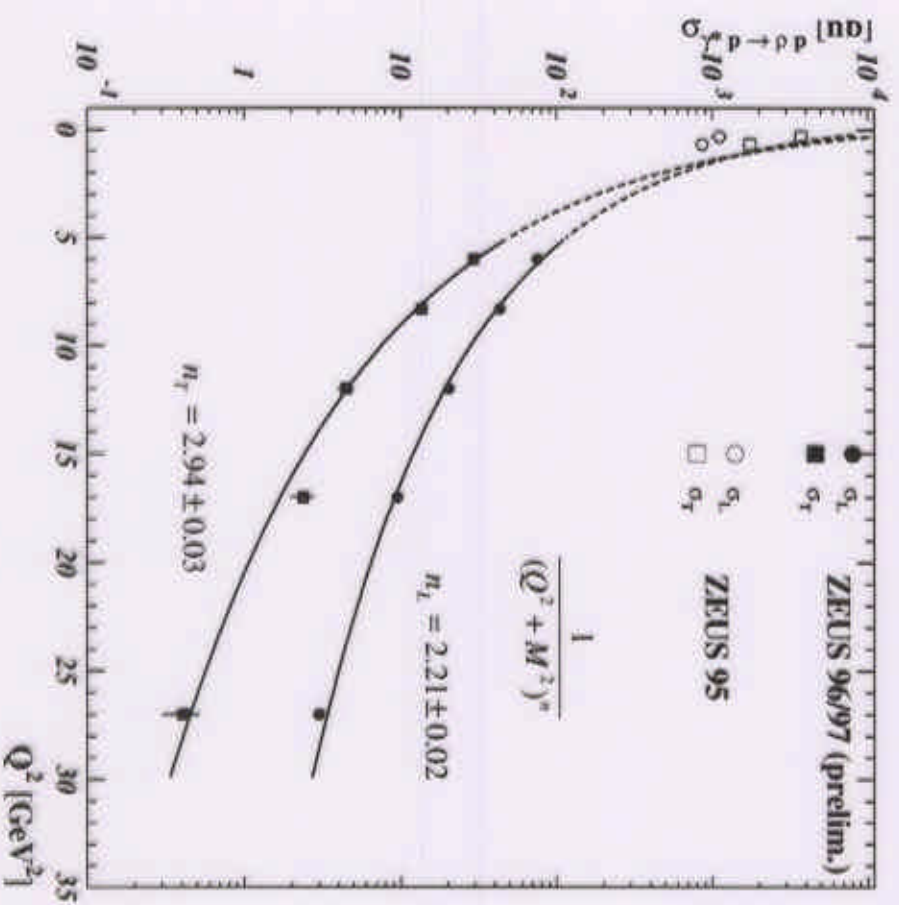
FKS (CTEQ4M)
MRT (CTEQ5M)
MRT (MRST99)

1   10

Q^2 [GeV^2]

Electroproduction of J/Psi (Cont.)

(Abstract #879, ZEUS Preliminary)

Transverse and longitudinal cross sections are extracted

R does not depend on W !

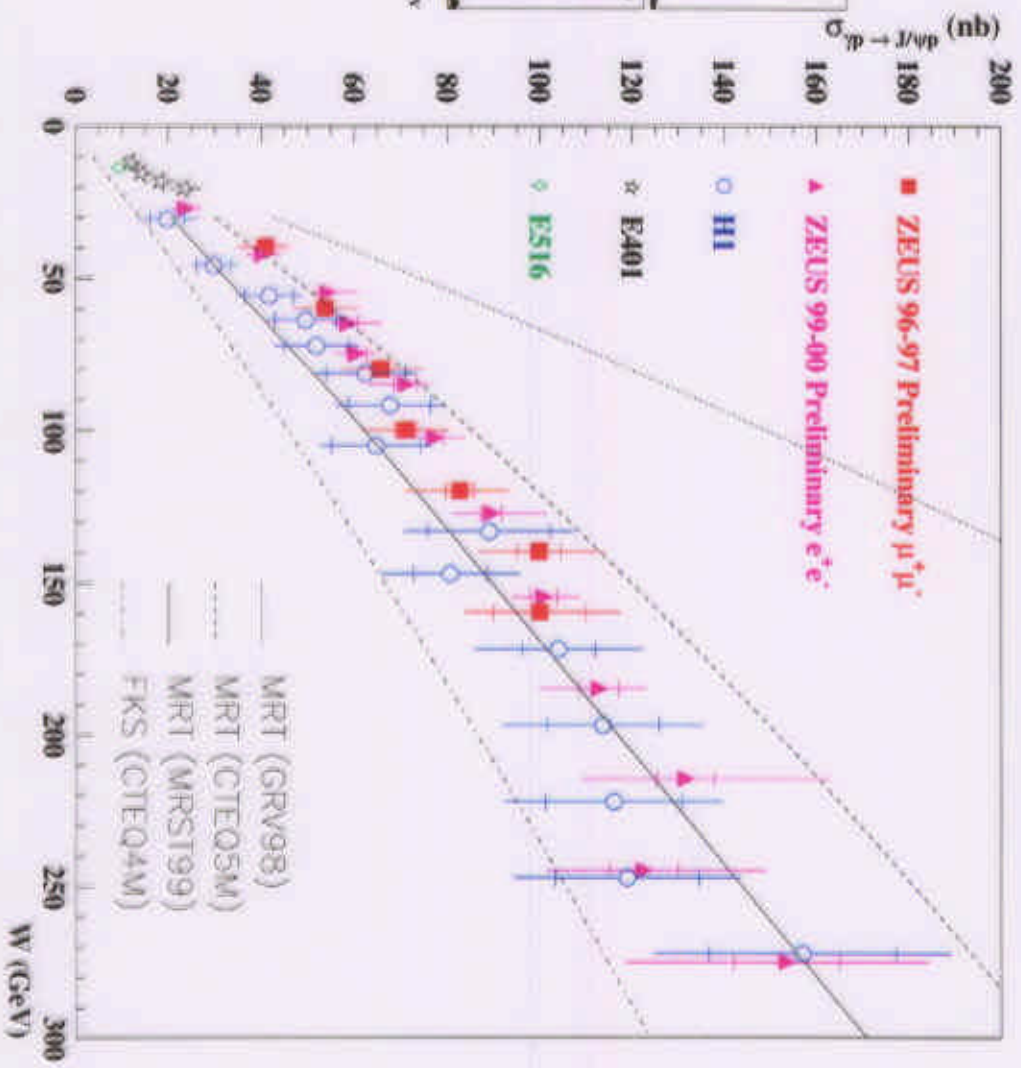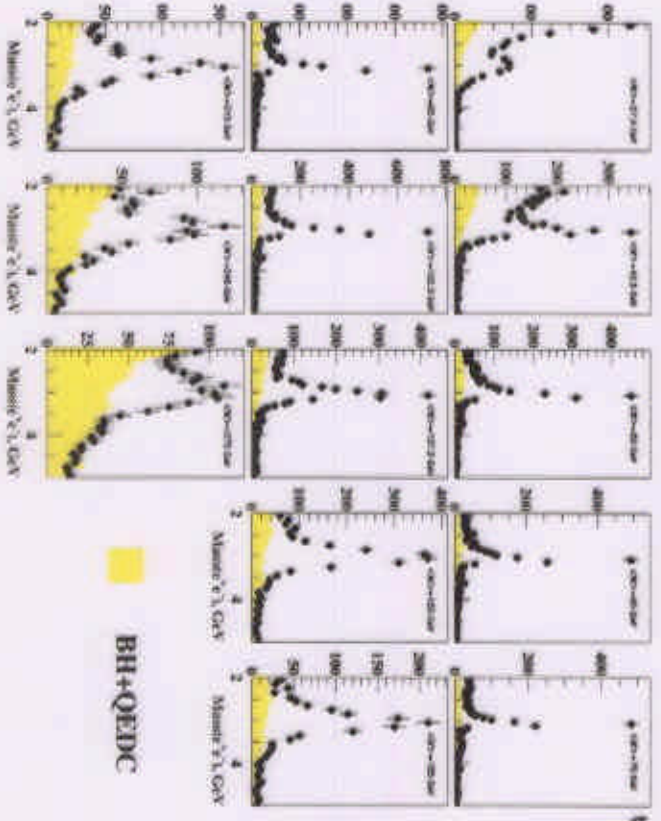$\sigma_{\gamma^* p \to \rho p}$ [nb]

σ_L σ_T

ZEUS 96/97 (prelim.)

ZEUS 95

$$\frac{1}{(Q^2 + M^2)^n}$$

$n_T = 2.94 \pm 0.03$

$n_L = 2.21 \pm 0.02$

Q^2 [GeV^2]

$R = \sigma_L / \sigma_T$

ZEUS 96/97 (prelim.)

$Q^2 = 19$ [GeV^2]
$Q^2 = 12$ [GeV^2]
$Q^2 = 7$ [GeV^2]

W [GeV]

Photoproduction of J/Psi

(Abstract #878, ZEUS Preliminary)
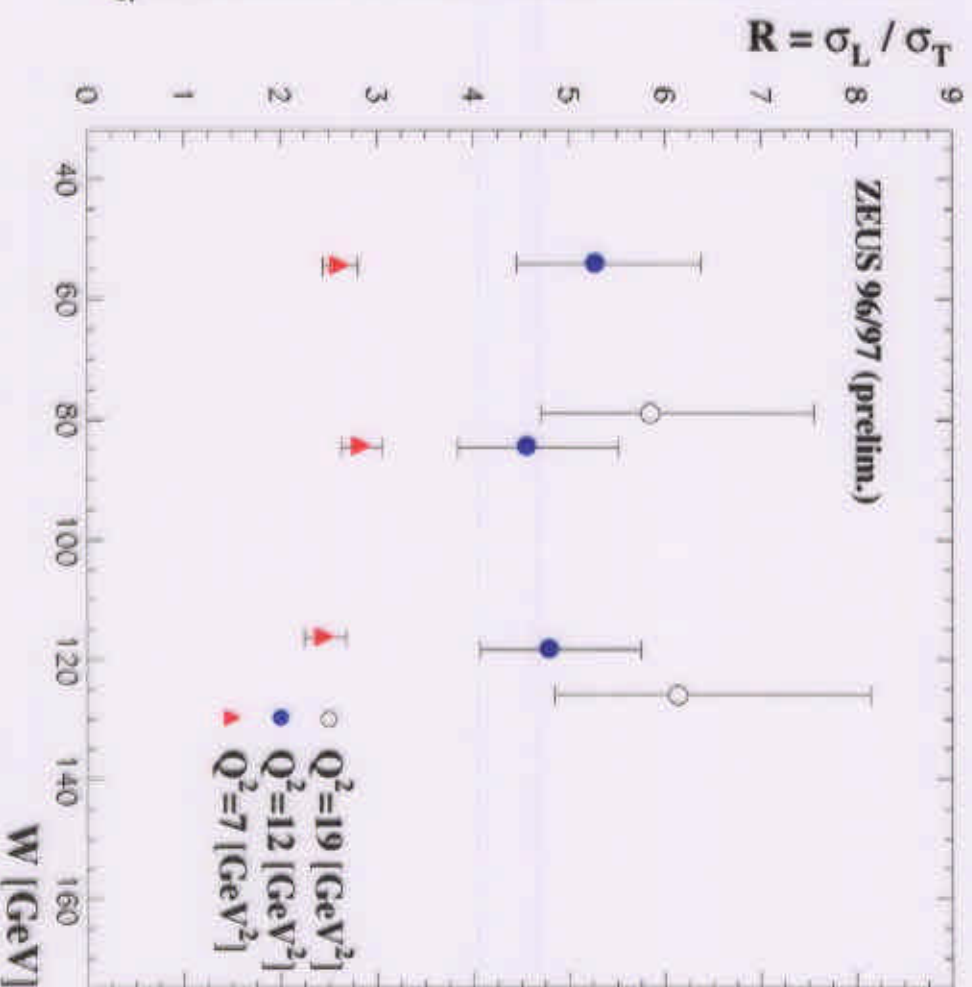
•48 pb-1 of data taken in 99-00
•Extension of W through combined use of tracking and CAL: 20<W<290 GeV
•21000 candidates

ZEUS 99-00 Preliminary

BH+QEDC

Steep rise of cross section with W

$\sigma_{\gamma p \to J/\psi p}$ (nb)

■ ZEUS 96-97 Preliminary $\mu^+\mu^-$
▲ ZEUS 99-00 Preliminary e^+e^-
○ H1
☆ E401
◇ E516

——— MRT (GRV98)
- - - - MRT (CTEQ5M)
——— MRT (MRST99)
········· FKS (CTEQ4M)

W (GeV)

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

Photoproduction of J/Psi (Cont.)

(Abstract #878, ZEUS Preliminary)

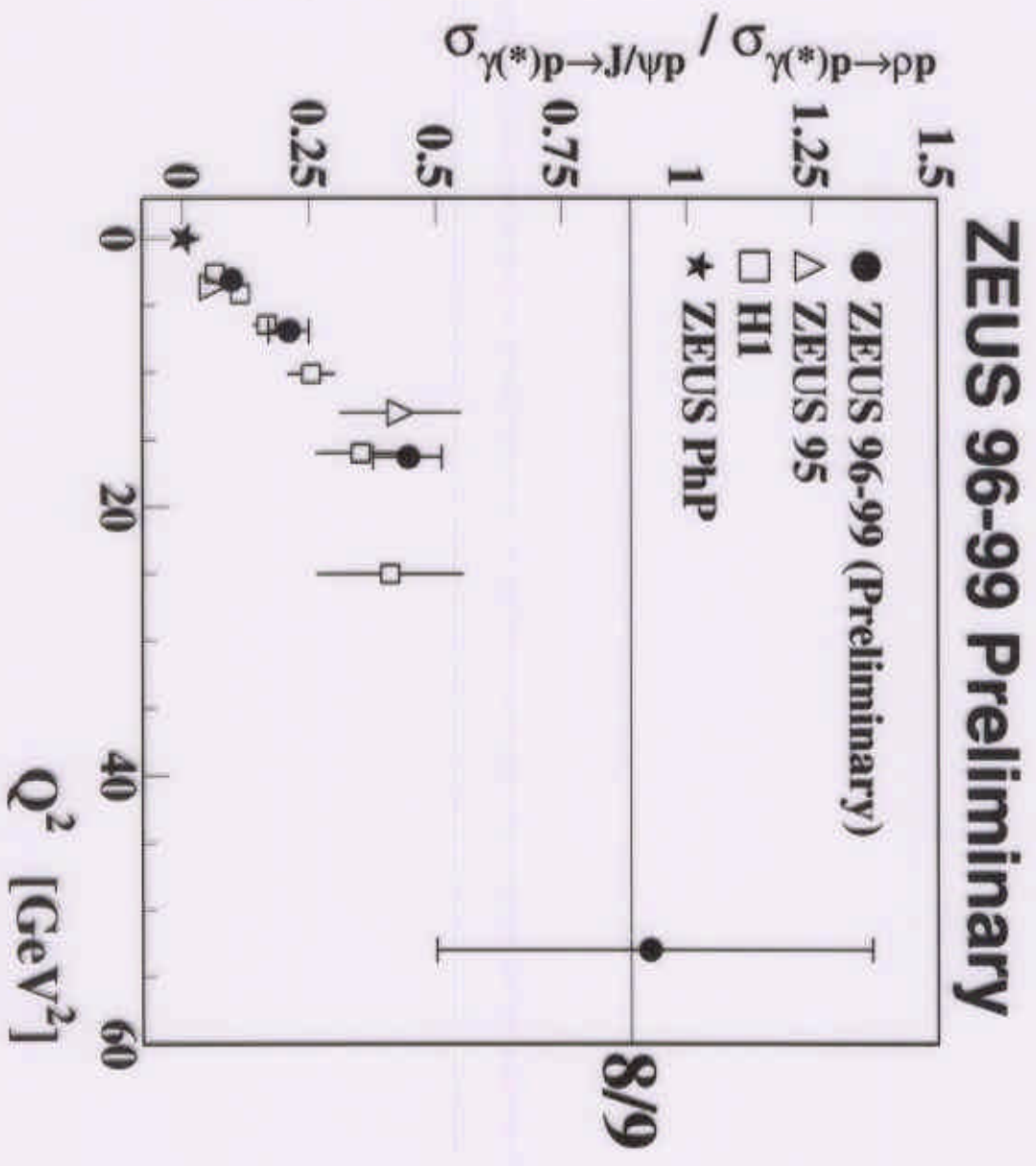- ● ZEUS 96-97 Preliminary
- ▼ H1
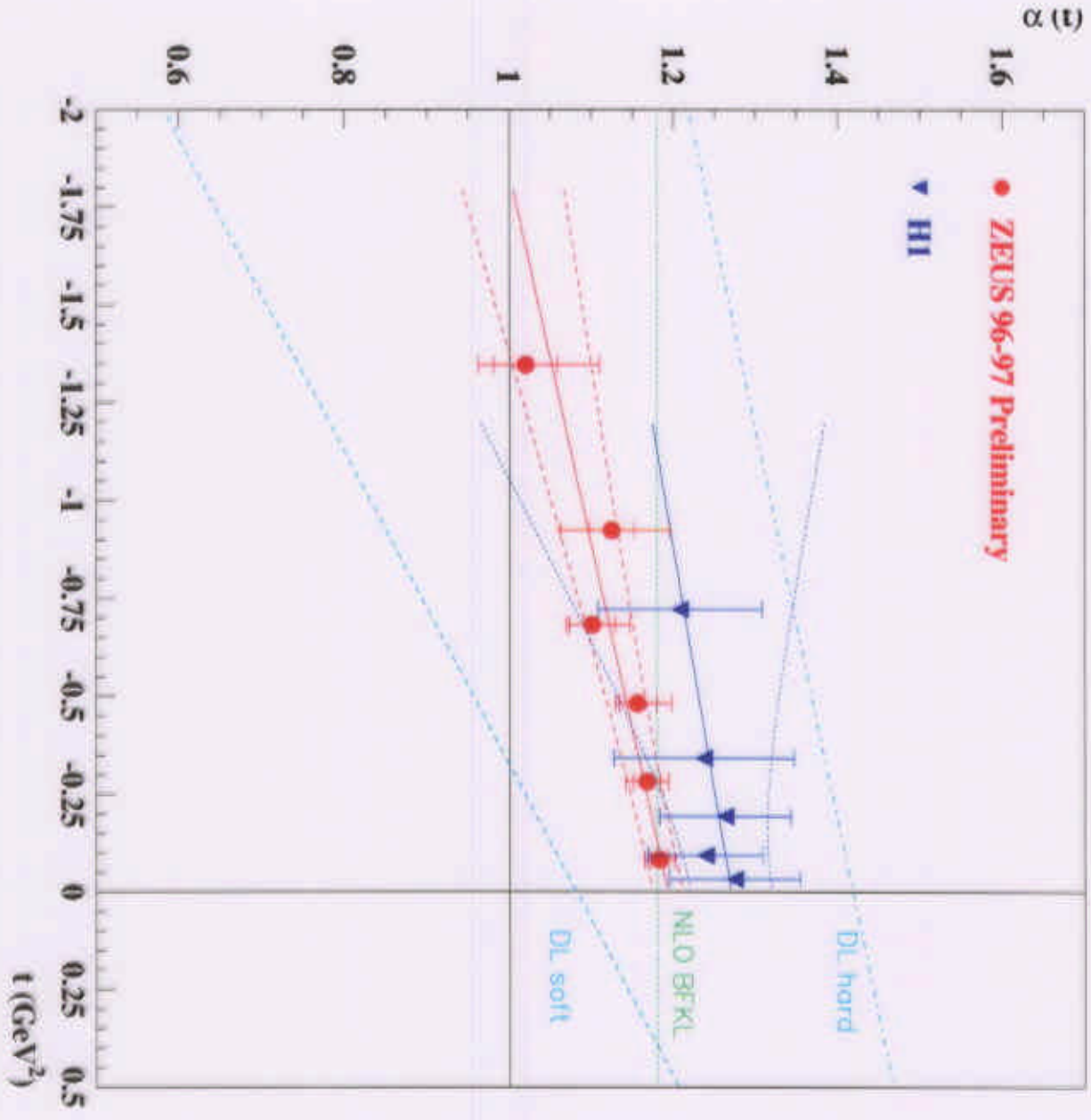
Small Shrinkage

Cross section ratio rises with Q^2

Electroproduction of J/Psi (Cont.)

(Abstract #879, ZEUS Preliminary)

ZEUS 96-99 Preliminary

$\sigma_{\gamma(*)p\to J/\psi p} / \sigma_{\gamma(*)p\to\rho p}$

- ● ZEUS 96-99 (Preliminary)
- △ ZEUS 95
- □ H1
- ★ ZEUS PhP

8/9

Q^2 [GeV²]

Photoproduction of Psi(2S)

(Abstract #987 985, H1 Preliminary)
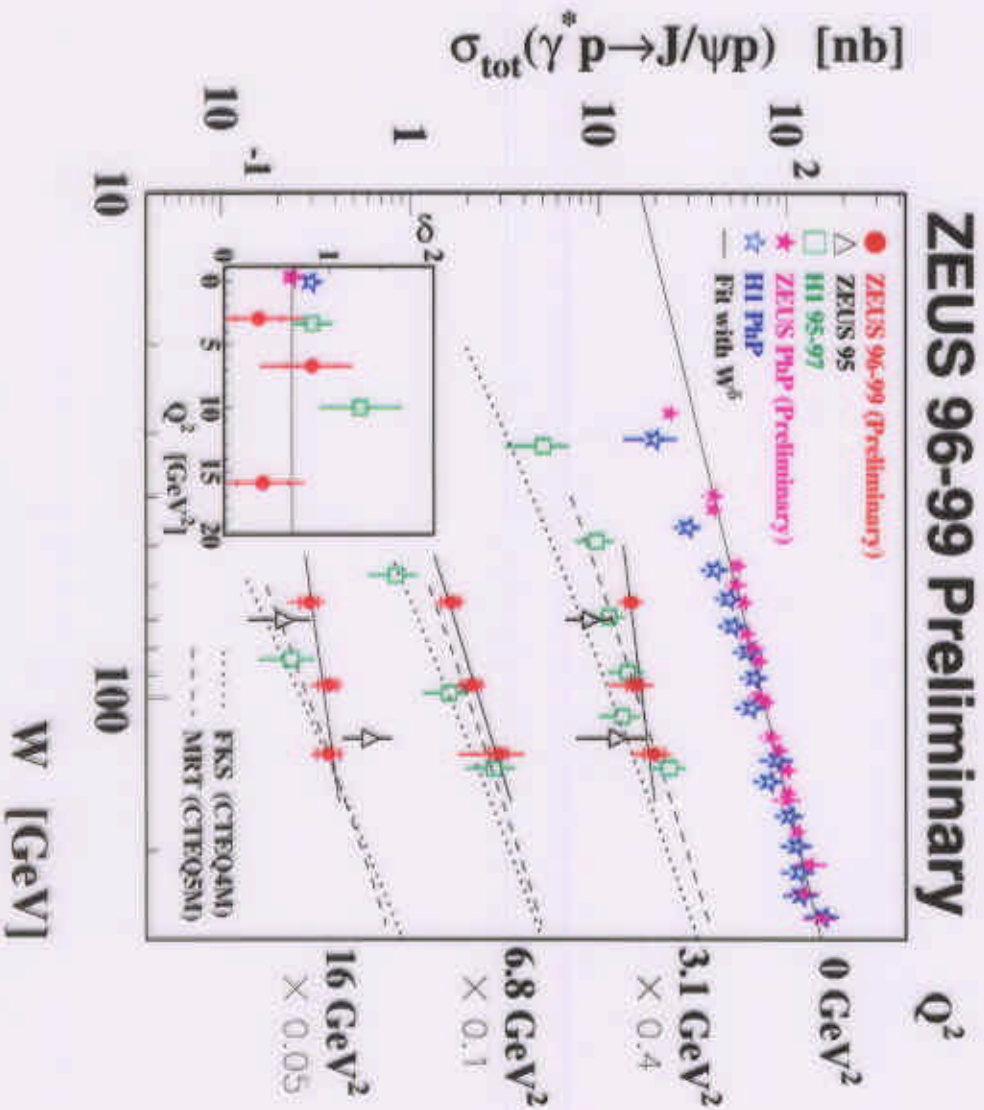
- 38 pb⁻¹ taken during 1996-1999
- 40<W<150 GeV
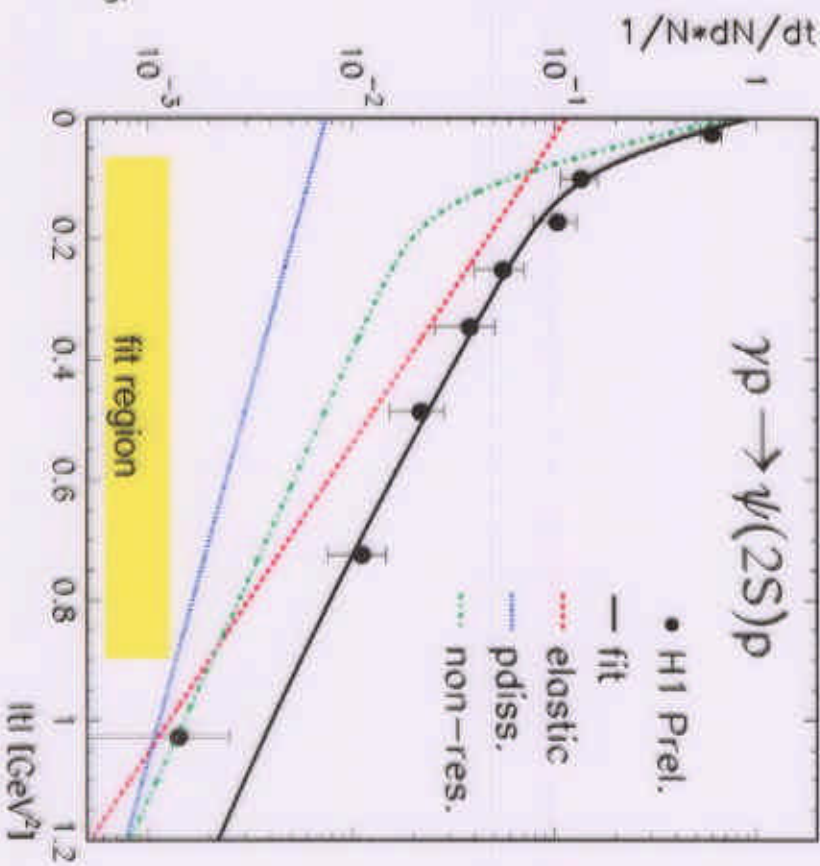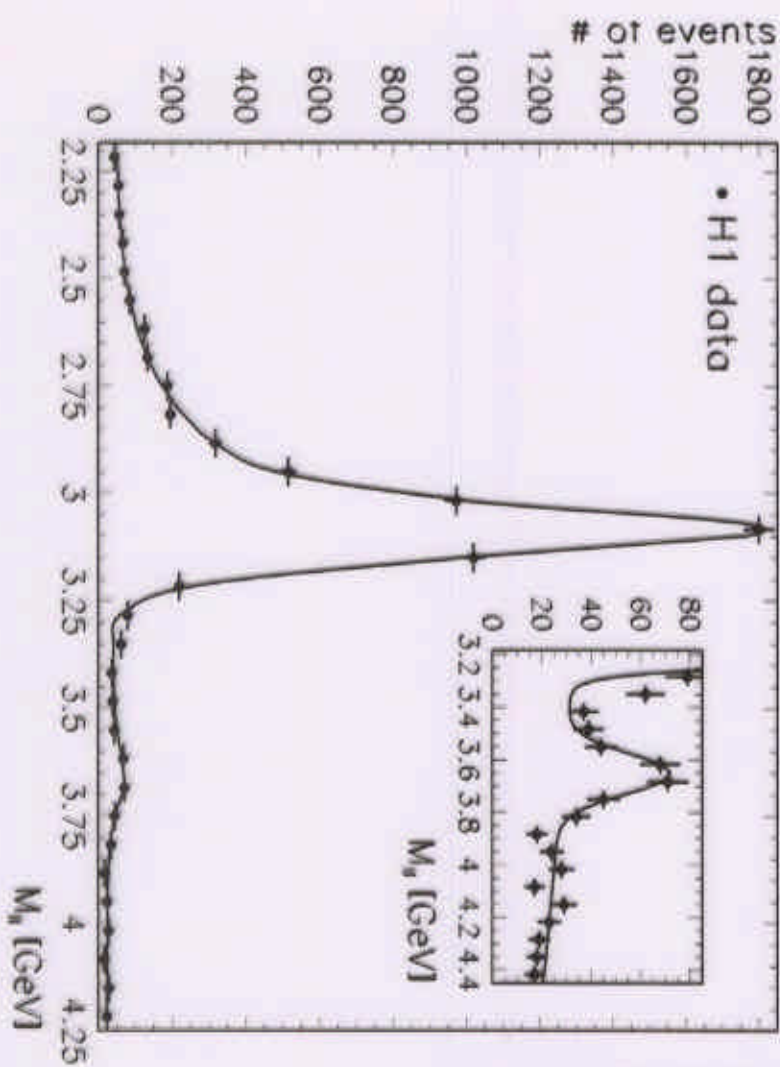
$$b_{\psi(2S)} = (4.5 \pm 1.2^{+1.4}_{-0.7})GeV^{-2}$$

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

Electroproduction of J/Psi

(Abstract #879, ZEUS Preliminary)

ZEUS 96-99 Preliminary

$\sigma_{tot}(\gamma^* p \rightarrow J/\psi p)$ [nb]

- ● ZEUS 96-99 (Preliminary)
- △ ZEUS 95
- □ H1 95-97
- ★ ZEUS PhP (Preliminary)
- ☆ H1 PhP
- — Fit with W^δ

..... FKS (CTEQ4M)
– – – MRT (CTEQ5M)

Q²

0 GeV²

3.1 GeV²
× 0.4

6.8 GeV²
× 0.1

16 GeV²
× 0.05

δ

Q² (GeV²)

W [GeV]

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

Steep rise of cross section with W does not depend on Q²

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
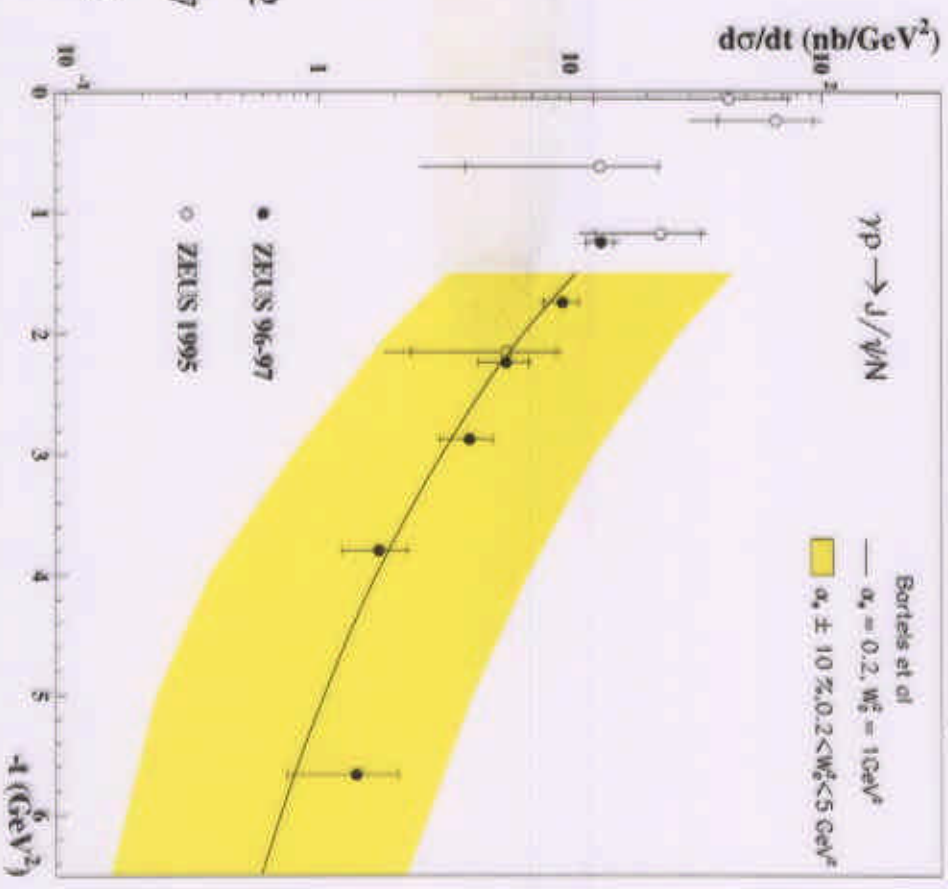- pQCD calculations describe J/Psi

ZEUS 96 - 97 Preliminary

dσ/dt (nb/GeV²)

γp → ρN

- ZEUS 96-97
○ ZEUS 1995

-t (GeV²)
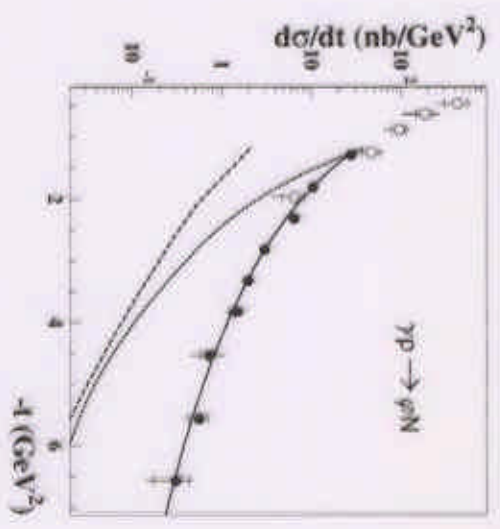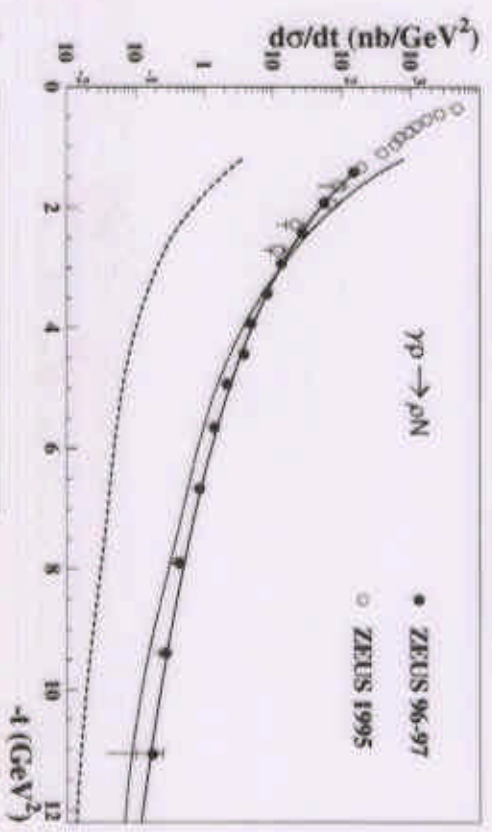
$$\frac{d\sigma}{d|t|} \propto |t|^{-n}$$

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

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

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

dσ/dt (nb/GeV²)

γp → φN

-t (GeV²)

ZEUS 96-97 Preliminary

dσ/dt (nb/GeV²)

γp → J/ψN

- ZEUS 96-97
○ ZEUS 1995

Bartels et al
— α_s = 0.2, W² = 1GeV²
α_s ± 10 %,0.2<W²<5 GeV²

-t (GeV²)

- Ratio Phi/Rho approaches SU(4) at
  |t|=3-4 GeV²
- Ratio J/Psi/Rho is suppressed
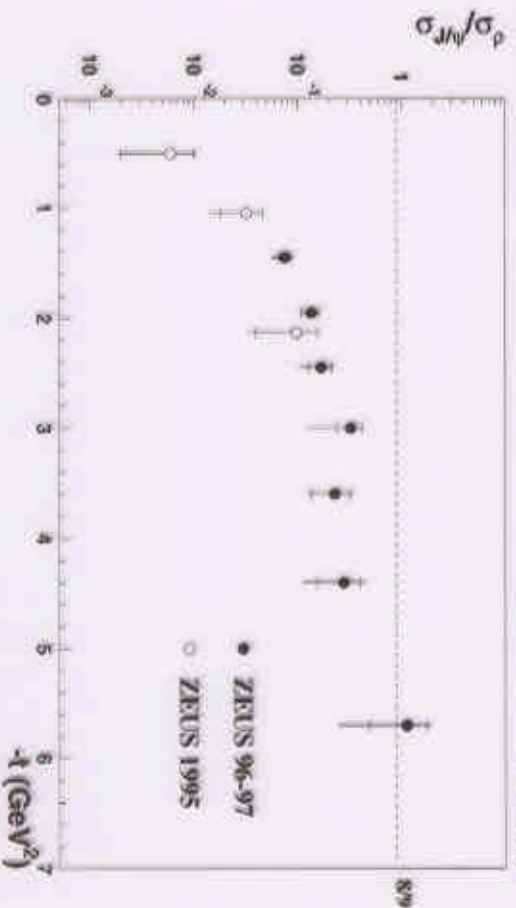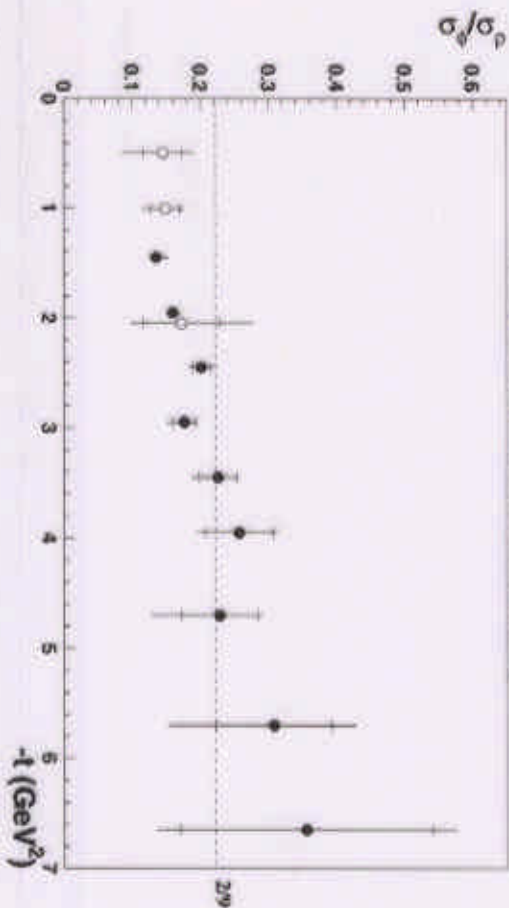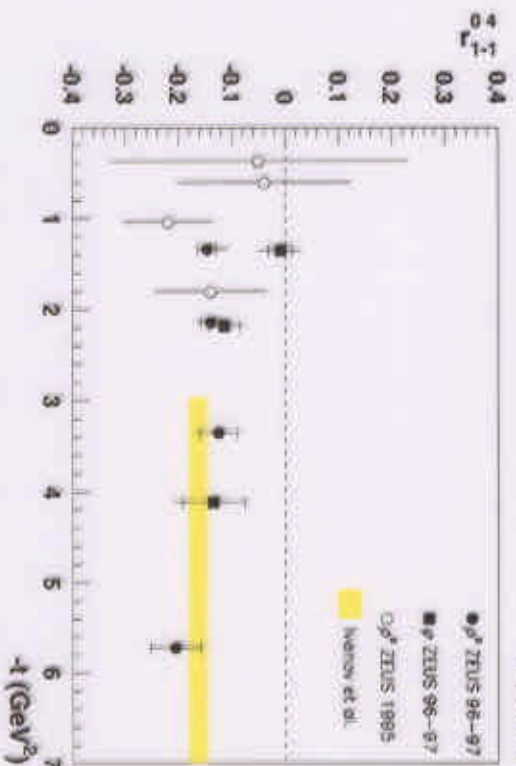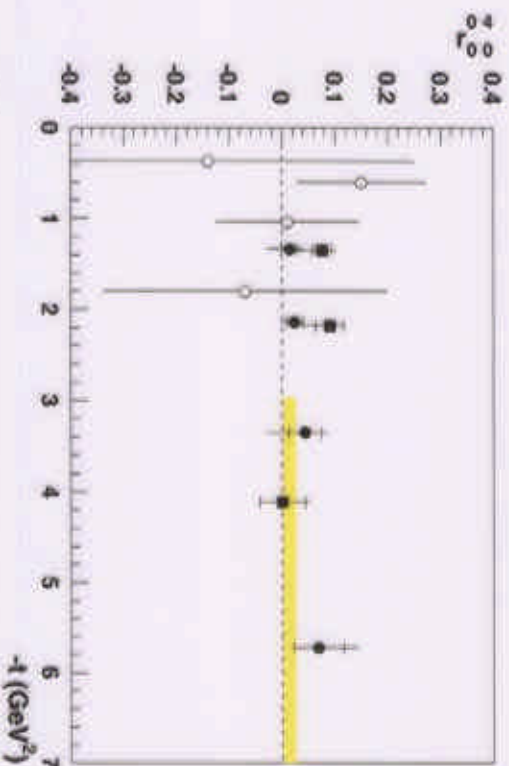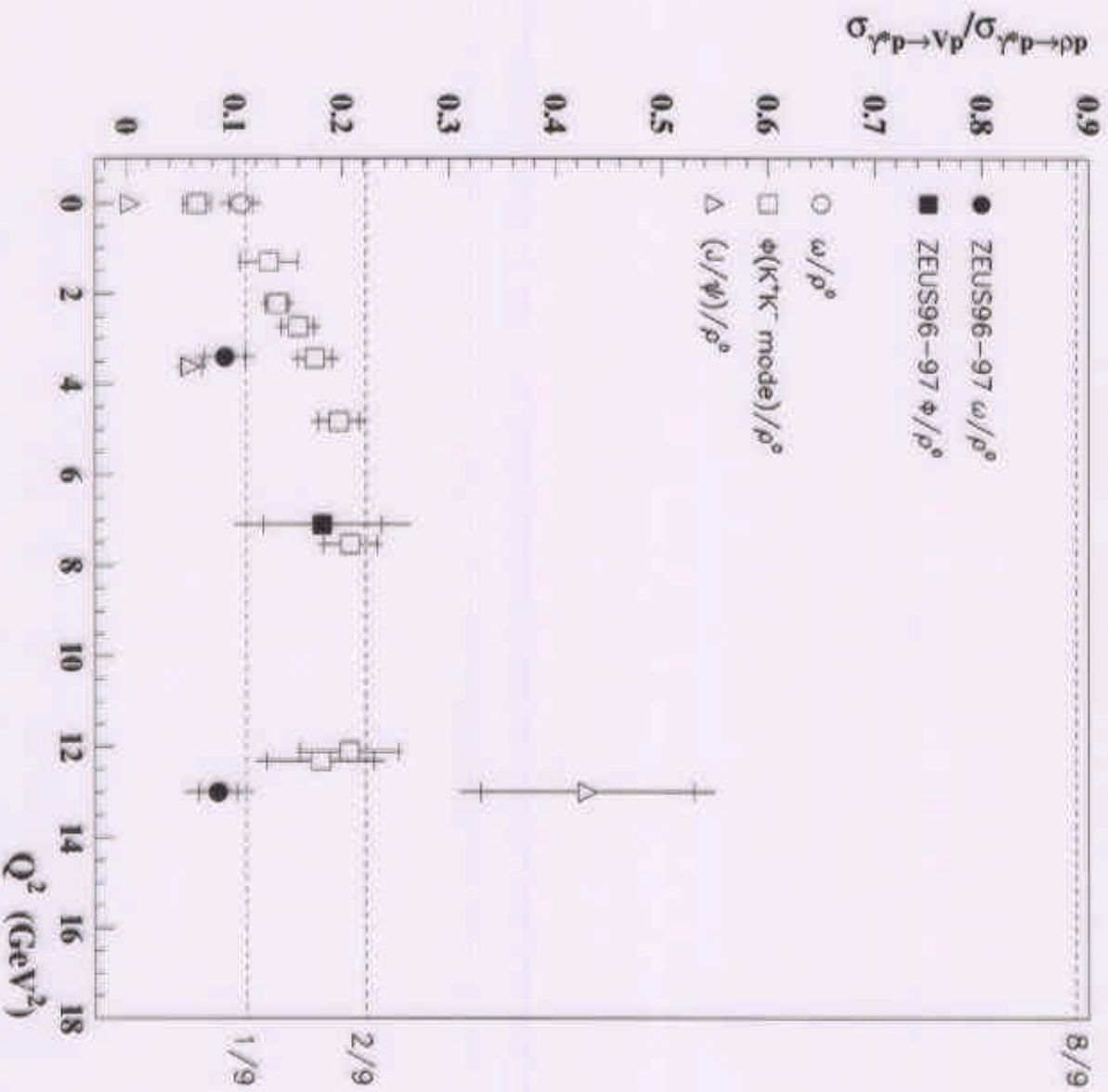
Proton dissociative VM production at High |t| (Cont.)

(Abstract #884, ZEUS preliminary)

SCHC breaking, consistent with pQCD
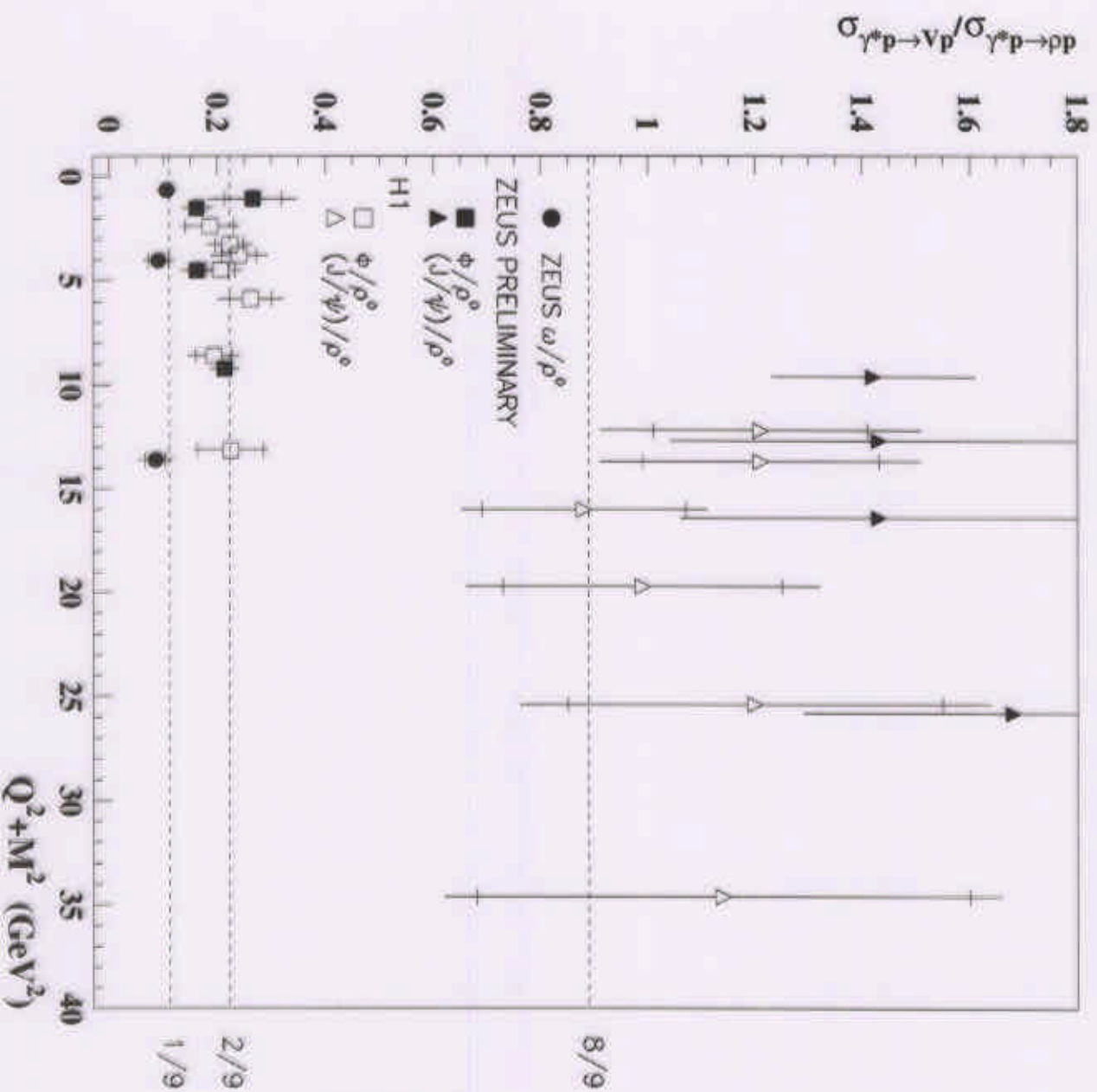

ZEUS 96 - 97 Preliminary

ZEUS 96-97 Preliminary

ZEUS 1996 - 1997

$\sigma_{\gamma^*p \to Vp}/\sigma_{\gamma^*p \to \rho p}$

- ● ZEUS96−97 ω/ρ^0
- ■ ZEUS96−97 Φ/ρ^0
- ○ ω/ρ^0
- □ $\Phi(K^+K^-\ mode)/\rho^0$
- △ $(J/\psi)/\rho^0$

Q^2 (GeV^2)

VM production at HERA
show that |t|, Q2 are not
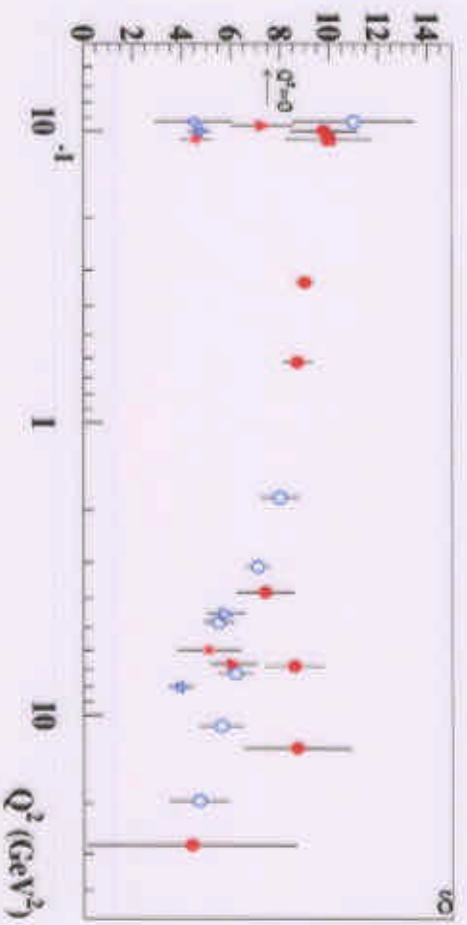universal scales

Elastic VM production at HERA

In elastic VM production |t| is small, try with Q^2+M^2
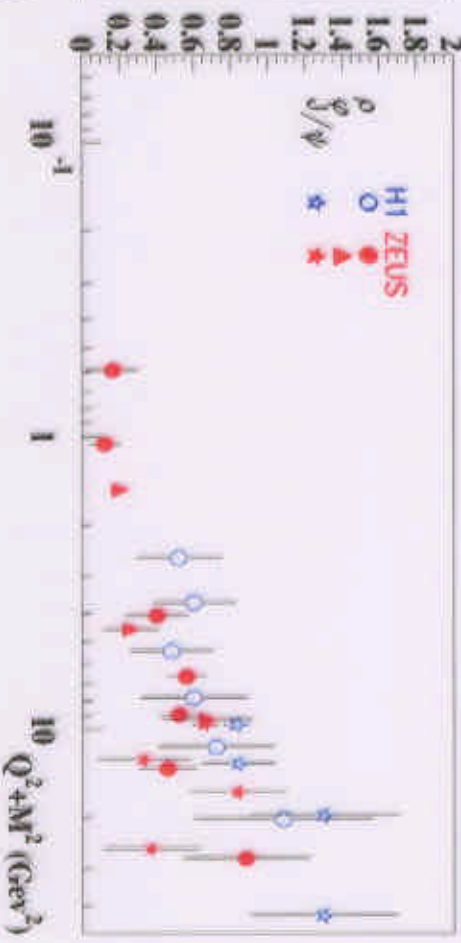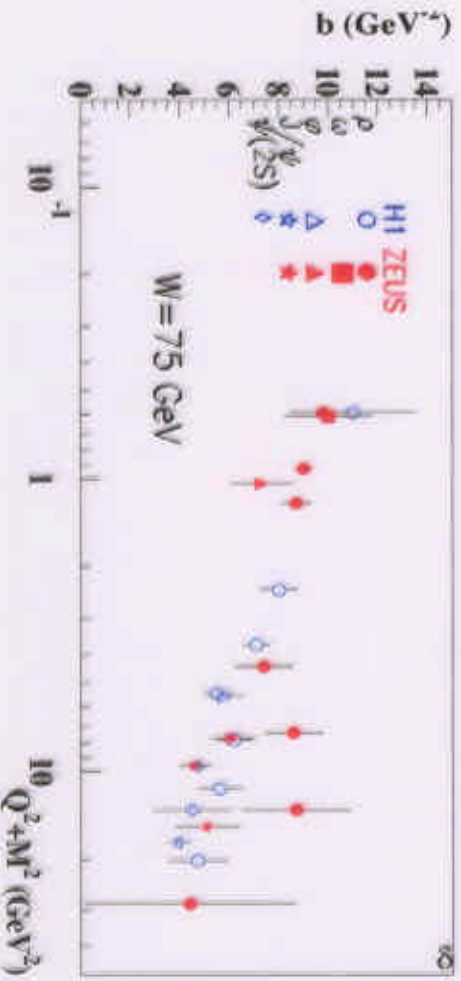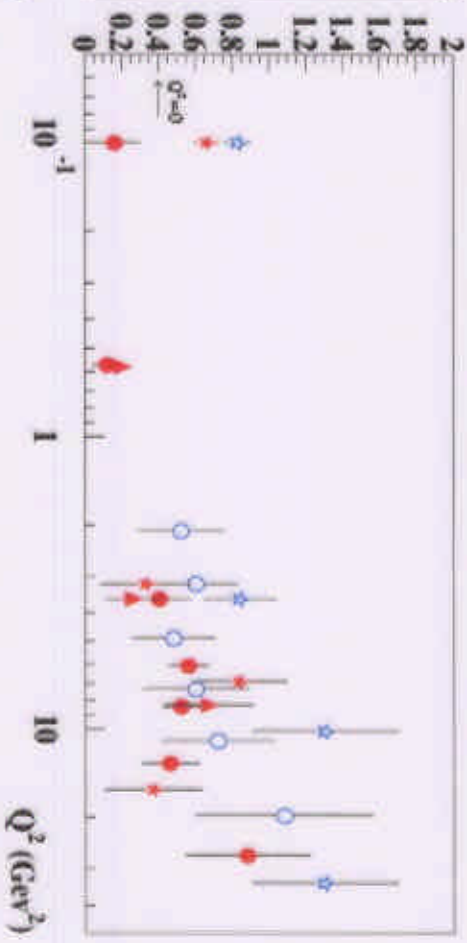
Ratios are constant with Q^2+M^2

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

Elastic VM Production at HERA
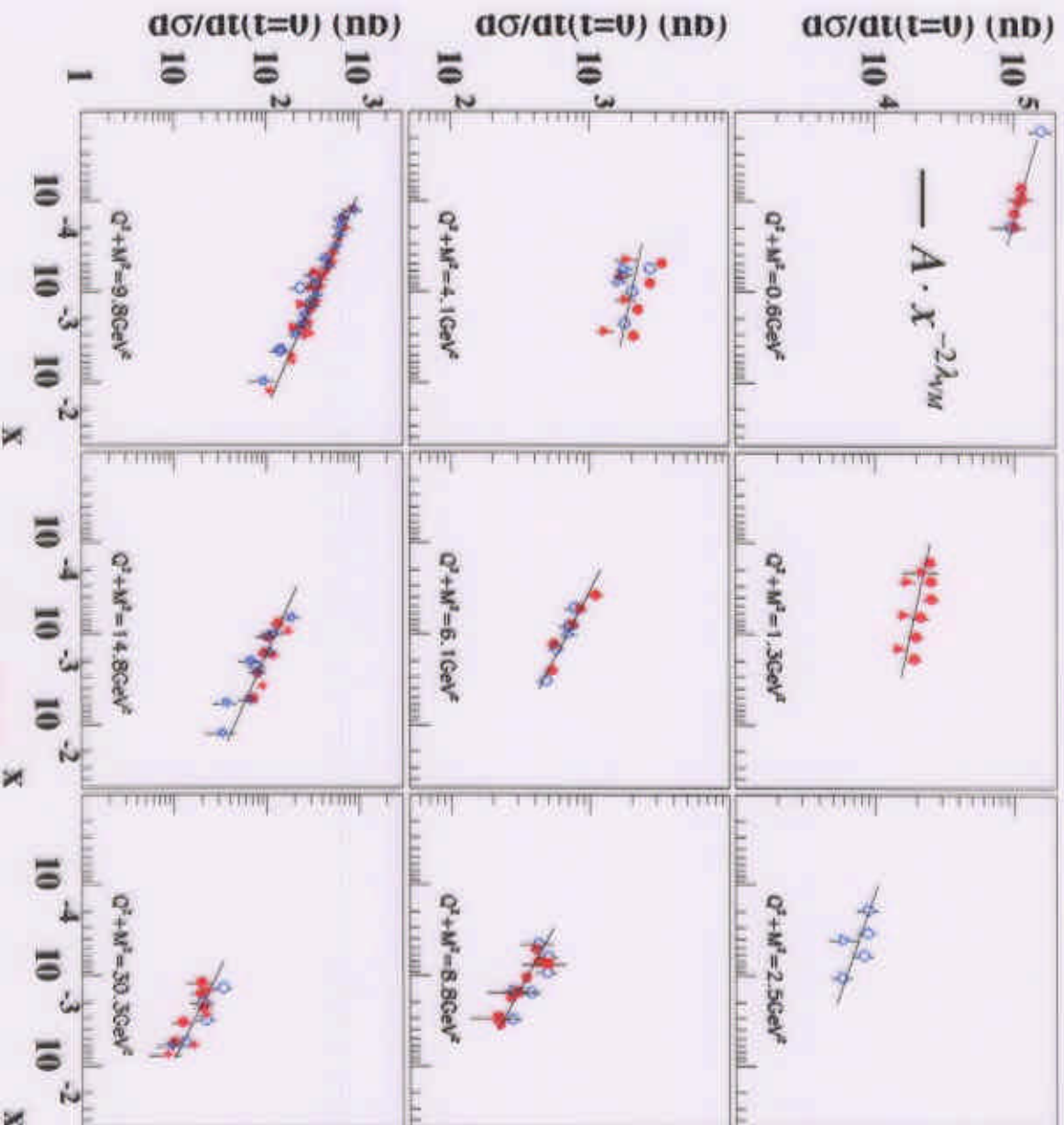
$$\sigma(W) \propto W^\delta$$

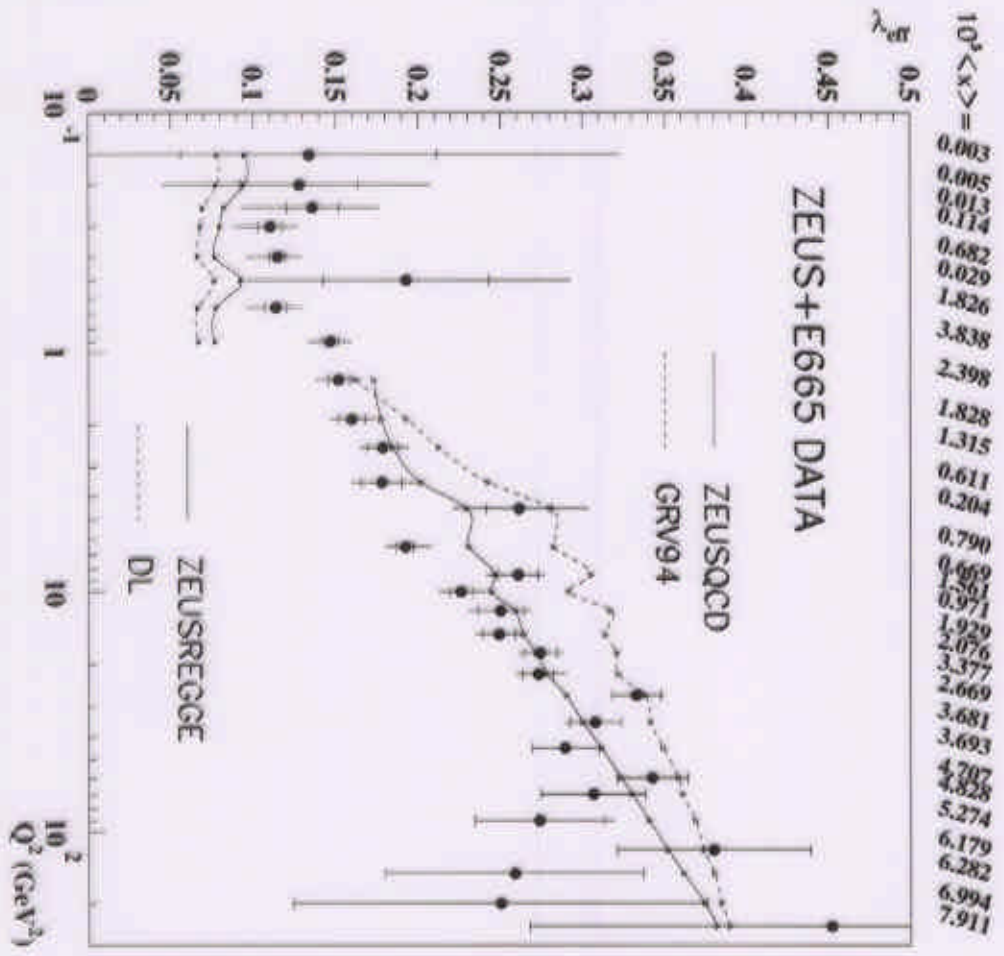Elastic VM Production at HERA

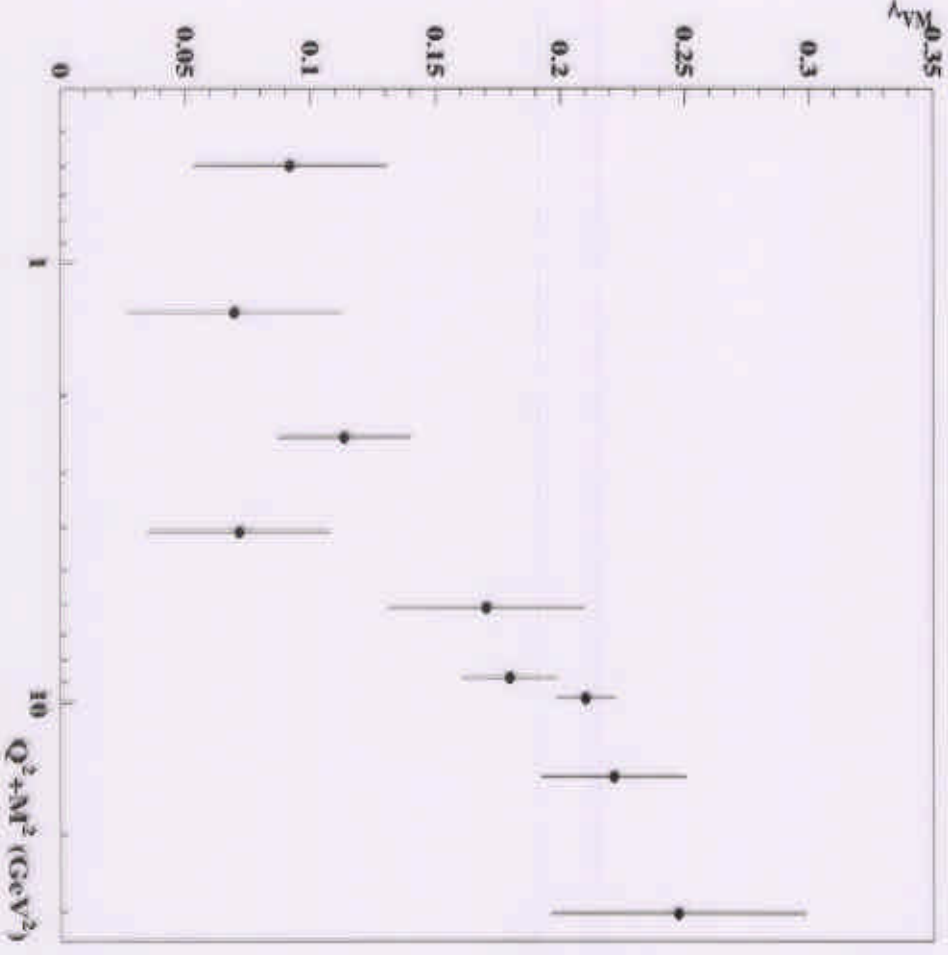# Elastic VM Production at HERA

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

Cross sections scale
with Q^2+M^2

Elastic VM Production at HERA

ZEUS 1995

Similar x dependence to inclusive

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