Vector Mesons Electroproduction in ep interactions

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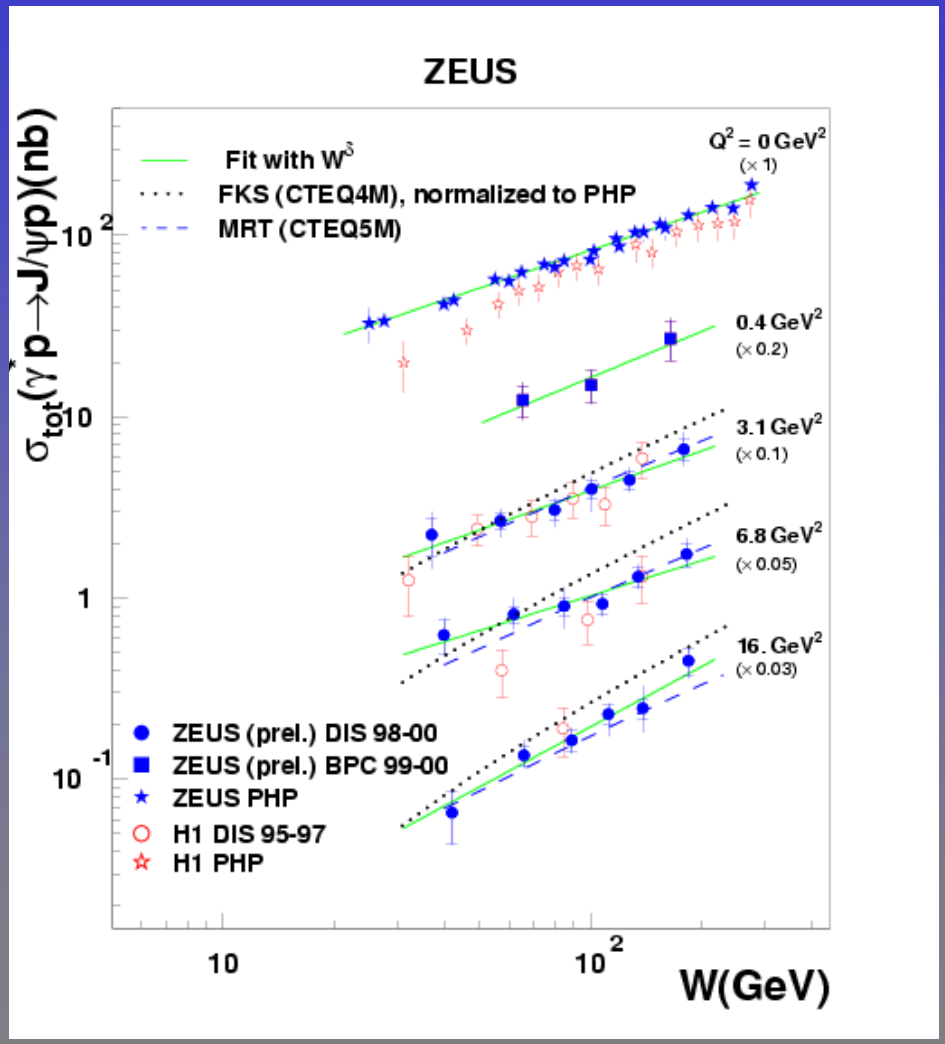
Energy dependence of ratios of cross sections

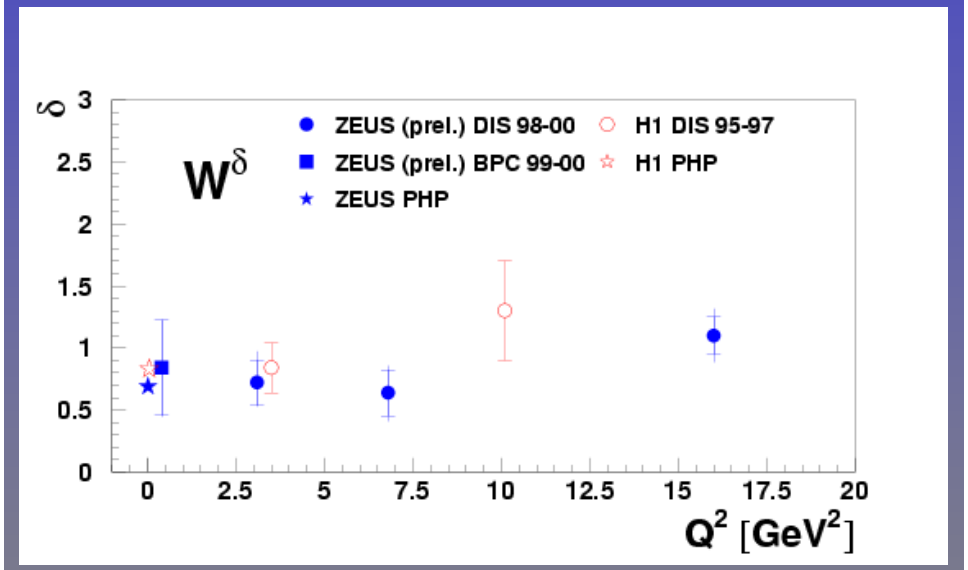
- Test universality of scaled VM cross sections by SU(4) factors at a scale of $Q^2 + M^2_V$
- Study the ratio $\frac{\sigma(\gamma^* p \to Vp)}{\sigma(\gamma^* p)}$
- Study the ratio $\frac{\sigma^2(\gamma^* p)}{\sigma(\gamma^* p \to Vp)}$

New preliminary data on J/ψ



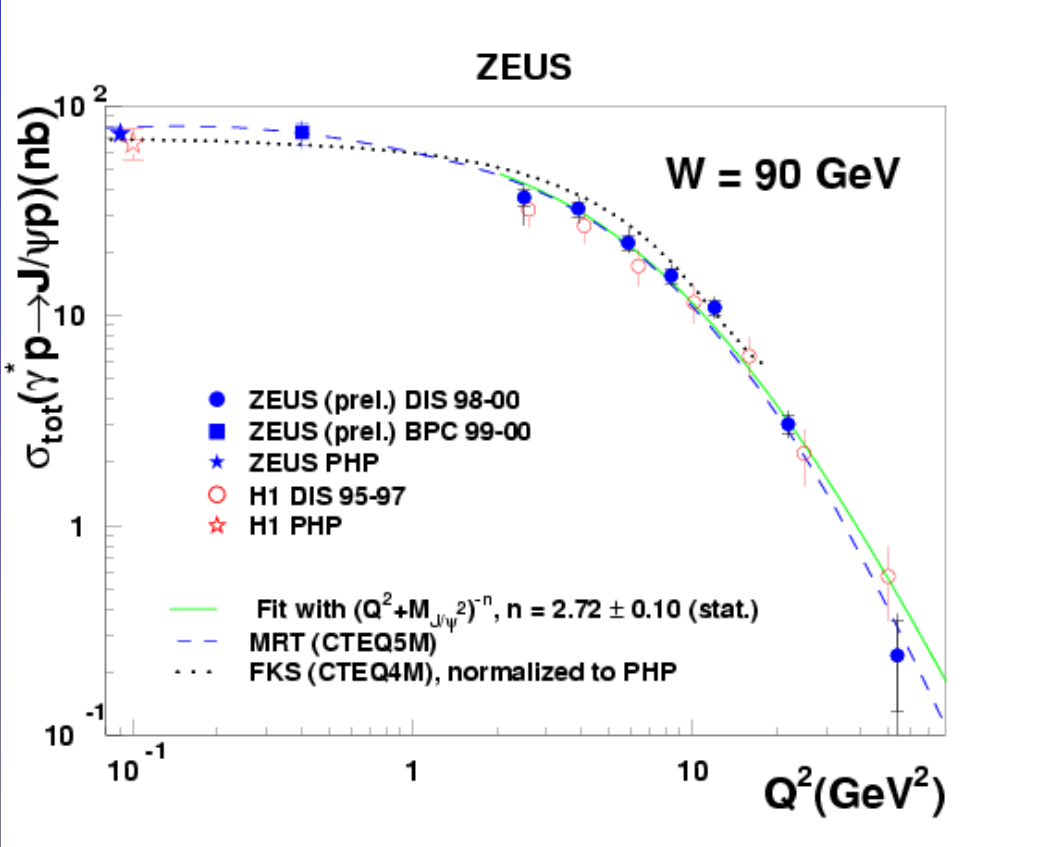
extended W range in DIS data

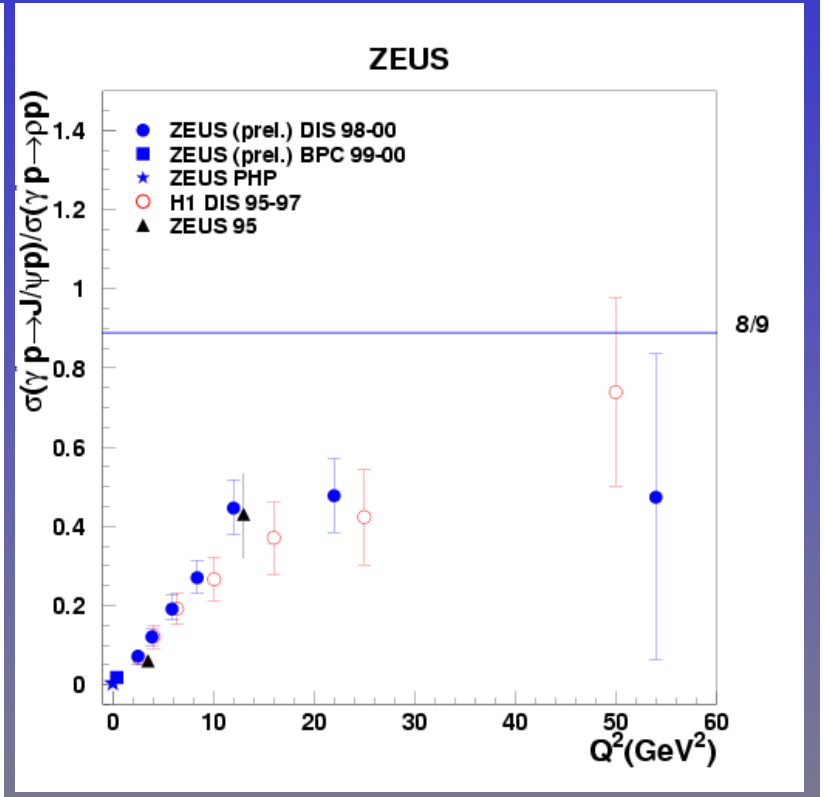
smaller errors on δ



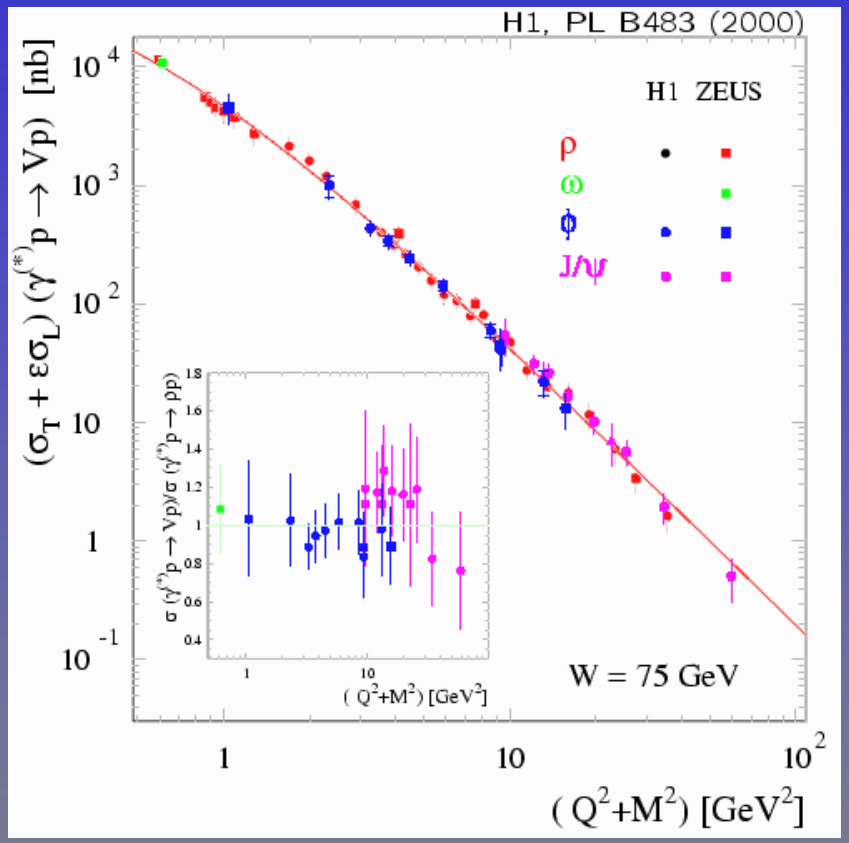
increase of δ with Q^2 ?

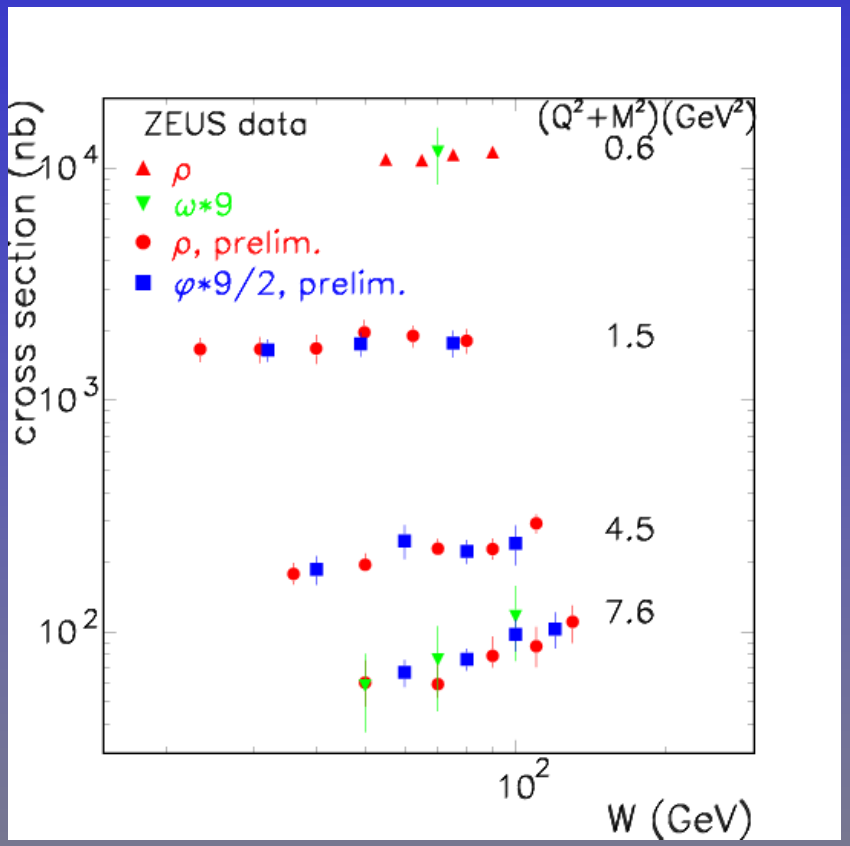
New preliminary data on J/ψ





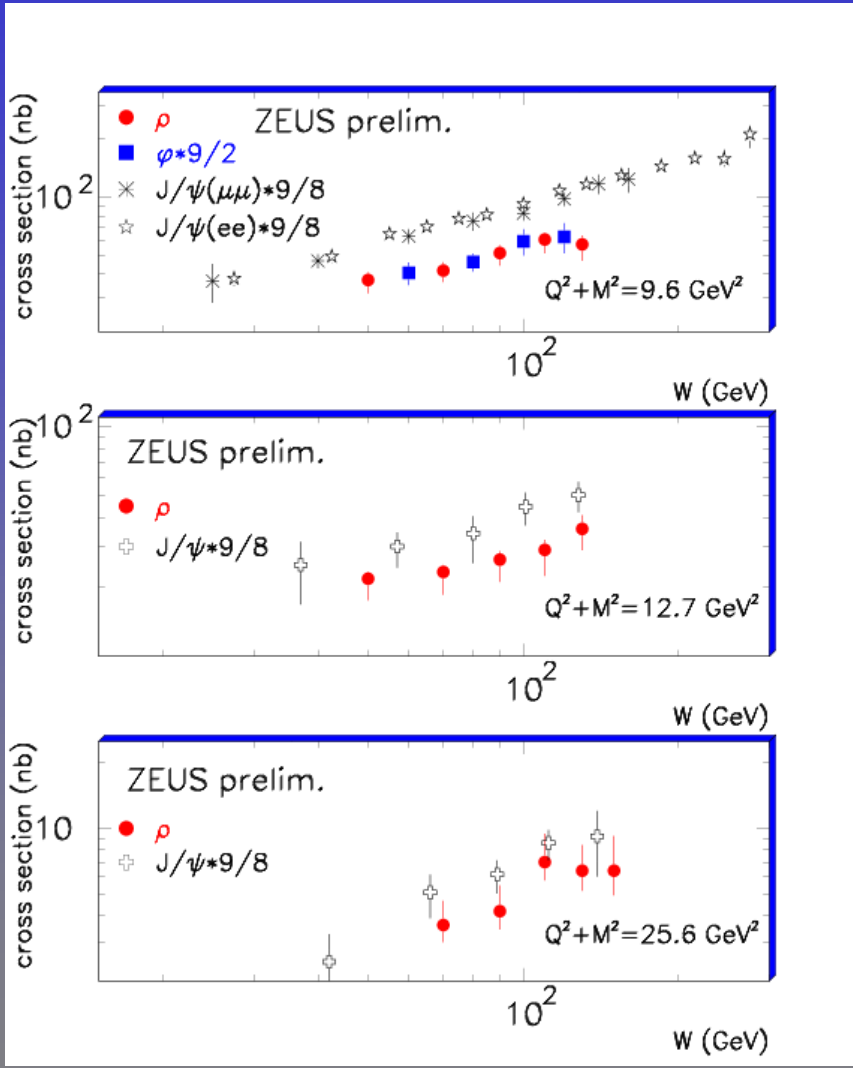
Universality?





Works well for light vector mesons, at all W.

Universality?



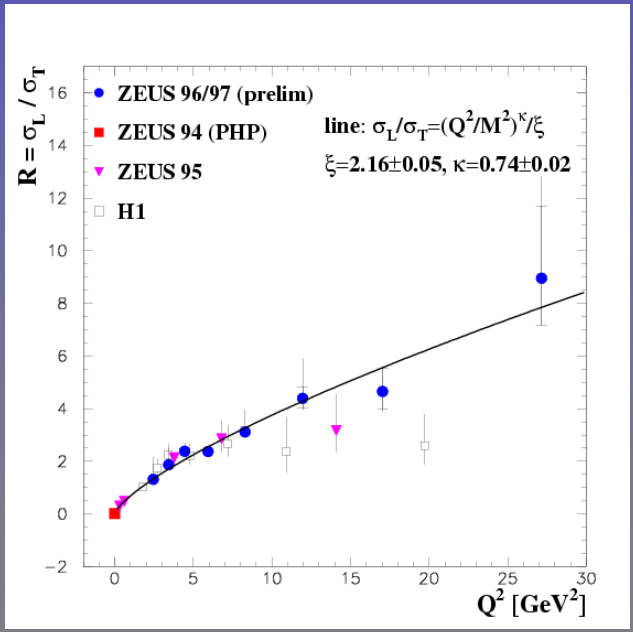
$\sigma_{J/\psi}$ scaled by SU(4) factor 9/8 is ≈ 40 % higher than σ_ρ

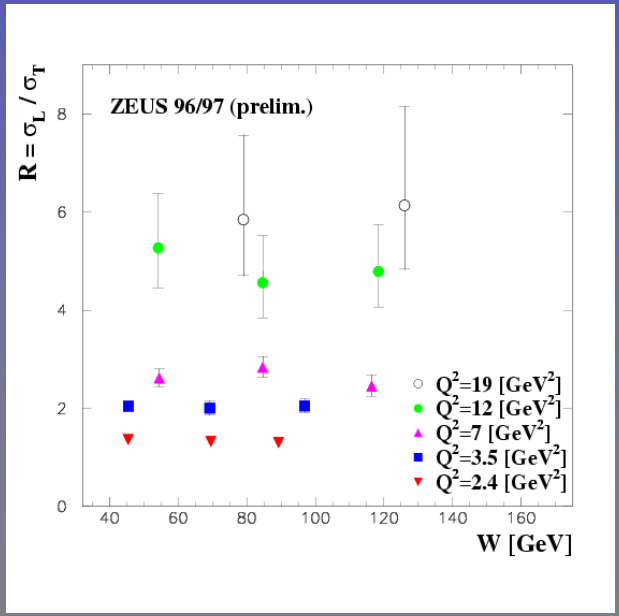
The ratio σ_V/σ_{tot}

pQCD:

$$\frac{\sigma_L}{\sigma_{tot}} \propto \frac{x^{-2\lambda(\mu^2)/b}}{x^{-\lambda(\mu^2)}} = x^{-\lambda/b} \propto W^{2\lambda/b}$$

- σ_L dominant
- R is W indep: σ_T same W dep as σ_L



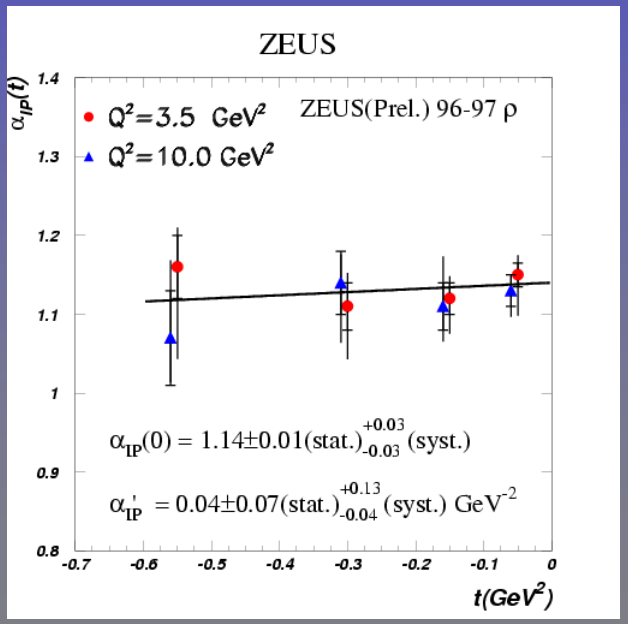


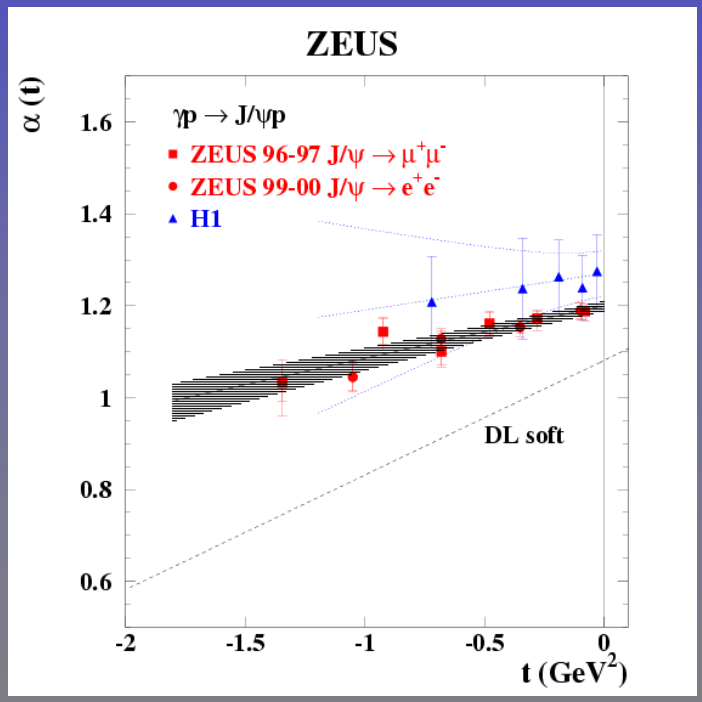
The ratio σ_V/σ_{tot}

Regge: $\sigma_V \sim W^{4(\alpha_P(0)-1)} / b$ $\sigma_{tot} \sim W^{2(\alpha_P(0)-1)}$

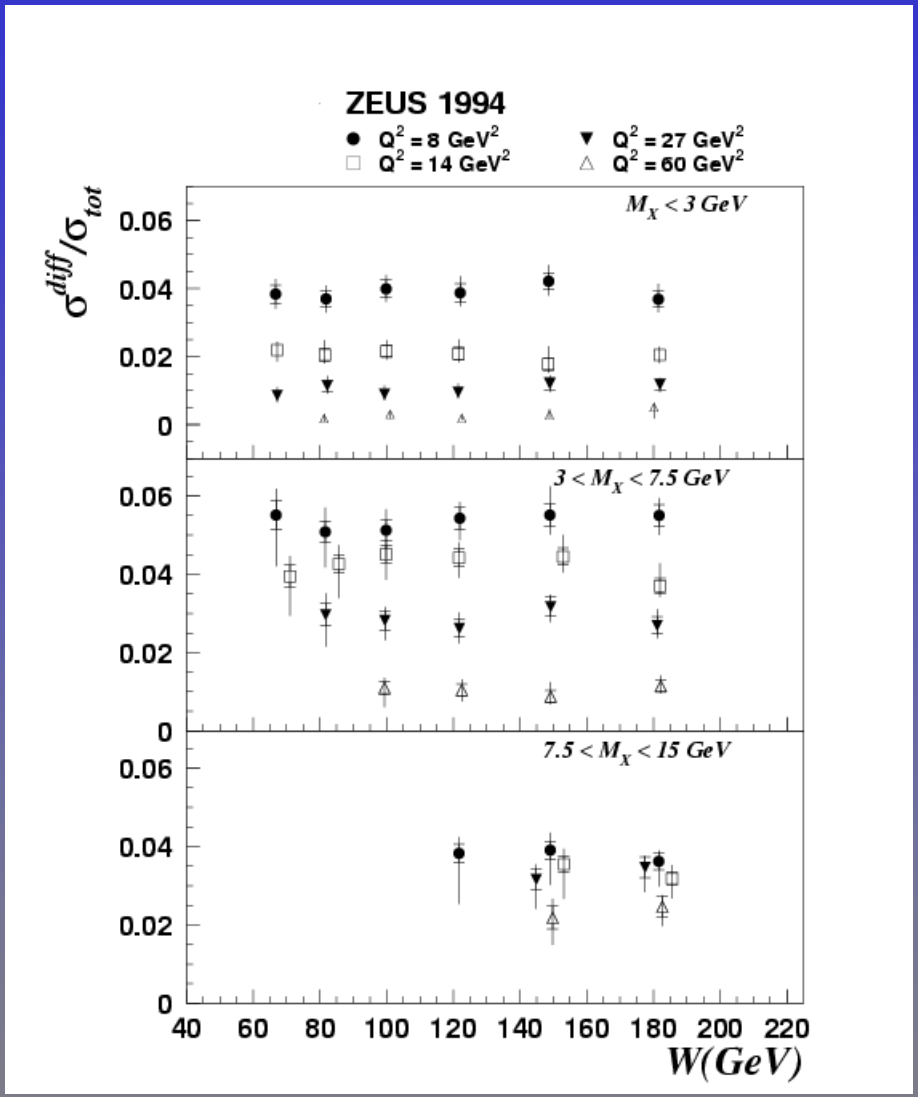
$\sigma_V/\sigma_{tot} \sim W^{2(\alpha_P(0)-1)} / b$ (same as pQCD)

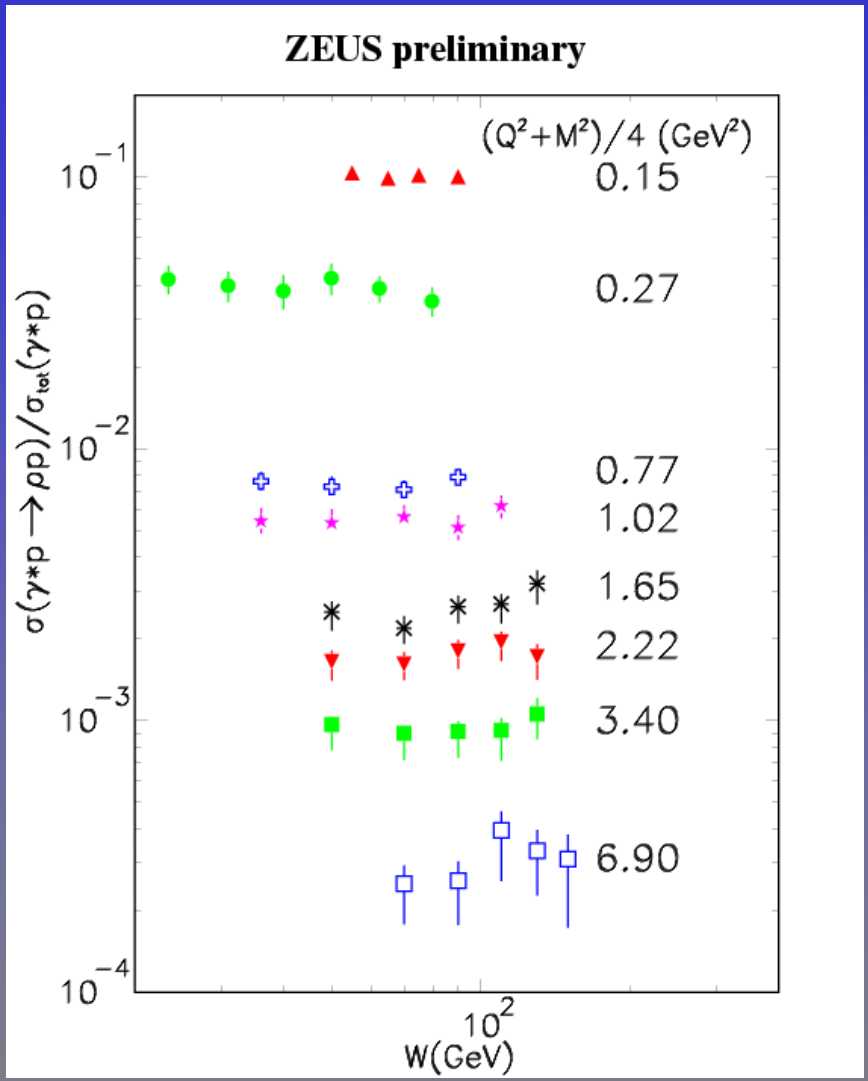
$b = b_0 + 4\alpha' \ln W$

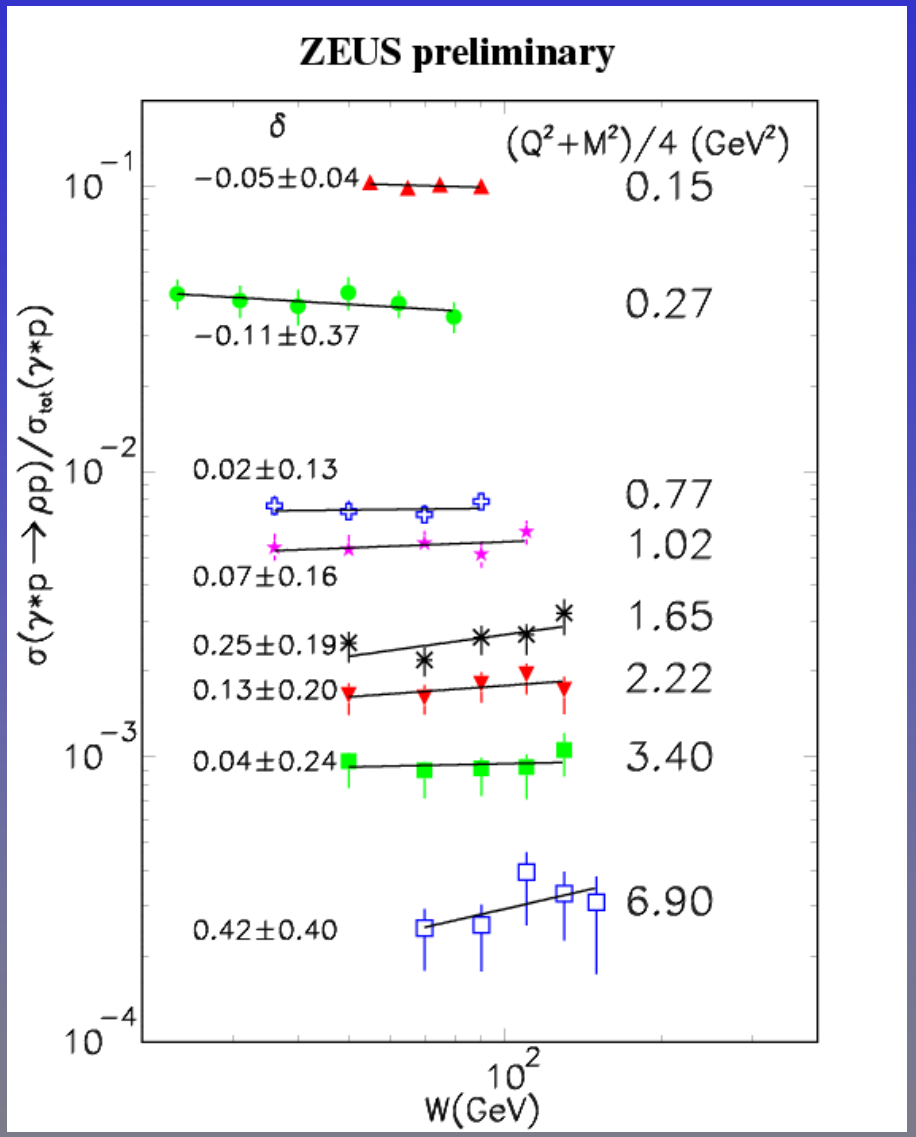


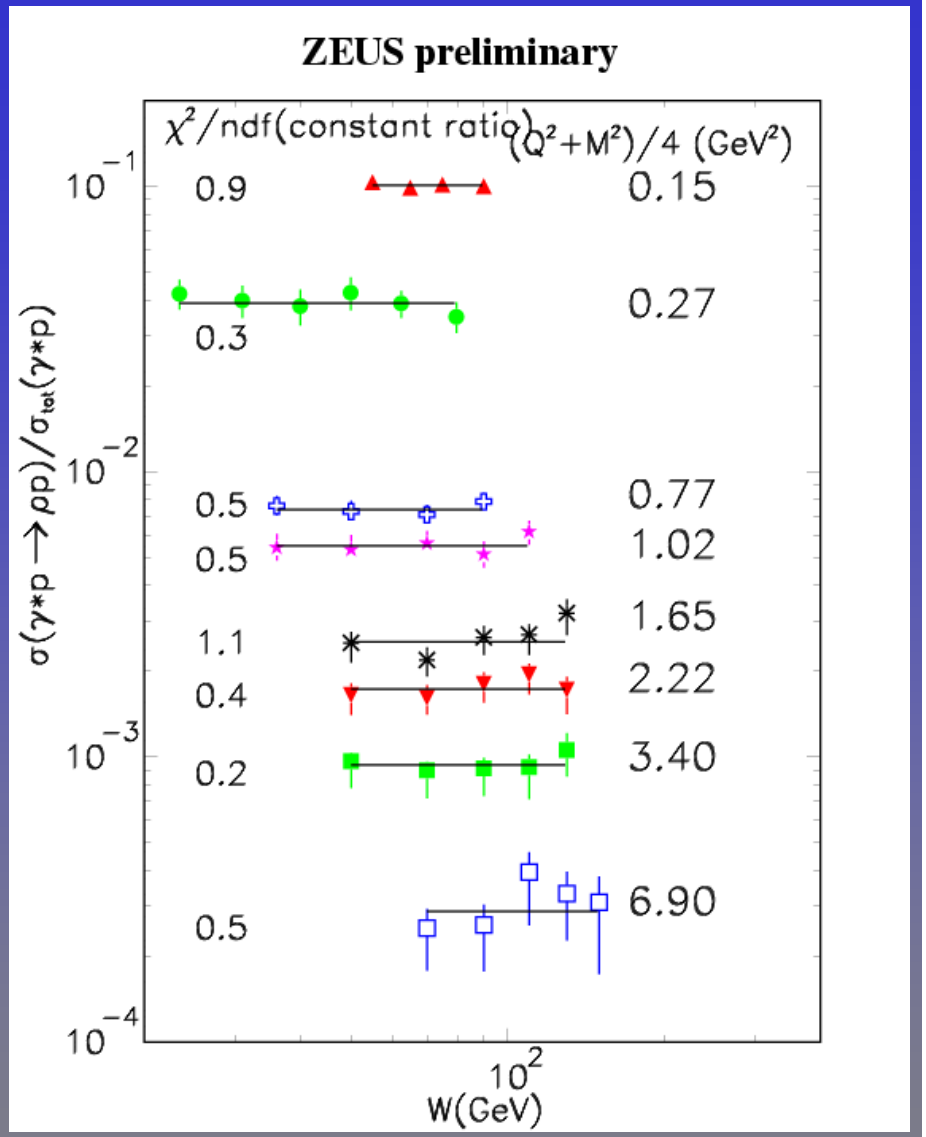


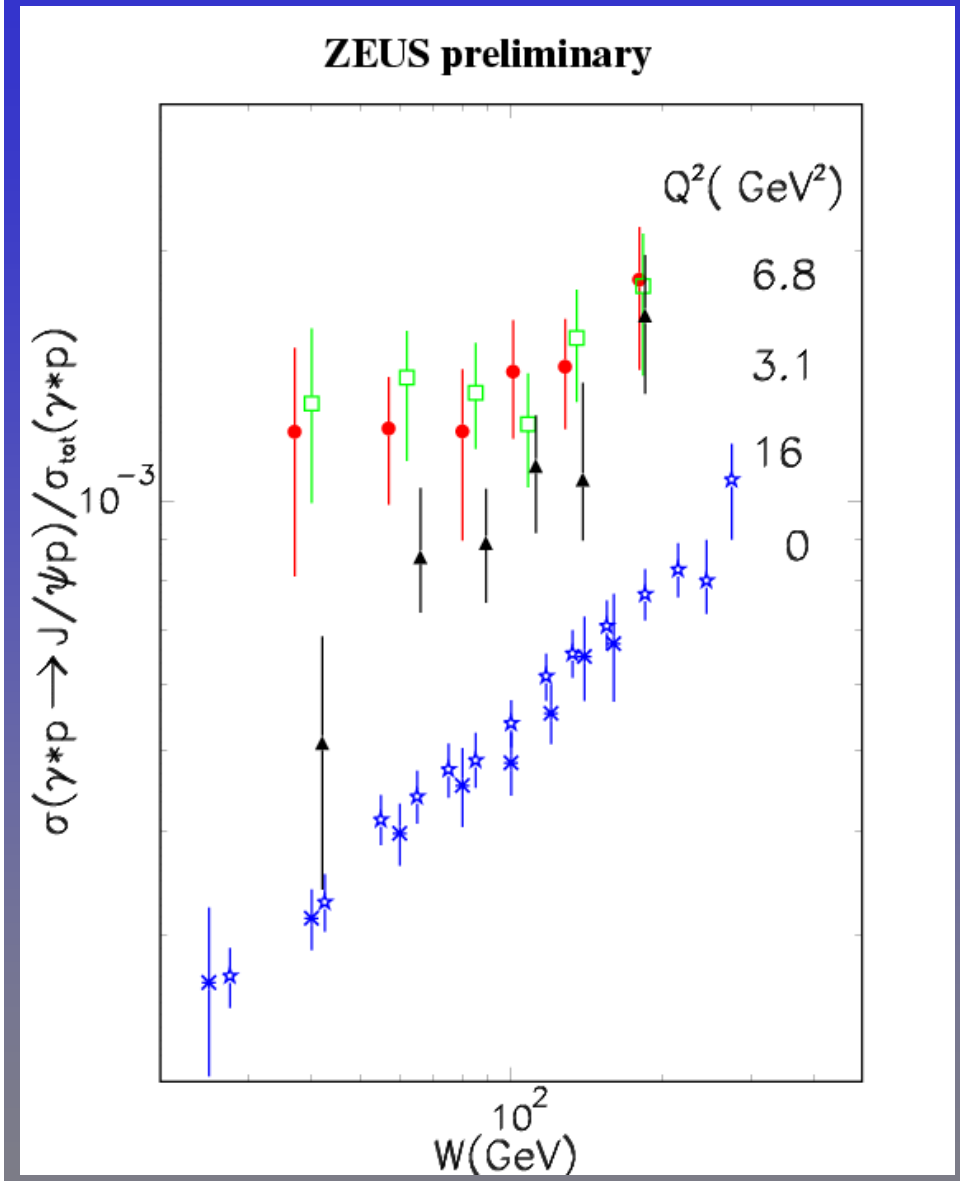
$\alpha' = .115 \pm .018^{+.008}_{-.015}$

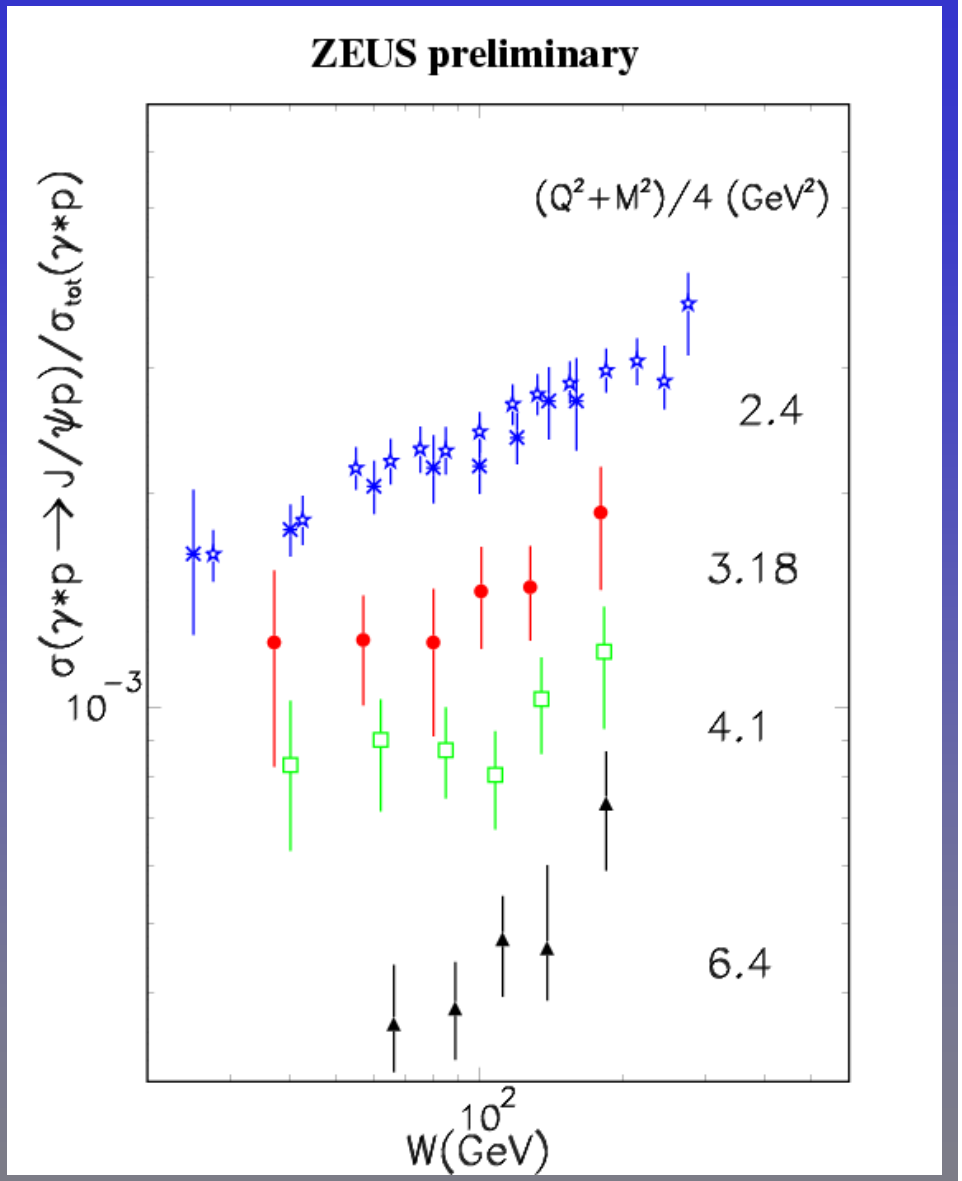

ZEUS 1994
Q^2 = 8 GeV^2
Q^2 = 14 GeV^2
Q^2 = 27 GeV^2
Q^2 = 60 GeV^2
M_X < 3 GeV
3 < M_X < 7.5 GeV
7.5 < M_X < 15 GeV
$\sigma^{diff}/\sigma_{tot}$
W(GeV)

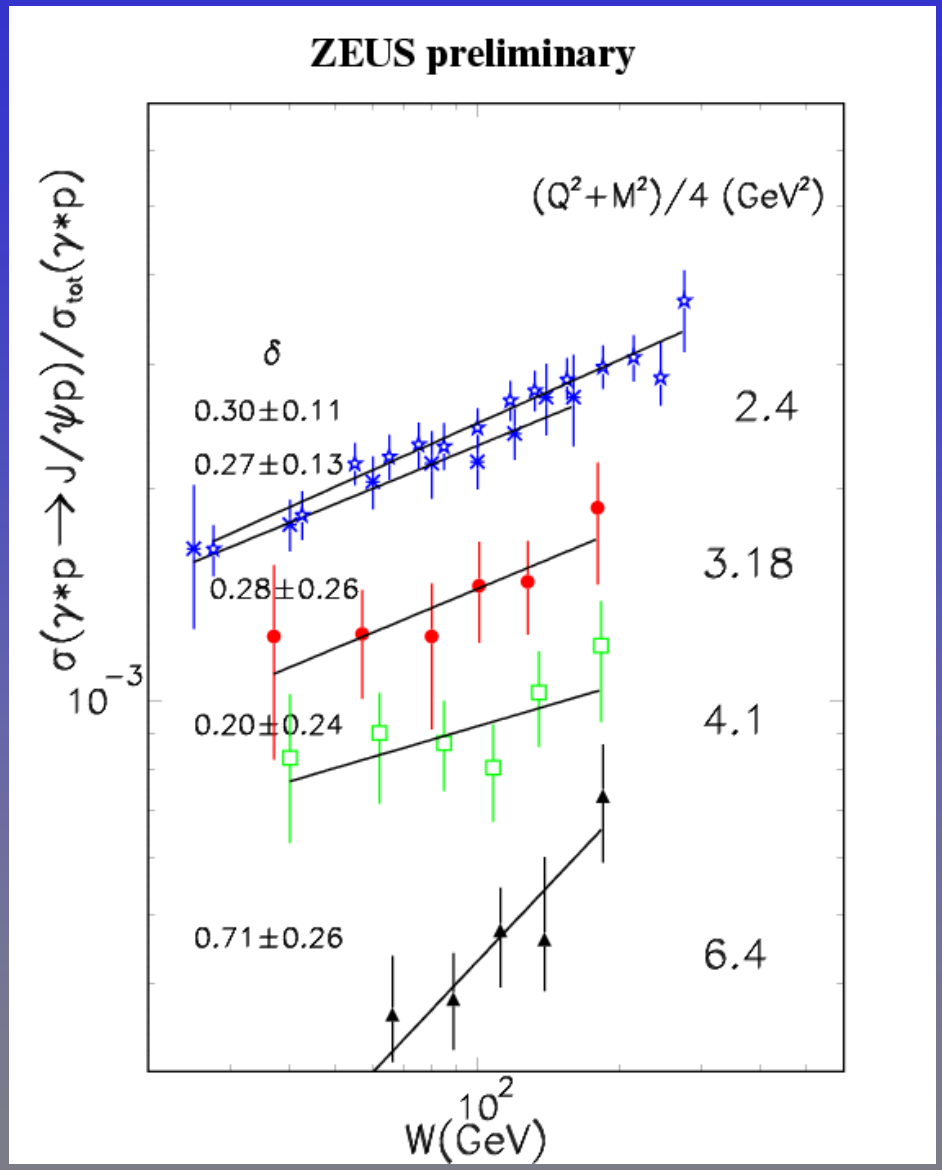

ZEUS preliminary
$(Q^2+M^2)/4$ (GeV^2)
0.15
0.27
0.77
1.02
1.65
2.22
3.40
6.90
$\sigma(\gamma^* p \to \rho p)/\sigma_{tot}(\gamma^* p)$
W(GeV)

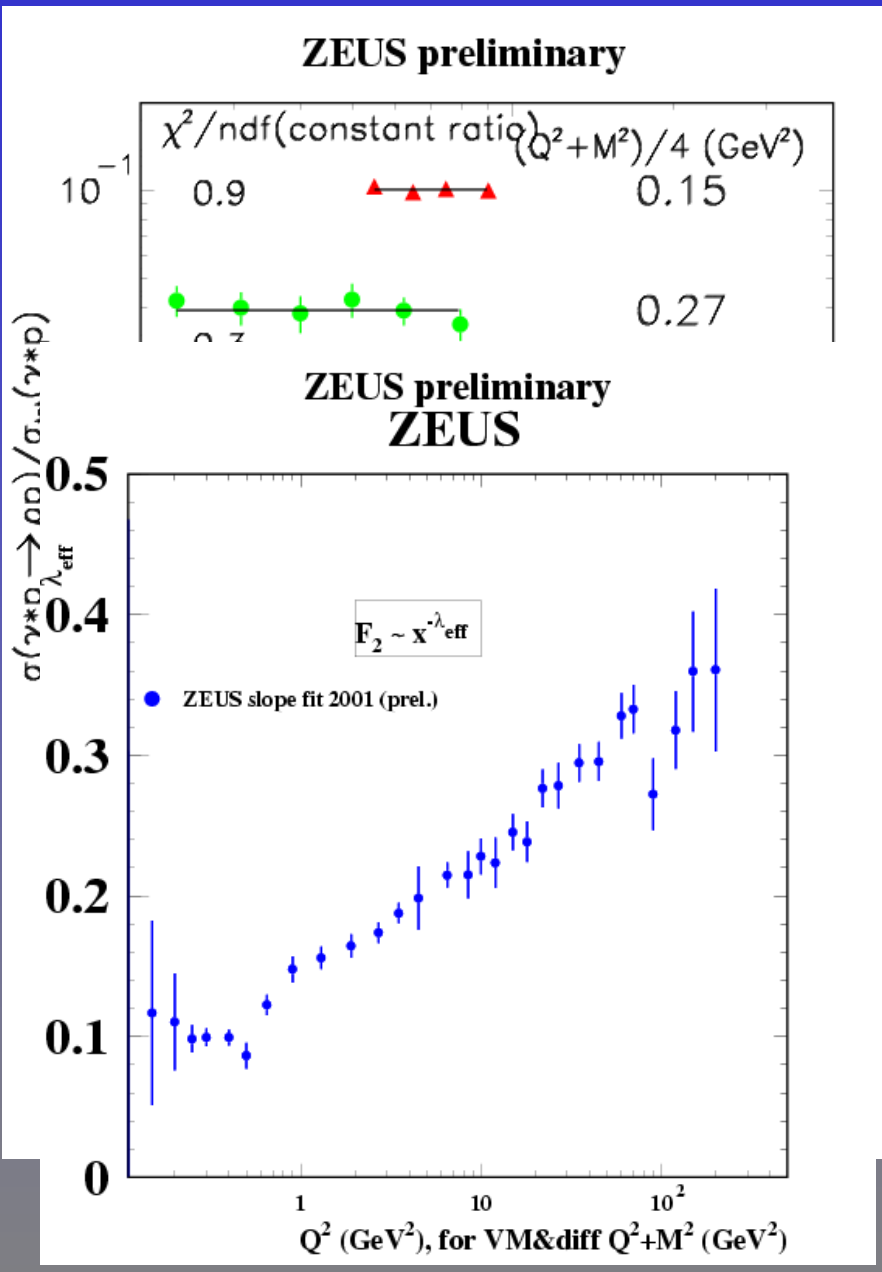

ZEUS preliminary
δ
(Q²+M²)/4 (GeV²)
−0.05±0.04
0.15
−0.11±0.37
0.27
0.02±0.13
0.77
0.07±0.16
1.02
0.25±0.19
1.65
0.13±0.20
2.22
0.04±0.24
3.40
0.42±0.40
6.90
σ(γ*p → ρp)/σtot(γ*p)
W(GeV)


ZEUS preliminary
χ²/ndf(constant ratio)
(Q²+M²)/4 (GeV²)
0.9
0.15
0.3
0.27
0.5
0.77
0.5
1.02
1.1
1.65
0.4
2.22
0.2
3.40
0.5
6.90
σ(γ*p → ρp)/σtot(γ*p)
W(GeV)


ZEUS preliminary
Q^2(GeV^2)
6.8
3.1
16
0
10^{-3}
$\sigma(\gamma^* p \to J/\psi p)/\sigma_{tot}(\gamma^* p)$
10^2
W(GeV)


ZEUS preliminary
$(Q^2+M^2)/4$ (GeV^2)
2.4
3.18
4.1
6.4
10^{-3}
$\sigma(\gamma^* p \to J/\psi p)/\sigma_{tot}(\gamma^* p)$
10^2
W(GeV)


ZEUS preliminary
$\sigma(\gamma^* p \to J/\psi p)/\sigma_{tot}(\gamma^* p)$
10^{-3}
$(Q^2+M^2)/4$ (GeV^2)
δ
0.30±0.11
0.27±0.13
2.4
0.28±0.26
3.18
0.20±0.24
4.1
0.71±0.26
6.4
10^2
W(GeV)


ZEUS preliminary
χ^2/ndf(constant ratio)
$(Q^2+M^2)/4$ (GeV^2)
10^{-1}
0.9
0.15
0.27
ZEUS preliminary
ZEUS
$\sigma(\gamma^* p \to \rho p)/\sigma_{...}(\gamma^* p)$
λ_{eff}
0.5
0.4
0.3
0.2
0.1
0
$F_2 \sim x^{-\lambda_{eff}}$
ZEUS slope fit 2001 (prel.)
1
10
10^2
Q^2 (GeV^2), for VM&diff Q^2+M^2 (GeV^2)

The ratio σ^2_{tot}/σ_v

pQCD:

$$\left.\frac{d\sigma_L}{dt}\right|_{t=0} \propto \frac{1}{Q^6}\alpha_S^2(Q^2)[xg(x,Q^2)]^2$$

$$\sigma_V \propto \frac{\alpha_S^2(Q^2)}{Q^6}[xg(x,Q^2)]^2\left(1+\frac{1}{R}\right)\frac{1}{b}$$

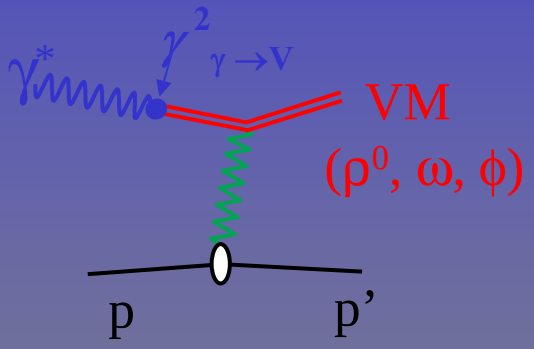
$$\sigma_{tot} = \frac{4\pi^2\alpha_{em}}{Q^2}F_2 \propto \frac{1}{Q^2}xg(x,Q^2)$$

$$\frac{\sigma^2_{tot}}{\sigma_V} \propto \frac{\frac{1}{Q^4}[xg(x,Q^2)]^2}{\frac{1}{Q^6}[xg(x,Q^2)]^2\alpha_S^2(Q^2)\left(1+\frac{1}{R}\right)\frac{1}{b}} \approx \frac{Q^2}{\alpha_S^2(Q^2)}b$$

The ratio σ^2_{tot}/σ_v

Regge: $\sigma_{tot}(\gamma p) \propto \sqrt{4\pi\alpha_{em}} \sum_V \{ \frac{4\pi}{\gamma^2_{\gamma V}} \frac{d\sigma(\gamma p \to Vp)}{dt}\Big|_{t=0} \}^{0.5}$

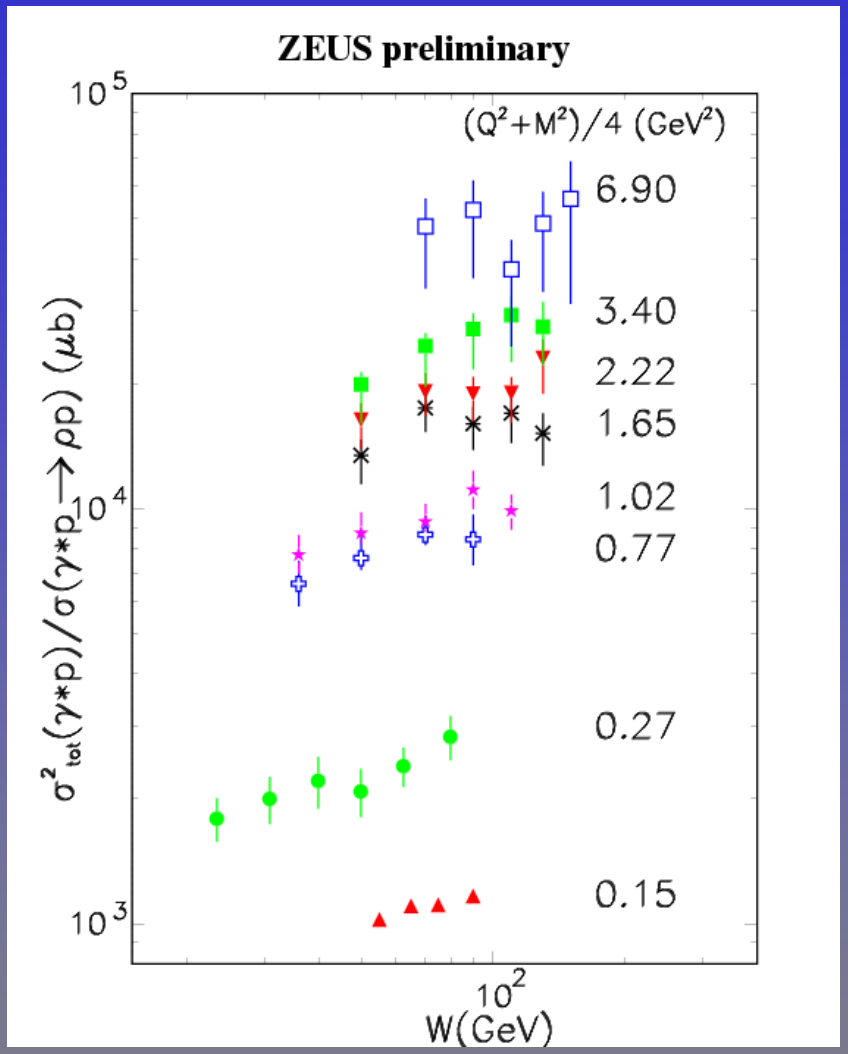
(+VDM)

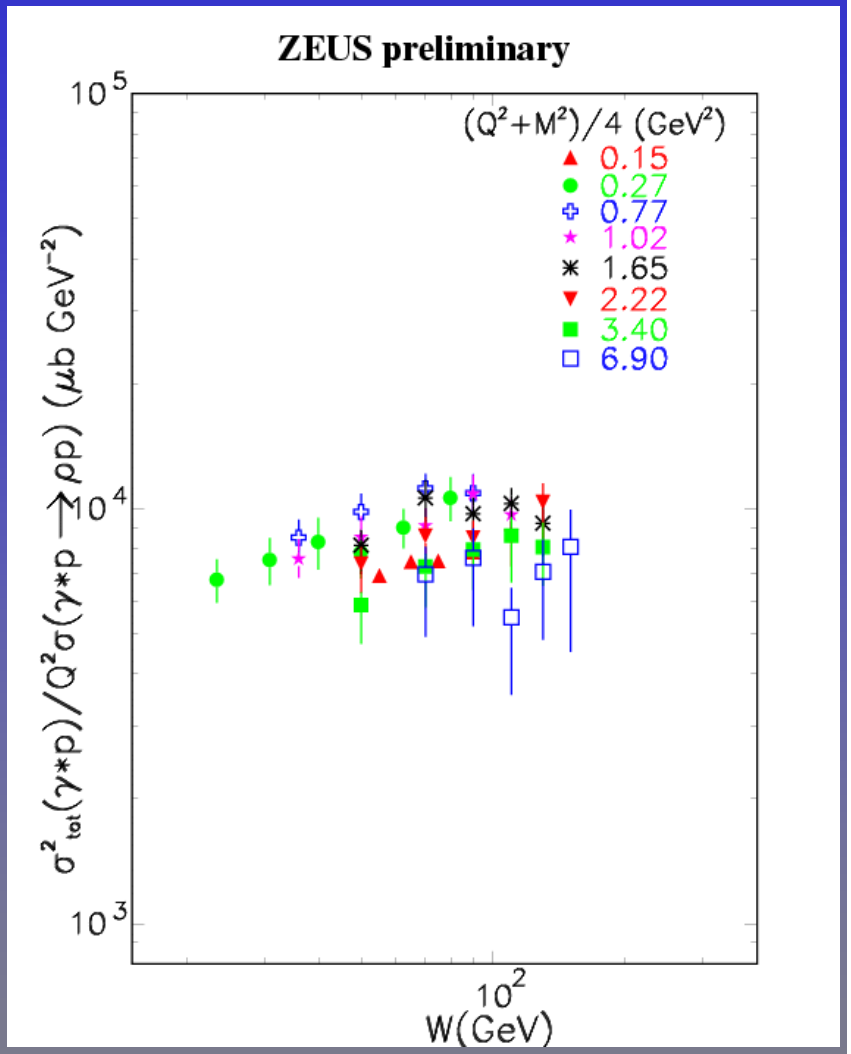


Assume ρ dominance :

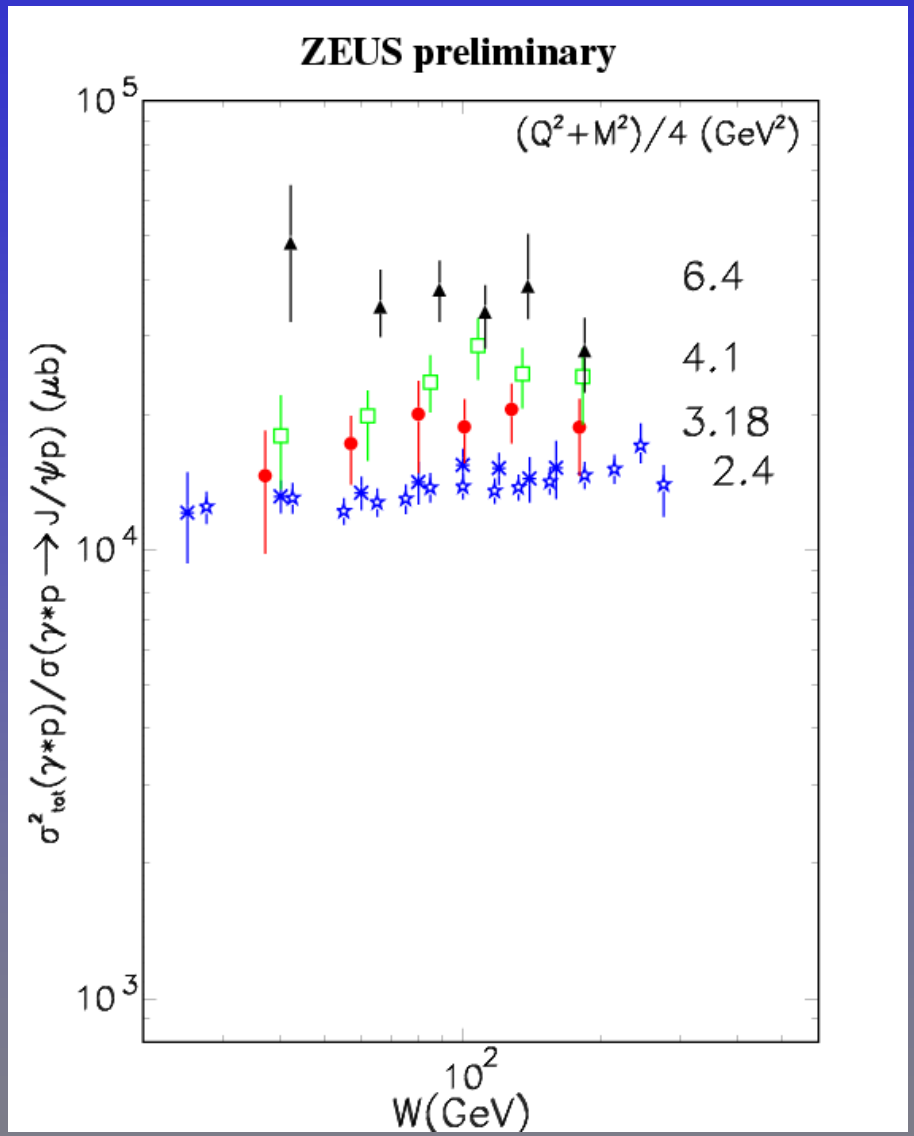
$$\sigma^2_{tot} = 4\pi\alpha_{em}\frac{4\pi}{\gamma^2_{\gamma\rho}}\sigma_\rho b$$

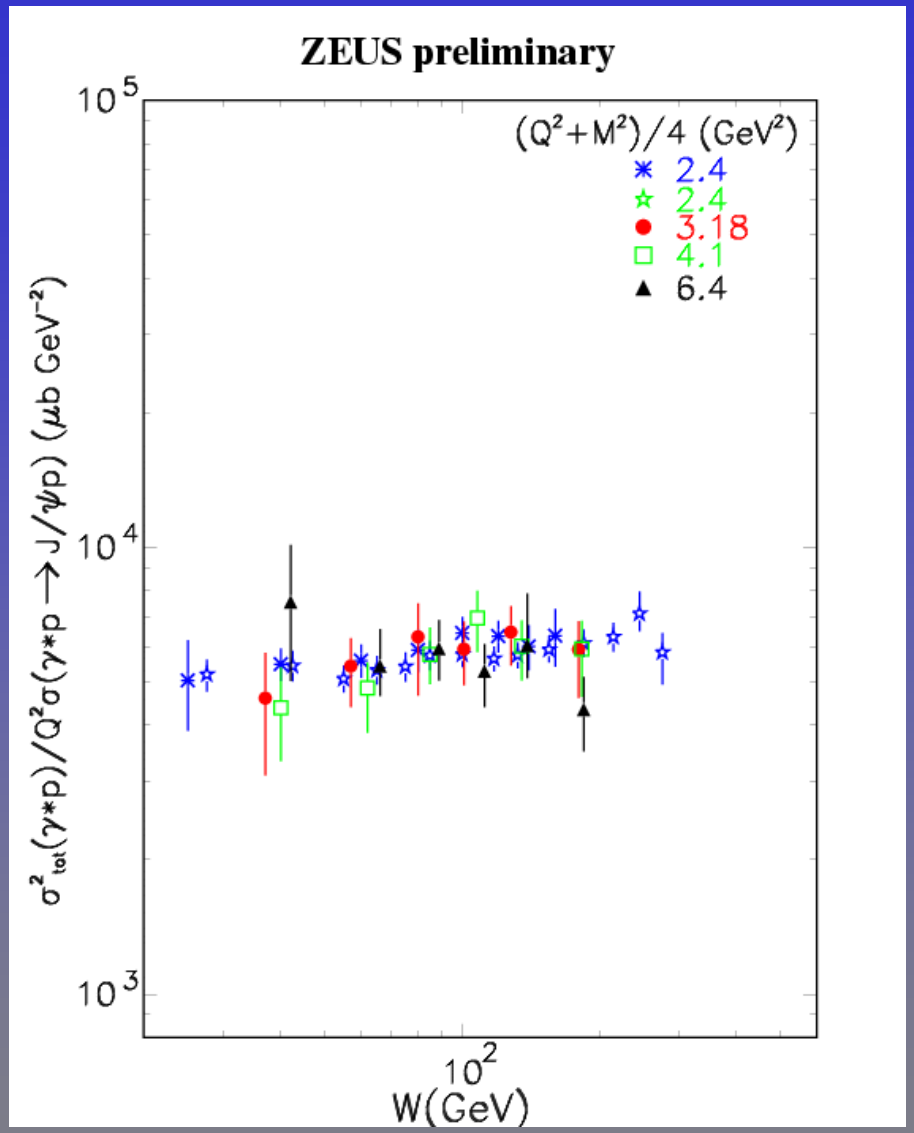
$$\frac{\frac{4\pi}{\gamma^2_{\gamma\rho}}\sigma^2_{tot}}{4\pi\alpha_{em}\sigma_\rho} = 0.014\frac{\sigma^2_{tot}}{\sigma_\rho} = b \quad \text{(in GeV}^{-2}\text{)}$$

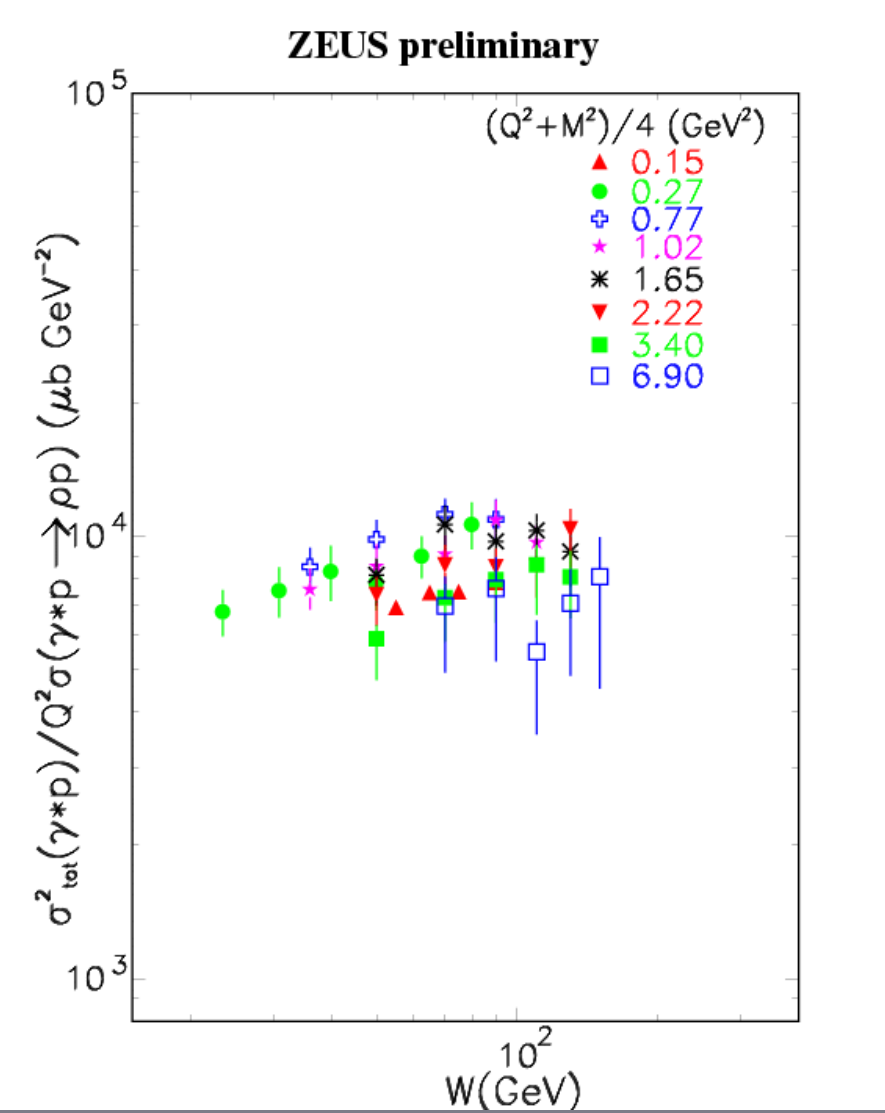


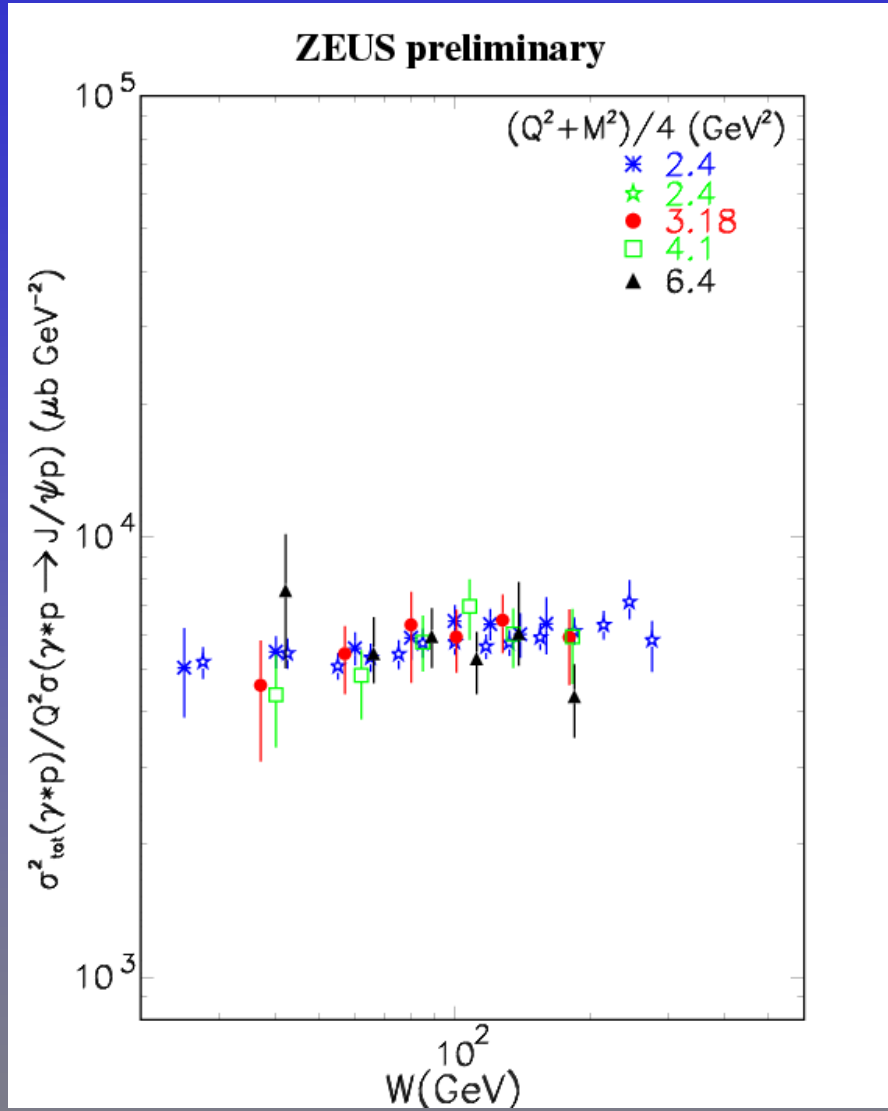


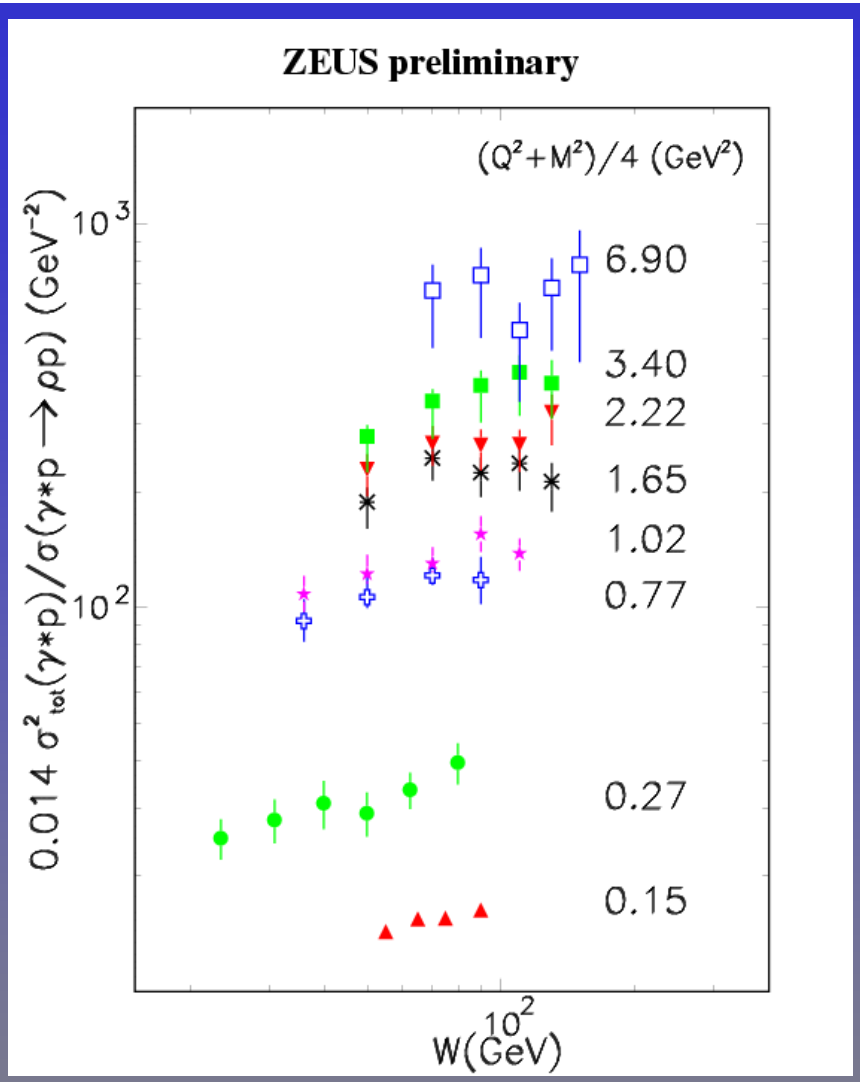
$$\frac{\sigma^2_{tot}}{\sigma_V} \propto \frac{Q^2}{\alpha_S^2(Q^2)}\, b$$

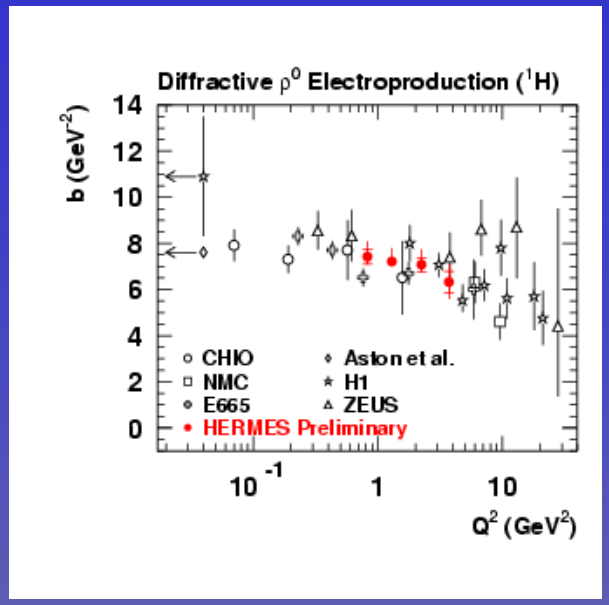

ZEUS preliminary
$(Q^2+M^2)/4$ (GeV^2)
6.4
4.1
3.18
2.4
$\sigma^2_{tot}(\gamma^*p)/\sigma(\gamma^*p \rightarrow J/\psi p)$ (μb)
W(GeV)

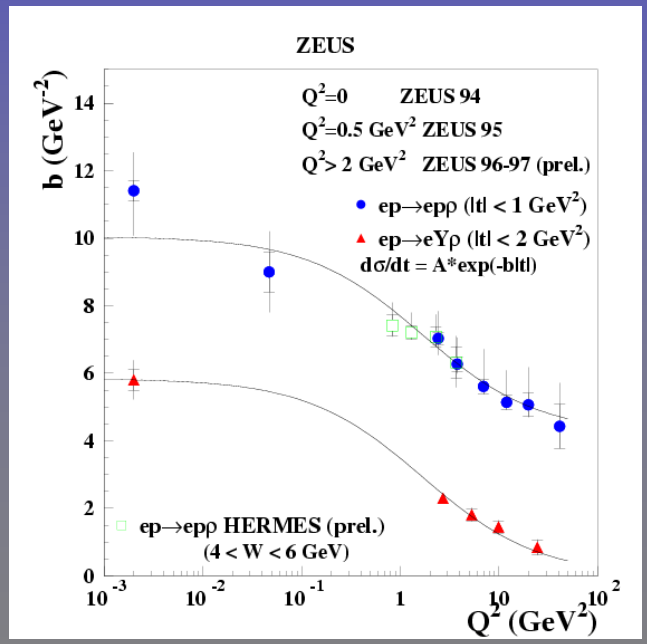

ZEUS preliminary
$(Q^2+M^2)/4$ (GeV^2)
2.4
2.4
3.18
4.1
6.4
$\sigma^2_{tot}(\gamma^*p)/Q^2\sigma(\gamma^*p \rightarrow J/\psi p)$ (μb GeV^{-2})
W(GeV)


ZEUS preliminary
$(Q^2+M^2)/4$ (GeV^2)
0.15
0.27
0.77
1.02
1.65
2.22
3.40
6.90
$\sigma^2_{tot}(\gamma^*p)/Q^2\sigma(\gamma^*p \to \rho p)$ (μb GeV^{-2})
10^5
10^4
10^3
10^2
W(GeV)


ZEUS preliminary
$(Q^2+M^2)/4$ (GeV^2)
2.4
2.4
3.18
4.1
6.4
$\sigma^2_{tot}(\gamma^*p)/Q^2\sigma(\gamma^*p \to J/\psi p)$ (μb GeV^{-2})
10^5
10^4
10^3
10^2
W(GeV)



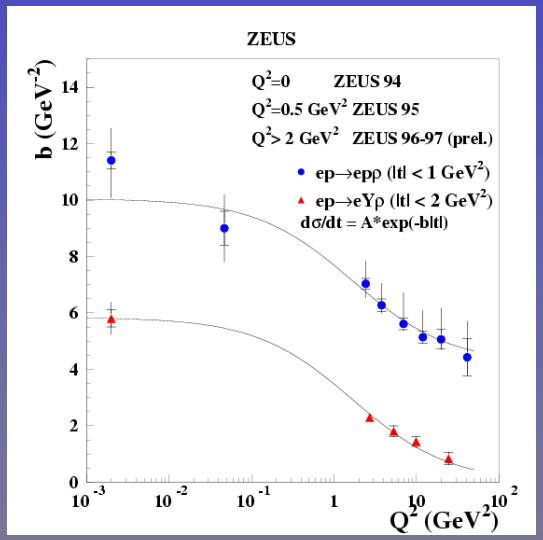


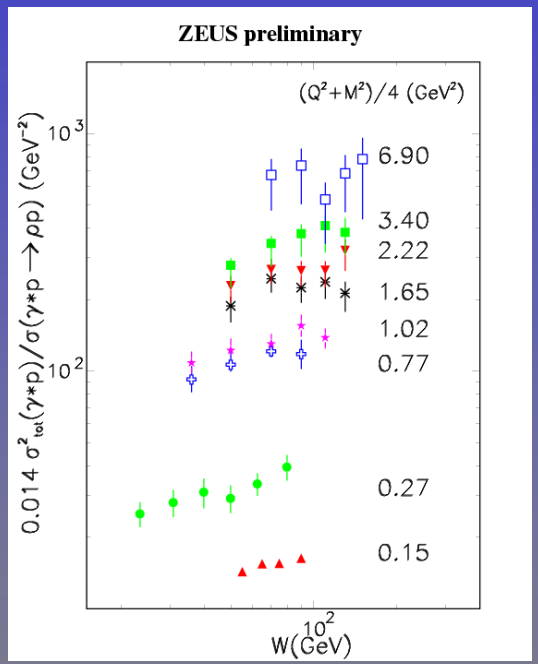


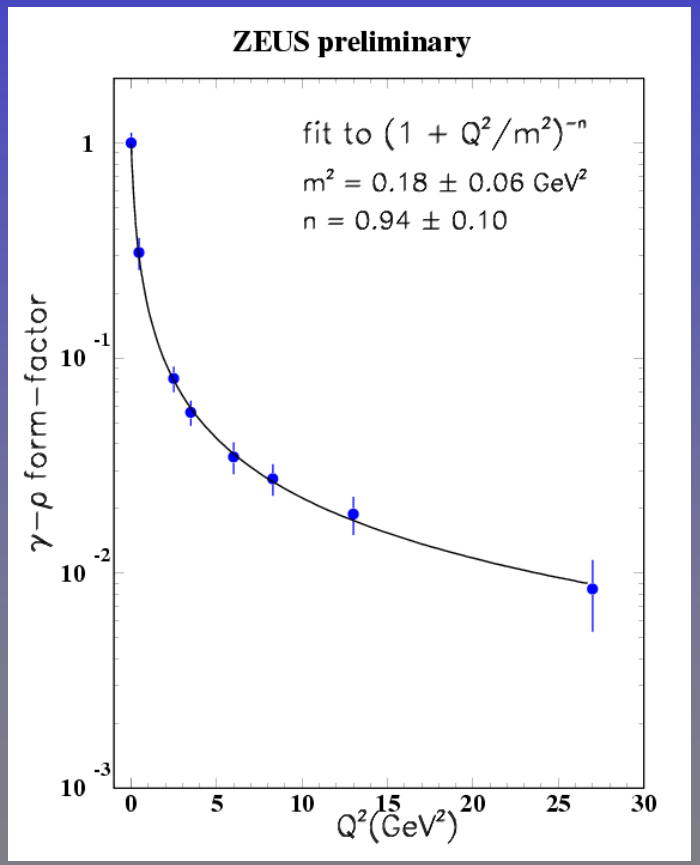
$$\frac{\frac{4\pi}{\gamma^2_{\gamma\rho}}\sigma^2_{tot}}{\frac{4\pi\,\alpha_{em}}{\sigma_p}} = 0.014\frac{\sigma^2_{tot}}{\sigma_p} = b$$

Q^2 dependence of γ-ρ coupling

use measured $b(Q^2)$ and $(0.014\sigma^2/\sigma_\rho)$ to calculate γ-$\rho(Q^2)$







Summary

Known facts:

1. σ_V grows with increasing Q^2
2. Q^2 dependence ~ $(Q^2 + M_V^2)^{-(2.2\text{-}2.7)}$
3. b decreases with Q^2 for ρ
4. R increases with Q^2
5. ratio of heavy/light VM increases with Q^2
6. Scaling in $Q^2 + M_V^2$ not valid for J/ψ

1–6 expected from pQCD

Summary

This study:

1. σ_ρ/σ_{tot} ~ constant with W (≠ pQCD)
2. $\sigma_{J/\psi}/\sigma_{tot}$ increases with W
3. Q^2 dependence – typical of 2-gluon exchange (soft or hard) ($\sigma_{tot}{}^2/\sigma_\rho \sim Q^2$)
4. #3 is incompatible with Regge-VDM, unless assume a form-factor ~ Q^{-2}

Questions

- How large are the effects of skewed distribution on VMs?
- What is the right form for the Q^2 dependence of VMs?
- Why is R independent of W?
- Why is σ_ρ/σ_{tot} constant in W? + another 'puzzle'?
- How well do we know the VM WF?
- What do we learn from SCH-non cons. at high t?
- Are Regge trajectories linear? $\alpha'(t)$?