Exclusive Electroproduction of Charmonium at HERA

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on behalf of

H1 & ZEUS

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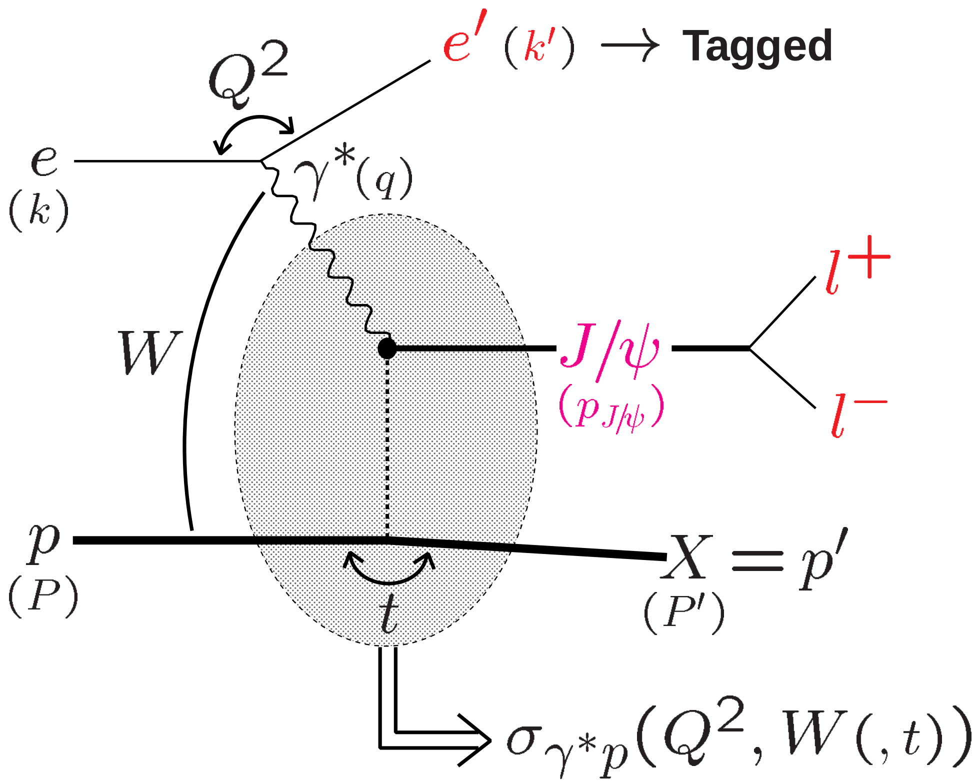
[1] Introduction

Exclusive Electroproduction of J/ψ at HERA

$$e^{\pm} \quad p \quad \longrightarrow \quad e^{\pm} \quad J/\psi \quad p$$

$\hookrightarrow e^+e^-$ or $\mu^+\mu^-$

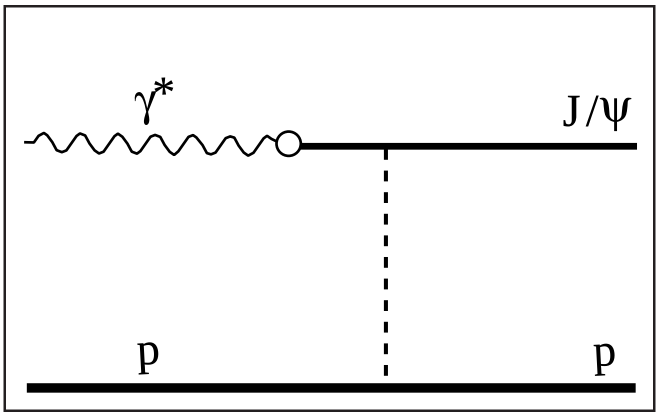


Measured kinematical variables

$$Q^2 = -q^2 = -(k - k')^2$$
$$W^2 = (q + P)^2 = \left\{(k - k') + P\right\}^2$$
$$t = (P' - P)^2 = \left\{k - (k' + p_{J/\psi})\right\}^2$$

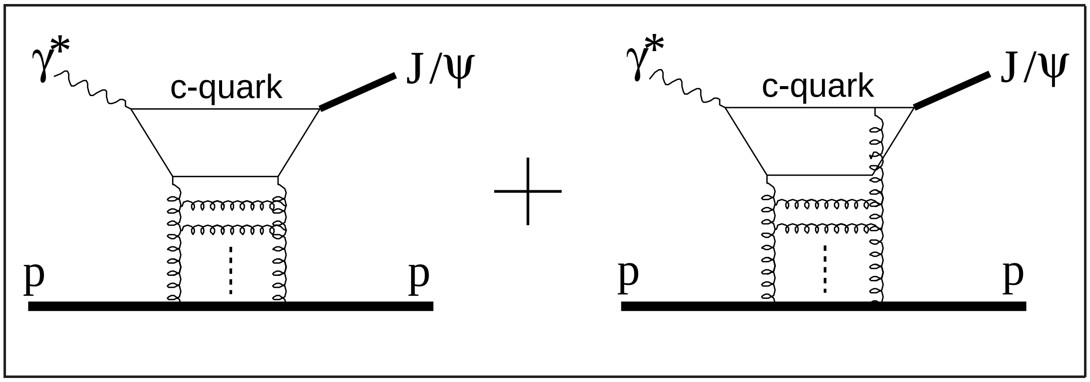
[2] Theories for J/ψ production

Vector Dominance Model + Regge theory



- $\sigma(W) \propto W^{0.22}$ (soft $I\!P$ exchange)
- $\sigma(Q^2) \propto \dfrac{1}{\left(Q^2 + M^2_{J/\psi}\right)^2}$
- explains soft VM production,
  i.e. light VM photoproduction(PhP).
- does not work for J/ψ PhP.

Perturbative QCD (pQCD)



- needs hard scale: $M^2_{J/\psi}(m_c^2)$, Q^2.
- $\sigma \propto \left\{\bar{x} \cdot g(\bar{x}, \bar{q}^2)\right\}^2$

$$\bar{x} = \frac{Q^2 + M^2_{J/\psi}}{W^2} \cong 10^{-4} \sim 10^{-2}$$

$$\bar{q}^2 = \frac{Q^2 + M^2_{J/\psi}}{4} \cong 3 \sim 16\, GeV^2$$

- $\sigma(W)$, $\sigma(Q^2)$ are related to gluon PDF.

[3] Motivation of This Measurement

- Two hard scales: $M^2_{J/\psi}(m_c^2)$ and Q^2

  $\rightarrow$ Calculable with pQCD

  $\rightarrow$ Test of gluon PDFs

- W-dependence: $\sigma(W; Q_0^2) \sim W^{\delta(Q_0^2)}$
  - Interplay of the two hard scales: $M^2_{J/\psi}$ and Q^2

- Q^2-dependence: $\sigma(Q^2) \sim \frac{1}{(Q^2+M^2_{J/\psi})^n}$?
  - Charm suppression in low-Q^2

    $\rightarrow$ Connection to PhP
  - Ratio to ρ^0

    $\rightarrow$ Compared to SU(4) expectation:

    $\rho^0 : \omega : \phi : J/\psi = 9 : 1 : 2 : 8$
  - $R(Q^2) = \sigma_L/\sigma_T$: How does it rise?

[4] Event Selection

H1 (Publ.)

$27 pb^{-1}$ taken in 1995-97

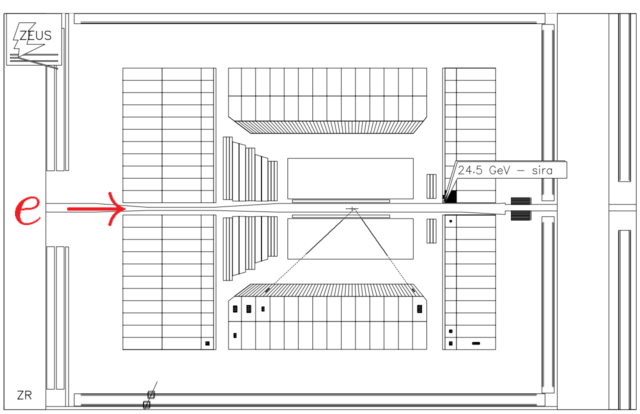
ZEUS (Prelim.)

$75 pb^{-1}$ taken in 1996-99

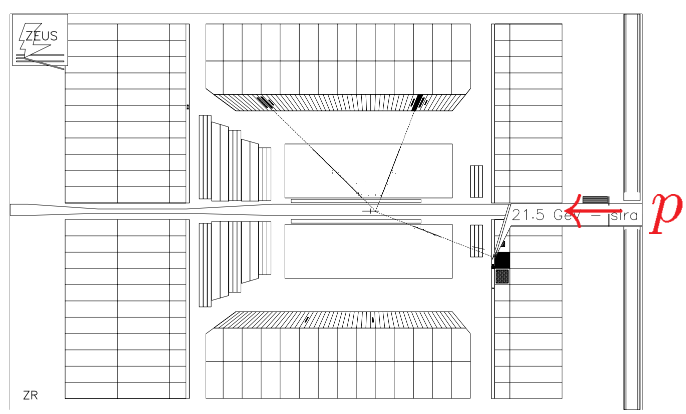
Common selection

- A scattered $e^{\pm}$ in the calorimeter
- 2(+1) tracks in Central Tracking Detector (CTD)
- Elasticity: no other tracks in CTD, etc.

Di-muon candidate

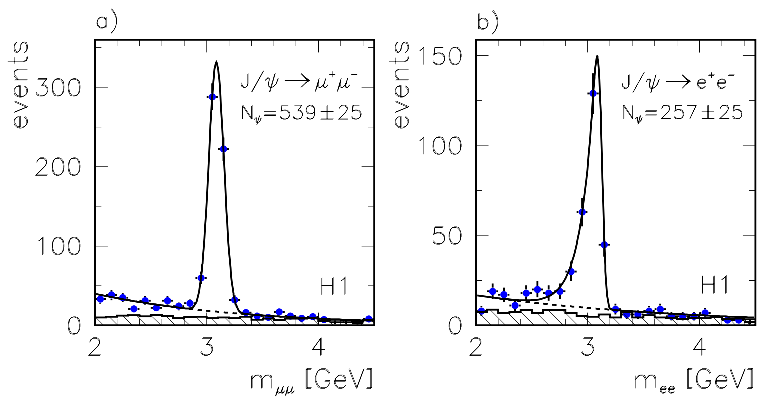


Di-electron candidate



H1 Kinematic Range

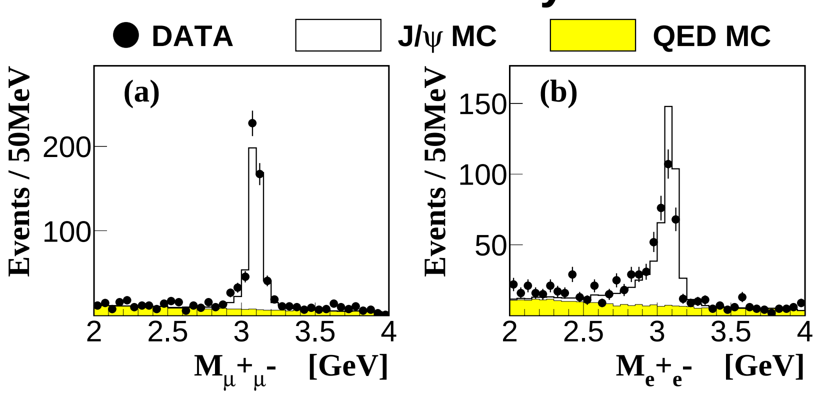
$25 < W < 160\,GeV$ for $2 < Q^2 < 6\,GeV^2$
$40 < W < 160\,GeV$ for $6 < Q^2 < 80\,GeV^2$



ZEUS Kinematic Range

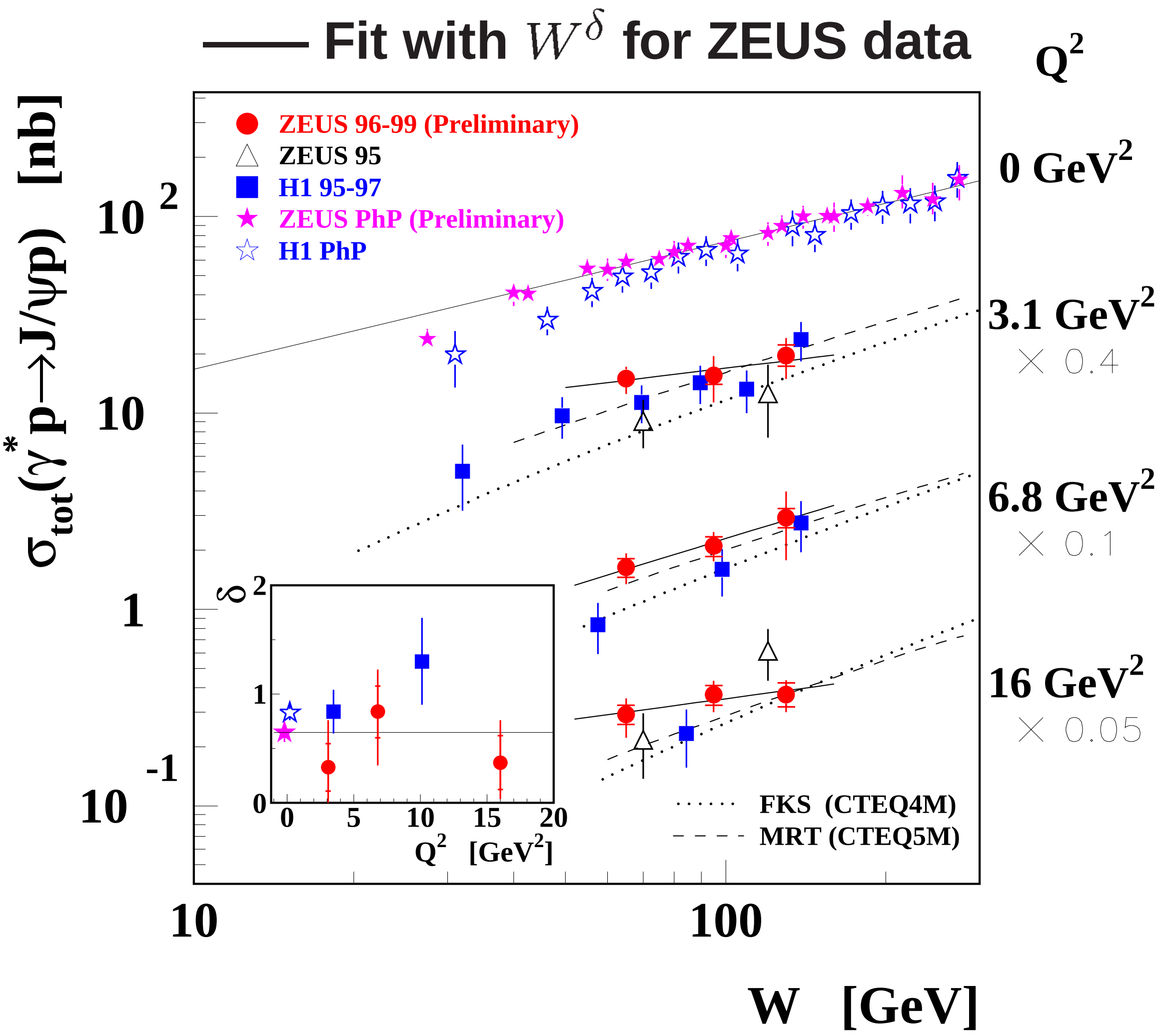
$50 < W < 150\,GeV$ and $2 < Q^2 < 100\,GeV^2$

ZEUS Preliminary 96-99



[5] Results

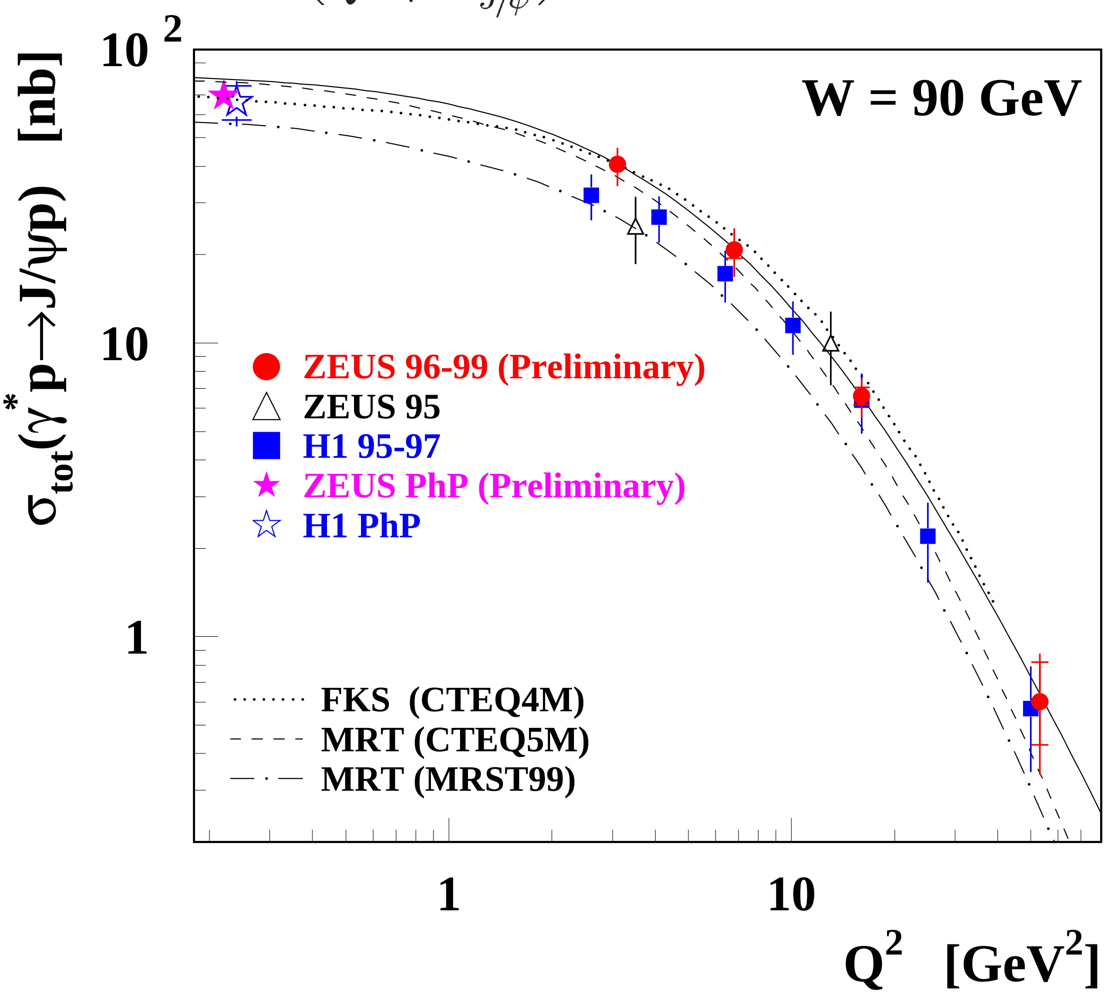
W-dependence



- W-slopes are consistent with that of PhP.
- W-slopes are agreement with those from pQCD within the errors.

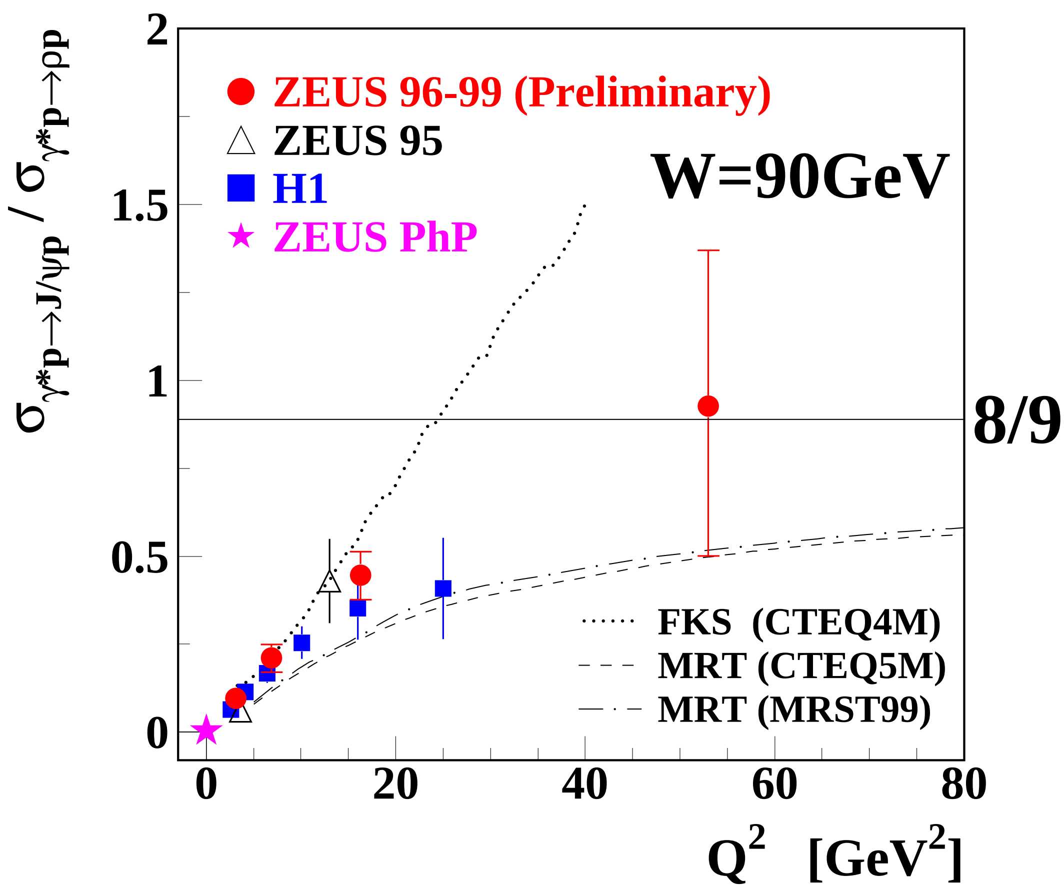
Q^2-dependence

—— Fit with $\frac{1}{(Q^2+M_{J/\psi})^n}$ for ZEUS data ($Q^2 > 3\,GeV^2$)



- Fairly well-described with pQCD.
- Fitting ZEUS data at $Q^2 > 3\,GeV^2$ with $1/(Q^2+M^2_{J/\psi})^n$
  $\longrightarrow n = 2.60 \pm 0.11(stat.)^{+0.08}_{-0.05}(syst.)$
  $\longrightarrow$ overshoots PhP points.

Ratio to ρ^0



- **Rising with Q^2 ($\leftarrow$ charm suppression)**
- **Ratio at $Q^2 = 53\,GeV^2$ is consistent with SU(4) expectation.**

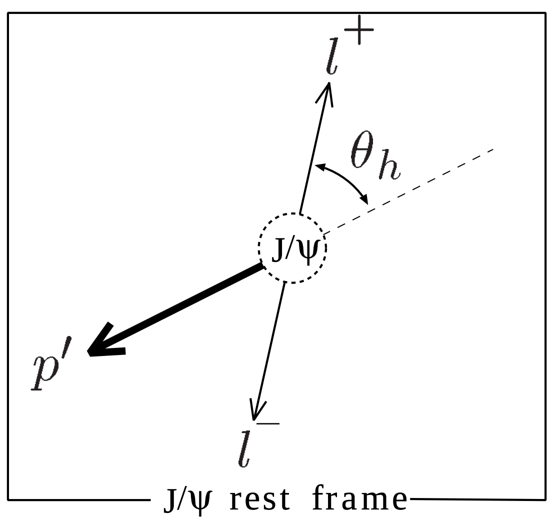
$$R(Q^2) = \frac{\sigma_L}{\sigma_T}$$

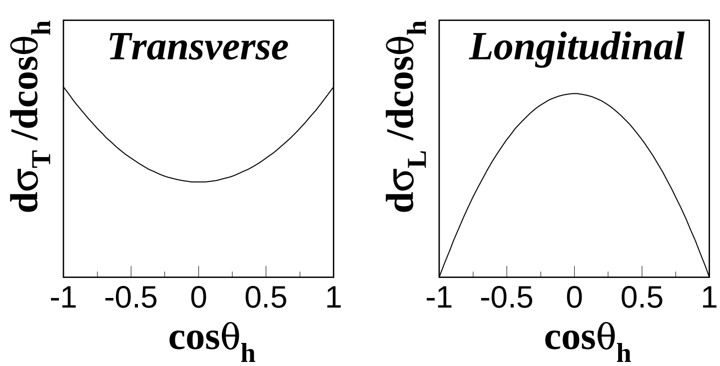
Assuming SCHC,

$$R = \frac{r^{04}_{00}}{\epsilon(1 - r^{04}_{00})} \quad \left(\epsilon \stackrel{\text{def}}{\equiv} \frac{\Gamma_L}{\Gamma_T} \sim 1\right).$$

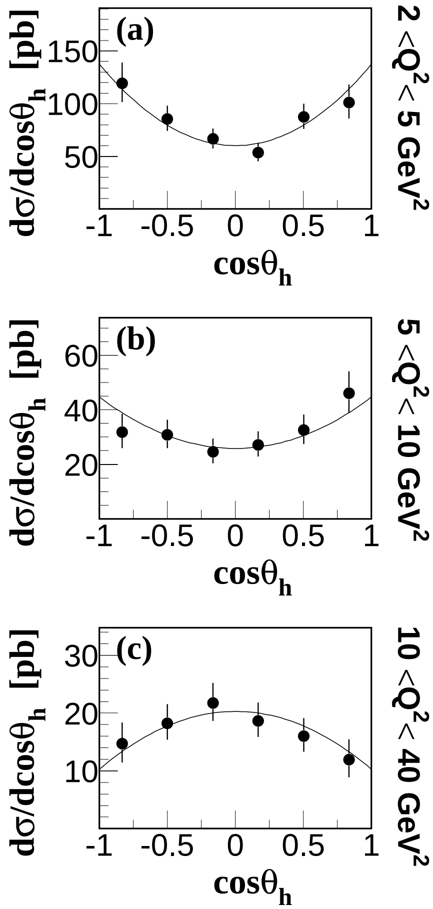
r^{04}_{00}: Spin density matrix element
(K. Schilling and G. Wolf, Nucl. Phys. **B61** (1973) 381-413)

$$\frac{d\sigma}{dcos\theta_h} \propto 1 + r^{04}_{00} + (1 - 3r^{04}_{00})cos^2\theta_h$$

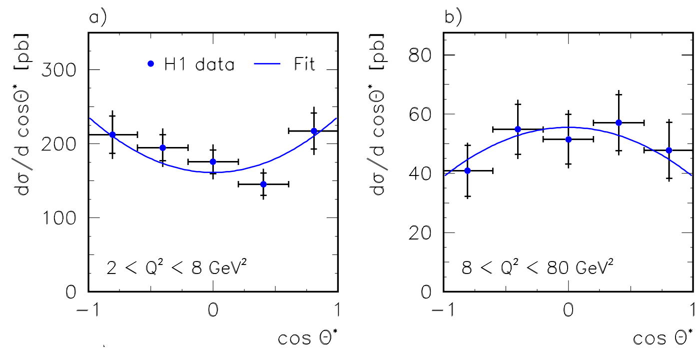




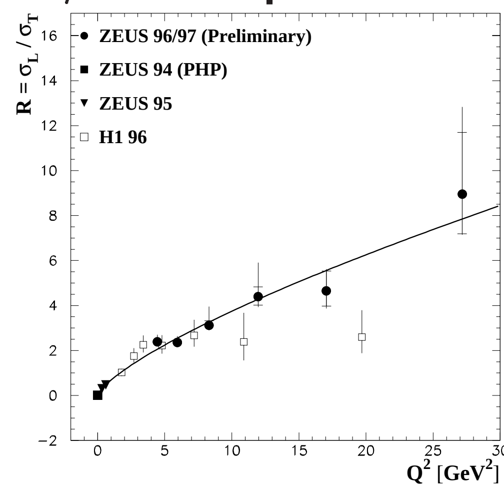
ZEUS 96-99 Preliminary



H1



ρ^0 electroproduction



H1

Q^2/GeV^2	$R_{J/\psi}$	$\tilde{R}^{fit}_{\rho^0} = \xi(Q^2/m_{J/\psi}^2)^n$
4	$+0.18^{+0.18}_{-0.14}$	0.24
16	$+0.94^{+0.79}_{-0.43}$	0.68

ZEUS

Q^2/GeV^2	$R_{J/\psi}$	$\tilde{R}^{fit}_{\rho^0} = \xi(Q^2/m_{J/\psi}^2)^n$
3.1	$-0.06^{+0.23}_{-0.09}$	0.20
6.8	$+0.08^{+0.17}_{-0.14}$	0.36
16	$+1.49^{+1.54}_{-0.83}$	0.68

- **R is rising with Q^2.**
- **The rising is much slower than that of ρ^0.**
- **The slope is consistent with that of ρ^0 with the suppression factor: $m_\rho^2/m_{J/\psi}^2$.**

[5] Conclusions

- Exclusive J/ψ electroproduction has been studied at HERA by both H1 and ZEUS.
- W-slopes
  - are consistent with that of PhP, and
  - are agreement with those from pQCD within the errors.
- Q^2-slope
  - is farily well-described with pQCD.
  - The extrapolation of the fit with $1/(Q^2+M^2_{J/\psi})^n$ overshoots PhP points. ($\leftarrow$ **ZEUS data**)
  - The ratio to ρ^0 is rising, and is consistent with SU(4) expectation at $Q^2=53\,GeV^2$.
- $R = \frac{\sigma_L}{\sigma_T}$ is rising much slower than R_{ρ^0}, but the slope is consistent if the suppression factor: $m^2_\rho/m^2_{J/\psi}$ is multiplied.