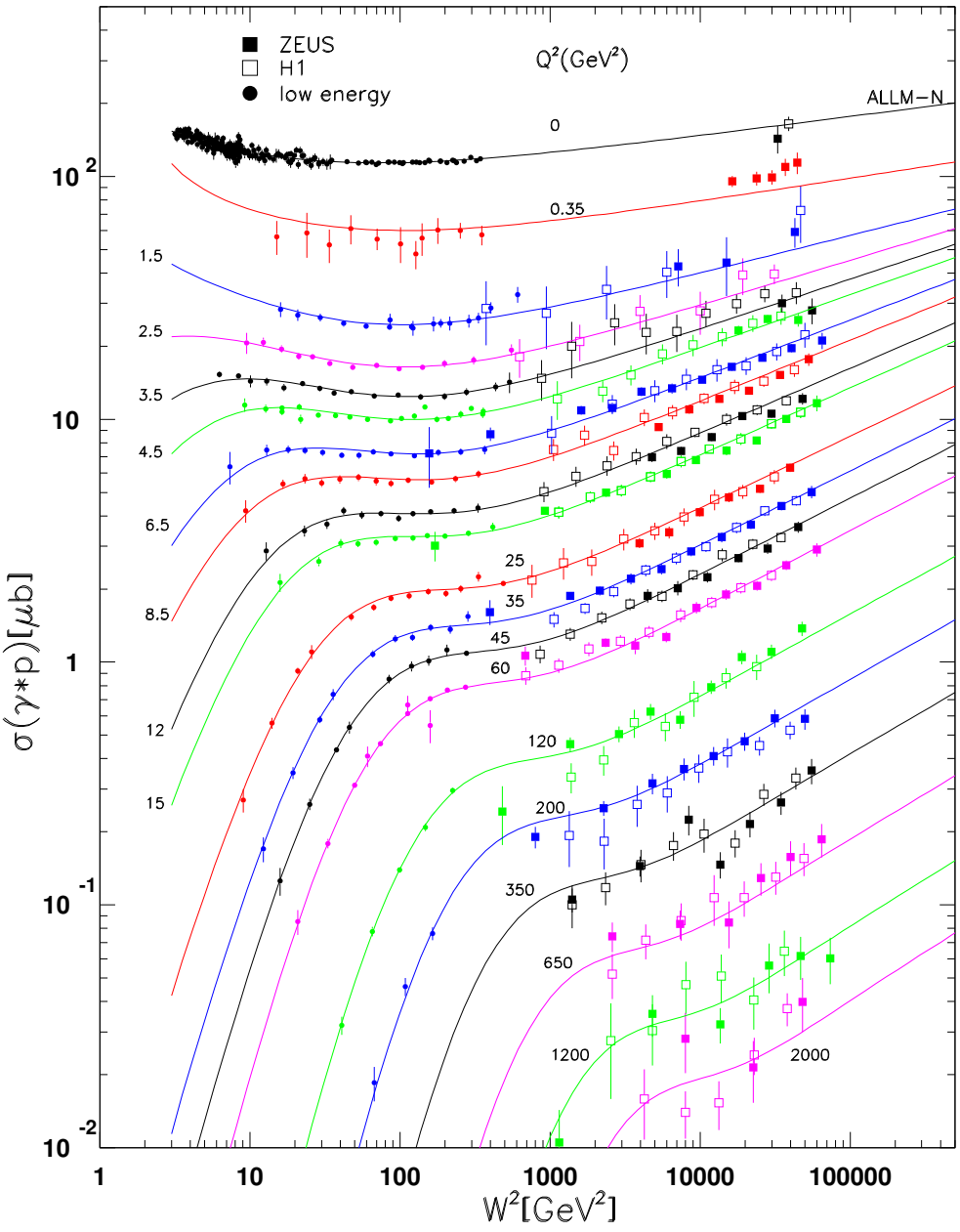
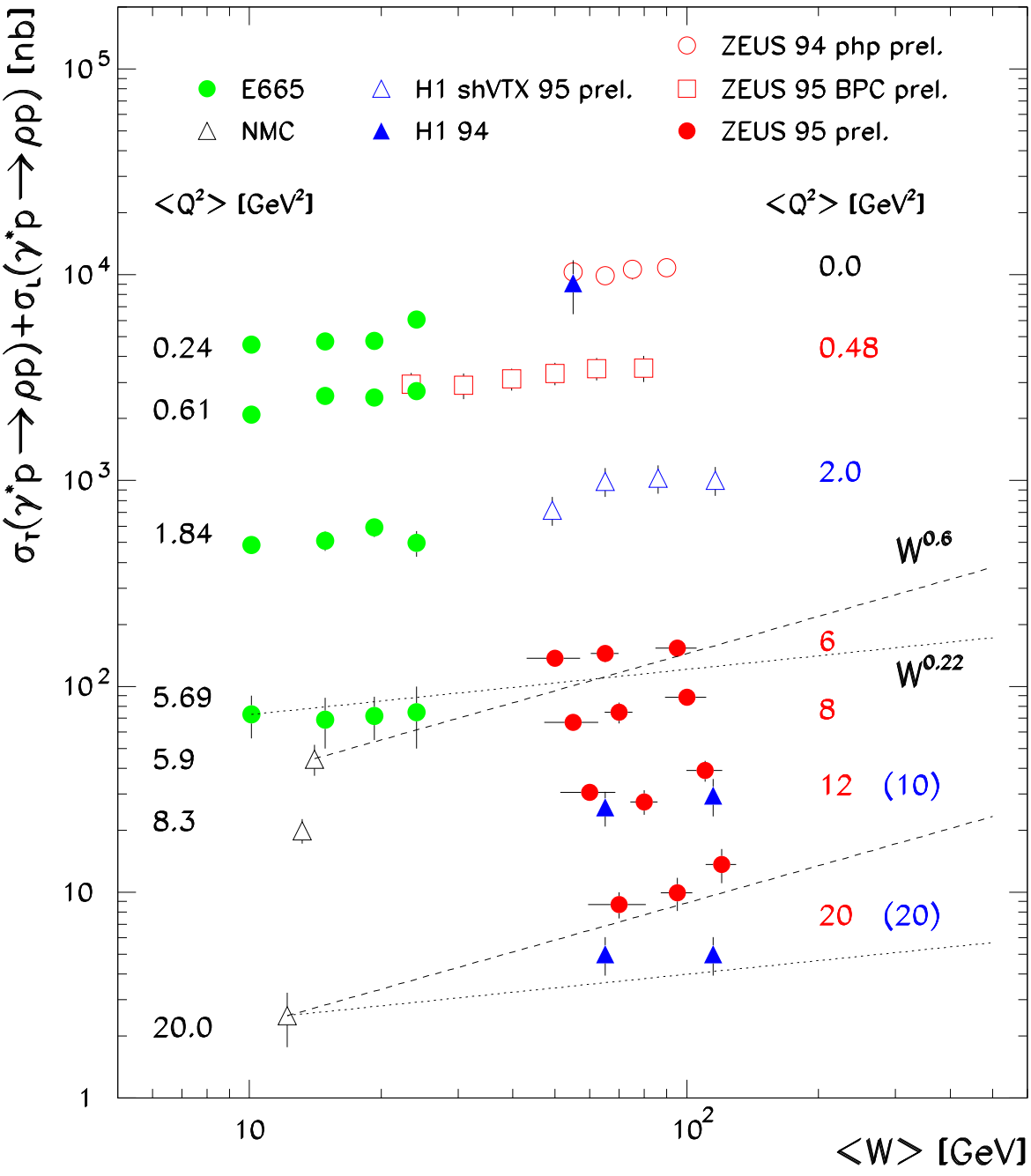
Total Photon-Proton Cross Sections

$$\sigma^{tot}_{\gamma^* p} \approx \frac{4\pi^2\alpha}{Q^2(1-x)} F_2(x,Q^2)$$



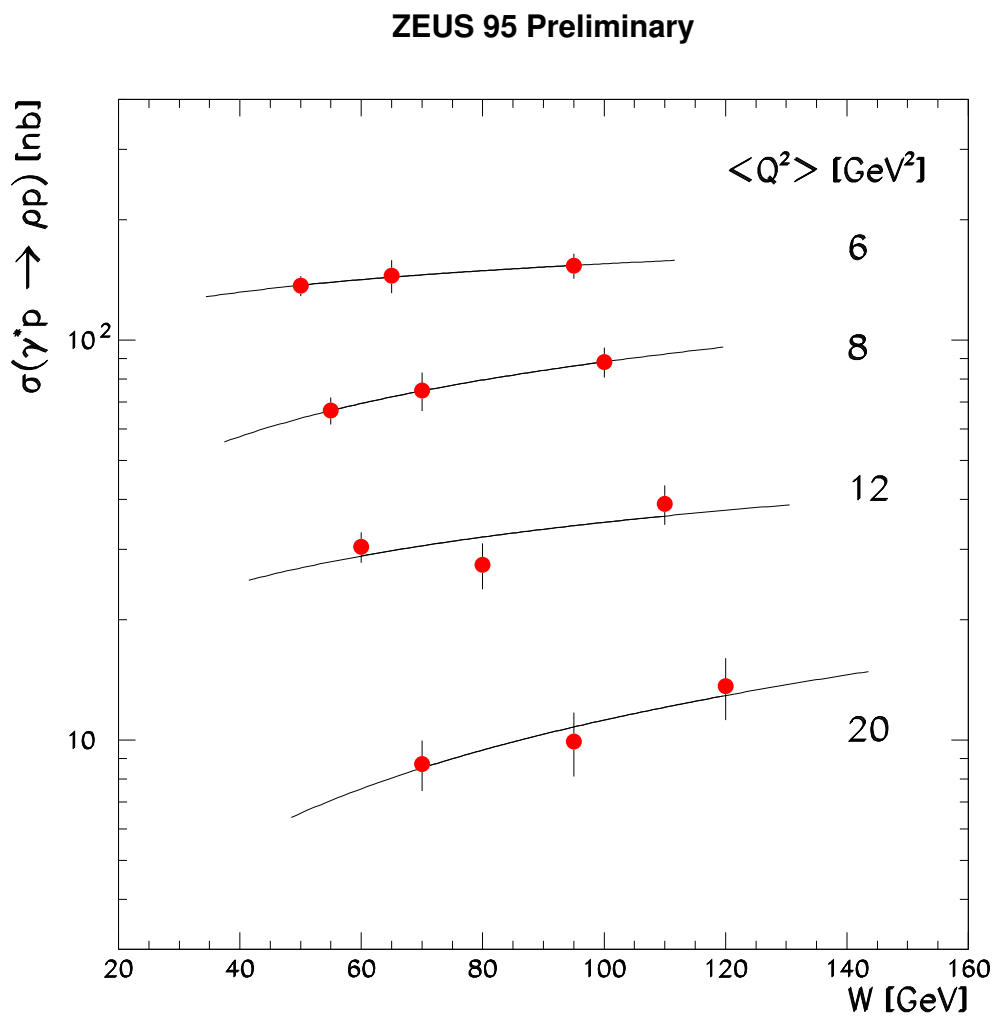
⇒ See Adi Bornheim's talk

Elastic ρ^0 Cross Sections



⇒ Experimental discrepancies require further study

Elastic ρ^0 Cross Sections at High Q^2

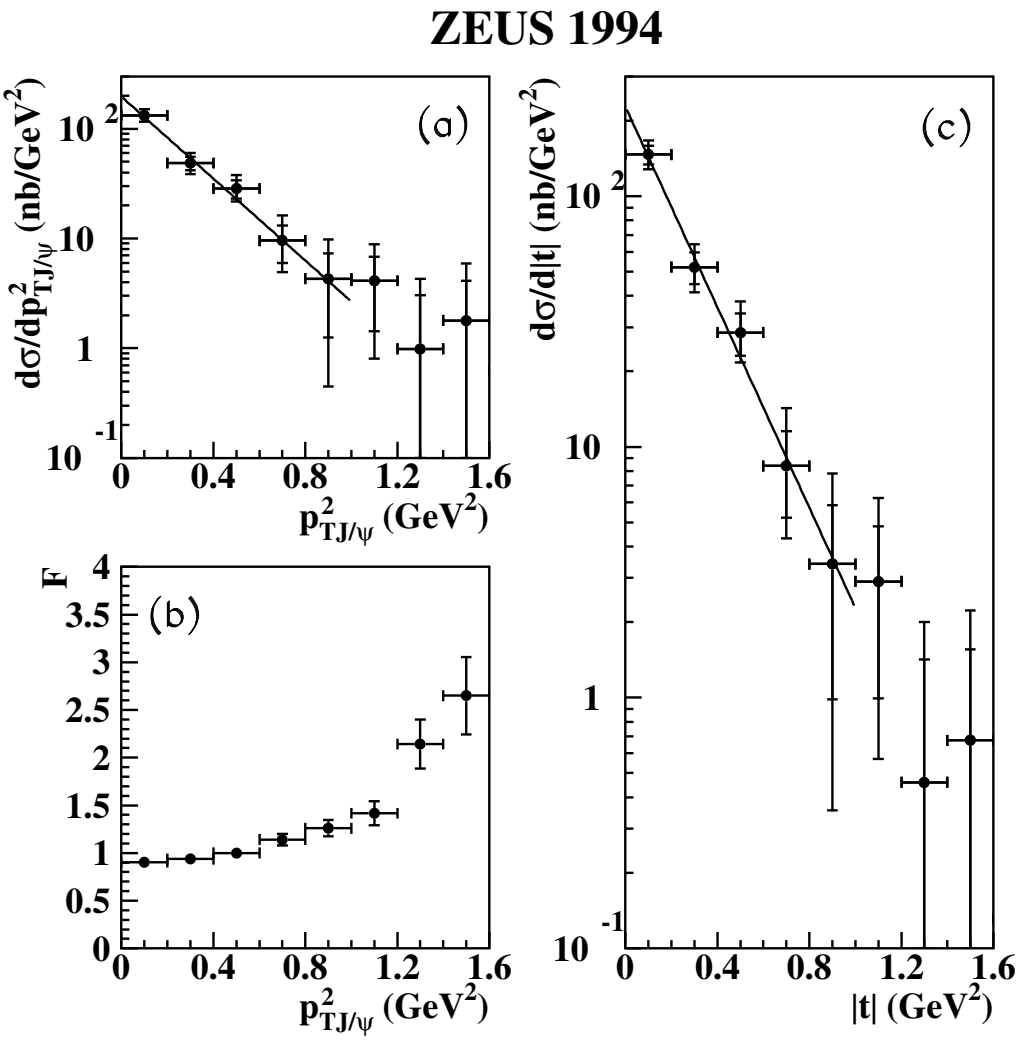


$\Rightarrow$ Steepening with Q^2 expected in pQCD

$\Rightarrow$ Need more data

Photoproduction of J/ψ Mesons

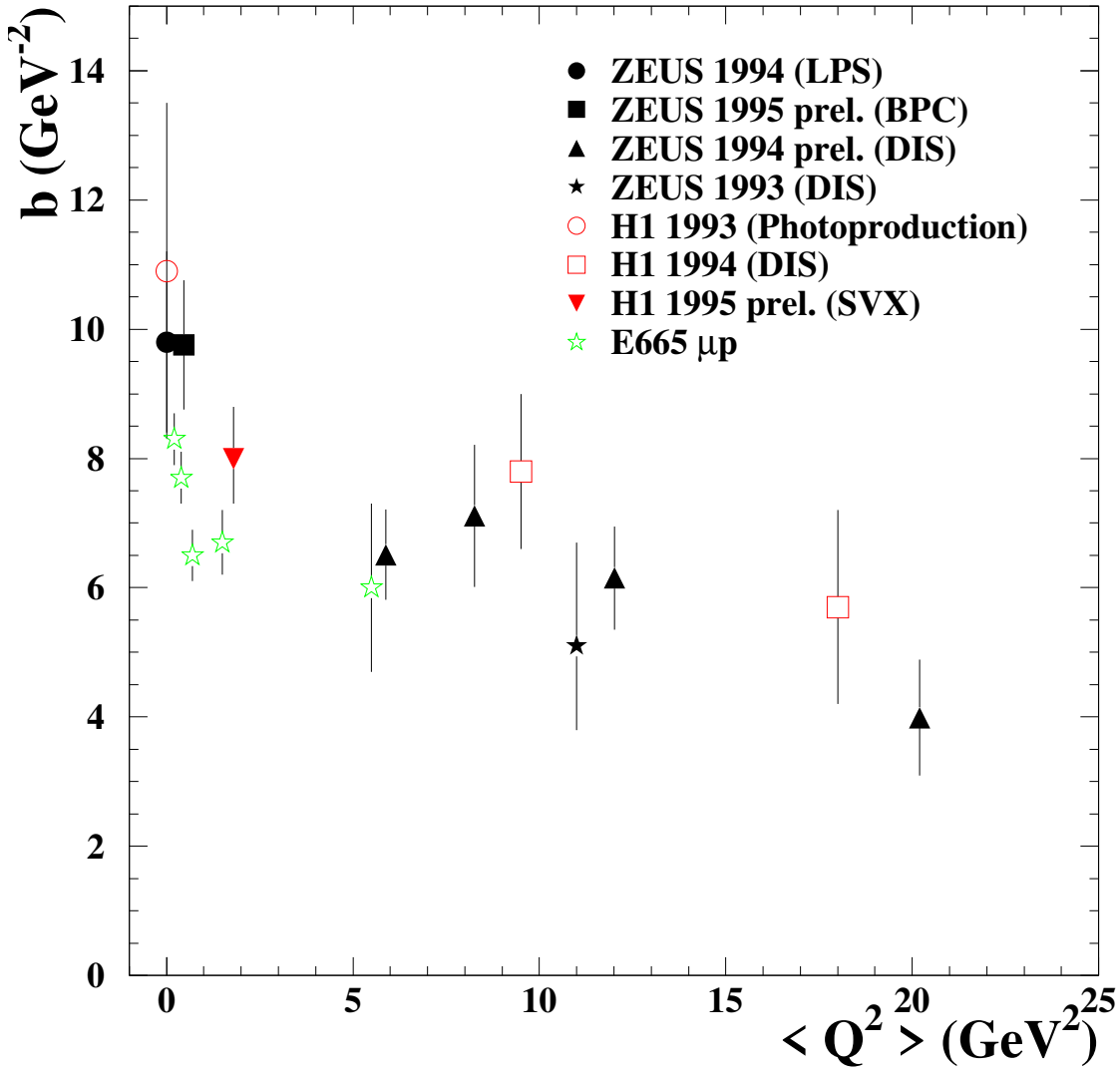
The Exponential Slope in $|t|$



$$b_{J/\psi} = 4.6 \pm 0.4\,(stat)^{+0.4}_{-0.6}\,(sys)\ \text{GeV}^{-2}$$

(Reminder : $b_{\rho^0} = 9.8 \pm 0.8\,(stat) \pm 1.1\,(sys)\ \text{GeV}^{-2}$)

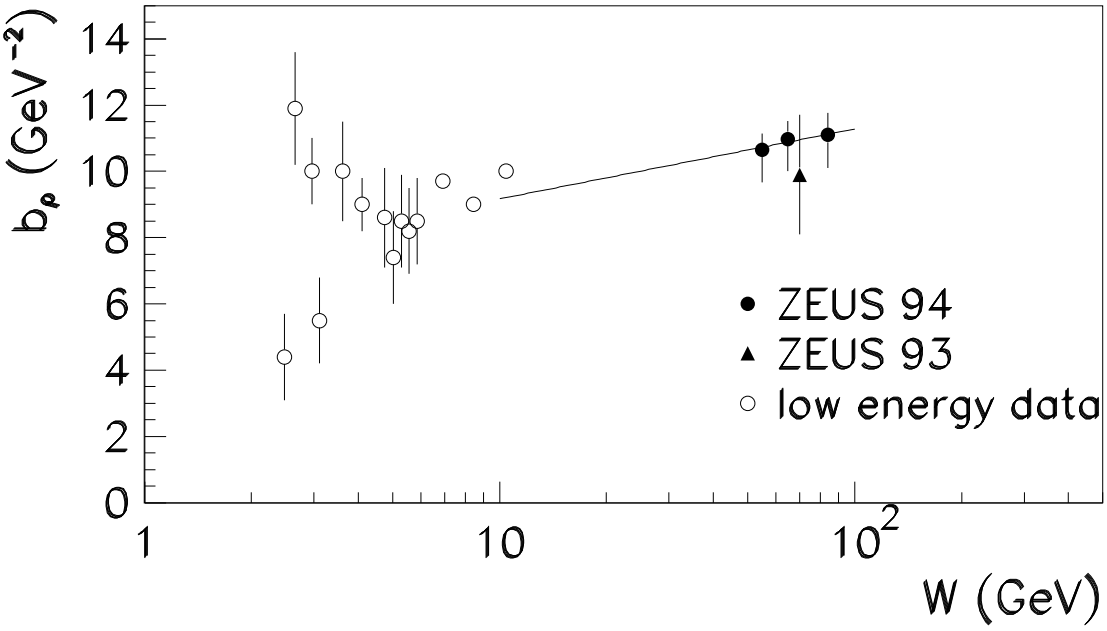
t-Slope for ρ^0 Mesons vs Q^2



$\Rightarrow$ The shrinking photon !!

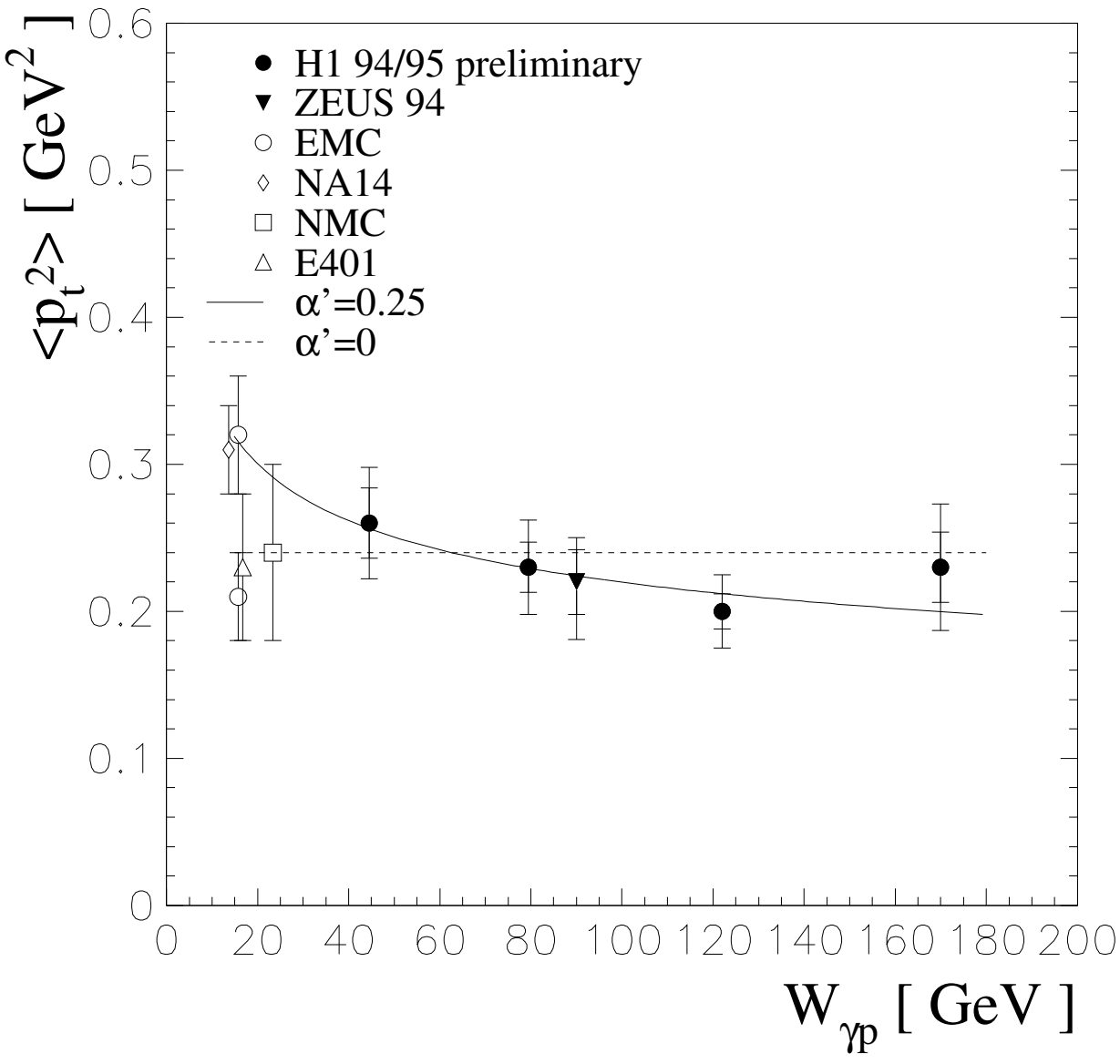
t-Slope for ρ^0 Mesons vs W

Does the t-slope depend on energy?



$\Rightarrow$ Test for shrinkage inconclusive

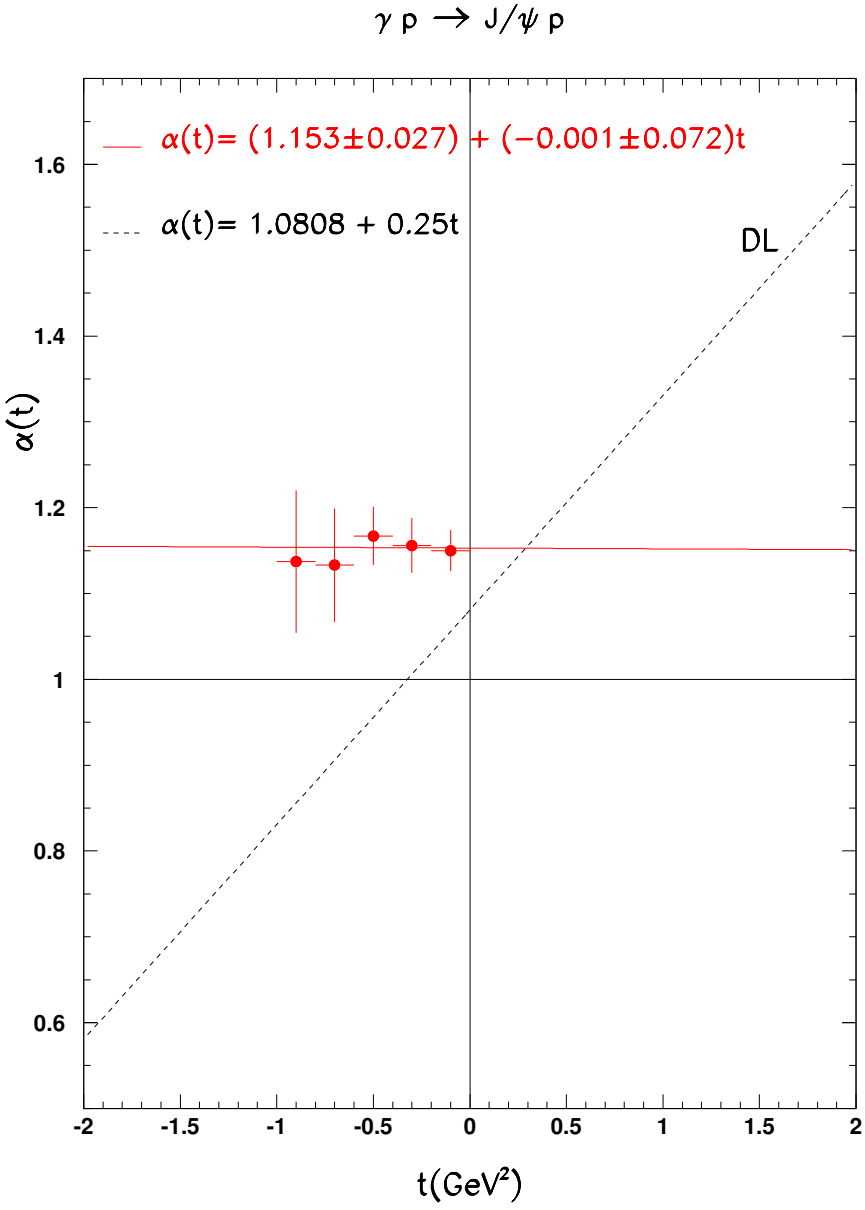
Elastic J/ψ Cross Sections



$\Rightarrow$ Again inconclusive on shrinkage

The Case Against Shrinkage

A. Levy, hep-ph/9712519

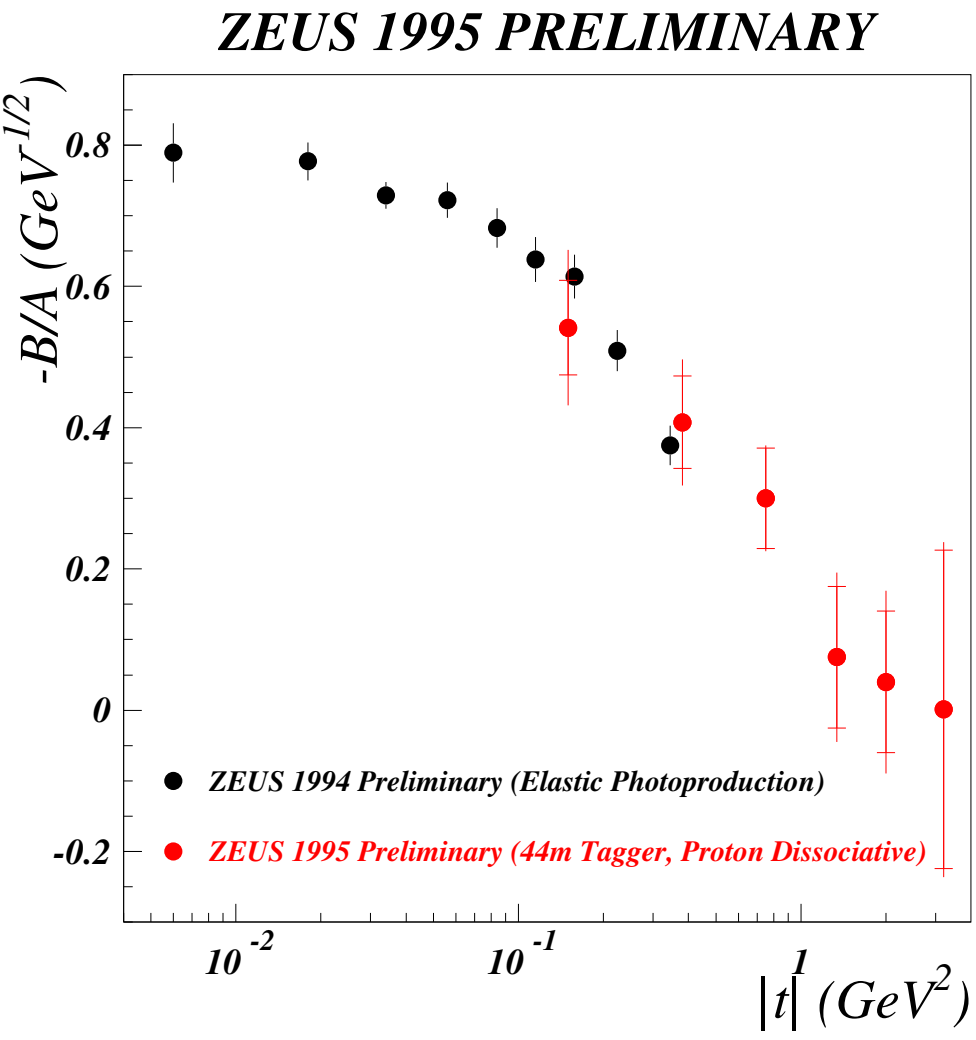


$\Rightarrow$ Inconsistent with $\alpha'_{I\!P} = 0.25$ GeV^{-2}

$\Rightarrow$ Concludes pQCD applicable

ρ^0 Mass Spectrum Skewing vs $|t|$

$$\frac{dN}{dM_{\pi\pi}} = \left| A \frac{\sqrt{M_{\pi\pi} M_\rho \Gamma_\rho}}{M_{\pi\pi}^2 - M_\rho^2 + i M_\rho \Gamma_\rho} + B \right|^2$$

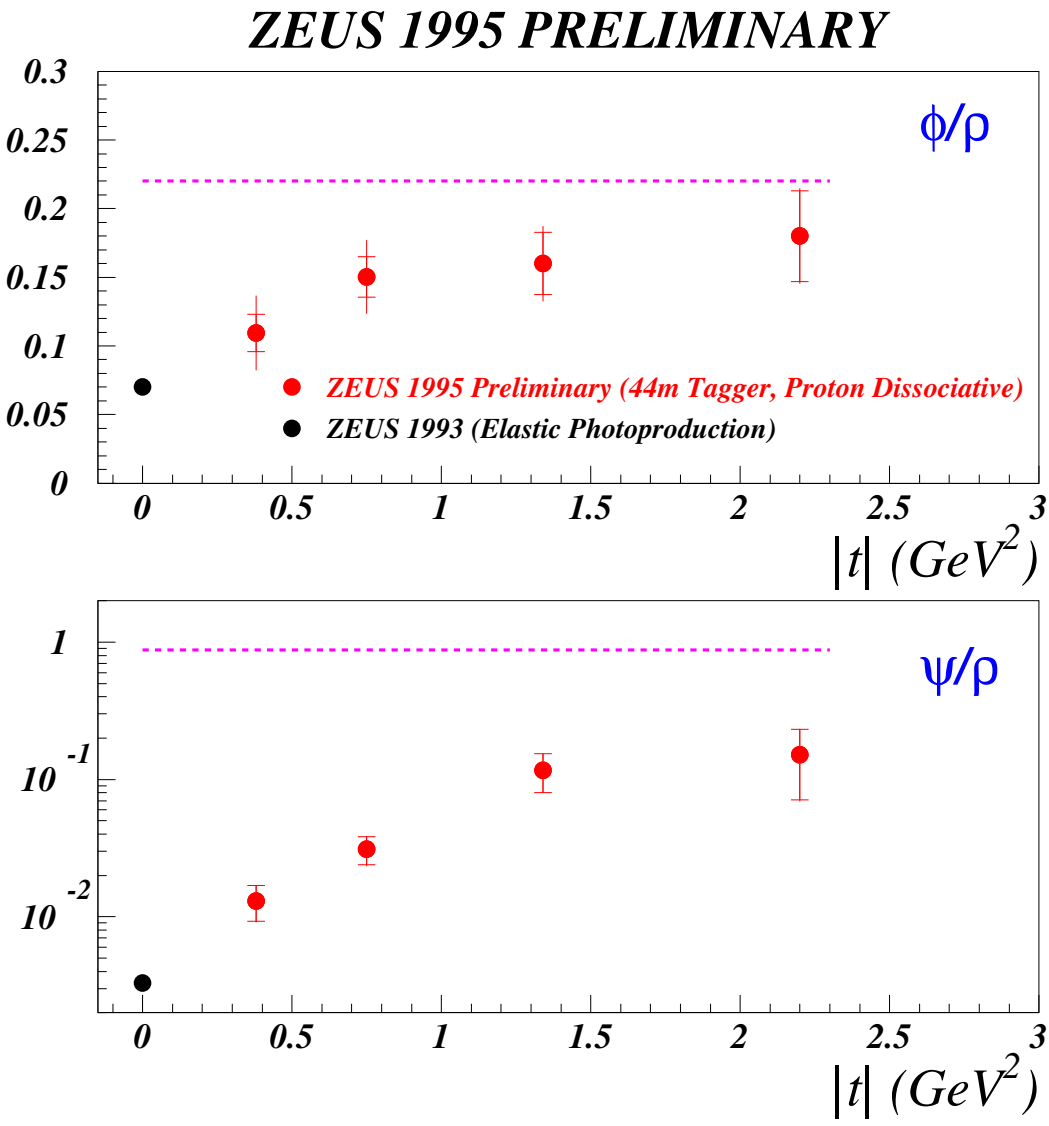


Vector Meson Production Ratios

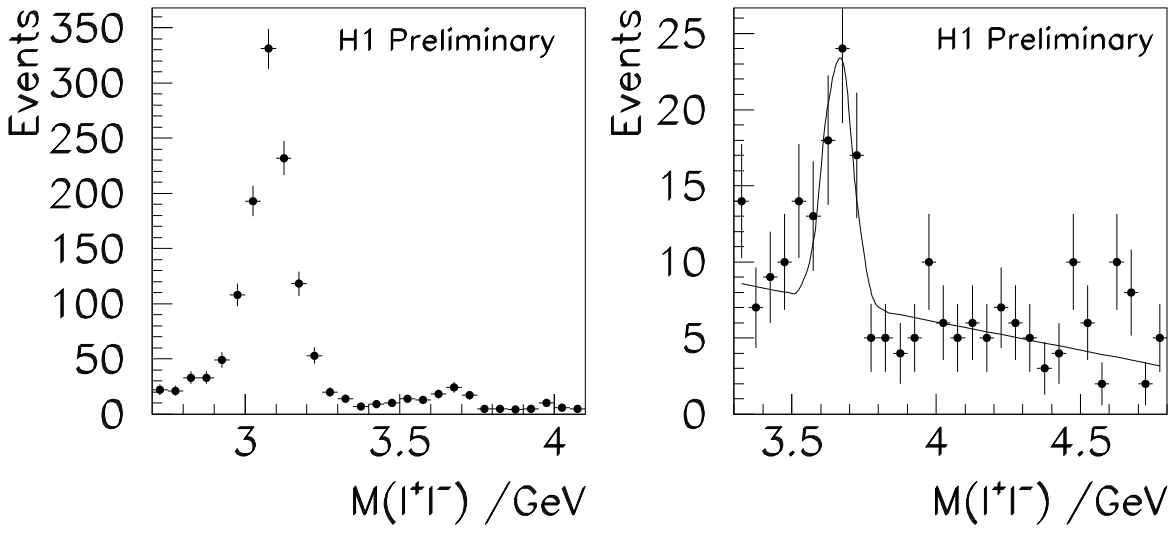
If direct e–m coupling to quarks without form factors

$$\rho^0 \;:\; \omega \;:\; \phi \;:\; J/\psi \;:\; \Upsilon$$

$$9 \;:\; 1 \;:\; 2 \;:\; 8 \;:\; 2$$

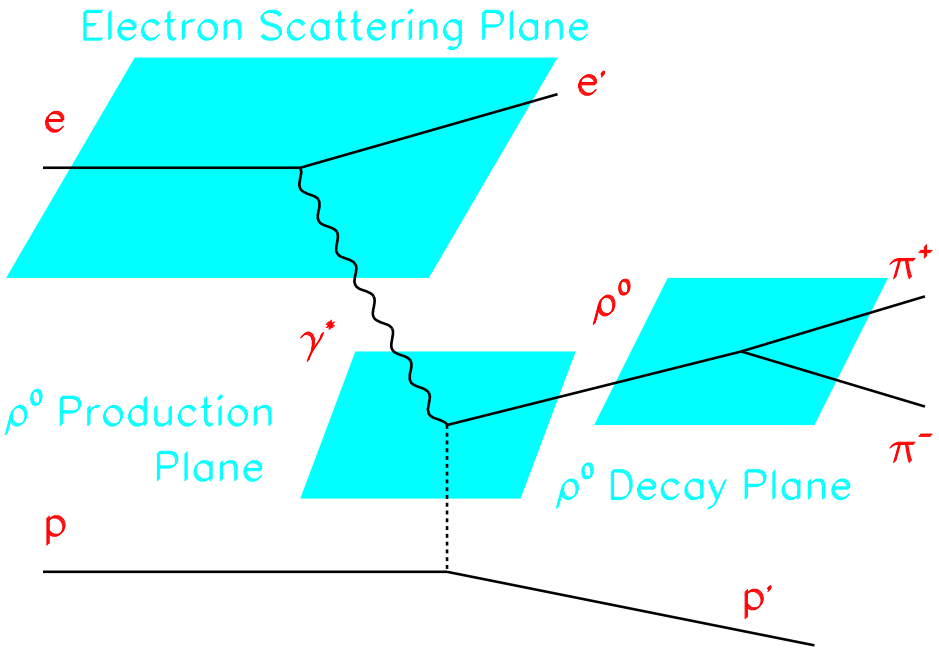


J/ψ(2S) Signal from H1



Striking effects expected for radially excited states in the color dipole model

Helicity Analyses



Φ_h Angle between the electron scattering plane and the ρ^0 production plane

θ_h Polar angle of π^+ in the ρ^0 rest frame

ϕ_h Azimuthal angle of π^+

If helicity is conserved in the γ/ρ^0 transition, then the decay angular distributions depend only on the difference $\psi_h = \phi_h - \Phi_h$.

Decomposing the Spin Density Matrix

How to couple real photons ($\lambda = \pm 1$)
to vector mesons ($\lambda = 0, \pm 1$) ??

Helicity conserved in strong interactions
(but in what frame??)

Schilling, Seyboth, and Wolf, Nucl.Phys. B15, 397 (1970)
Formalism developed generally for arbitrary
real photon polarization (2x2 matrices!)

- Circular polarization: $\vec{\epsilon_\gamma} = \pm P_\gamma^c\ (0, 0, 1)$
- Linear polarization: $\vec{\epsilon_\gamma} = P_\gamma^l\ (-\cos\Phi, \sin\Phi, 0)$

Decompose ρ^0 decay angle distribution $W(\theta,\phi)$
into four parts $W^i(\theta,\phi)$ (i=0,3) such that:

1. Unpolarized: $W(\theta,\phi) = W^0(\theta,\phi)$
2. Circularly polarized:
   $W(\theta,\phi) = W^0(\theta,\phi) \pm P_\gamma^c\ W^3(\theta,\phi)$
3. Linearly polarized:
   $W(\theta,\phi,\Phi) = W^0(\theta,\phi) - P_\gamma^l \cos 2\Phi\ W^1(\theta,\phi)$
   $- P_\gamma^l \sin 2\Phi\ W^2(\theta,\phi)$

Generalizing to $R = \frac{\sigma_L}{\sigma_T} > 0$

Schilling and Wolf, Nucl.Phys. B61, 381 (1973)

Define linear combinations of the matrix elements

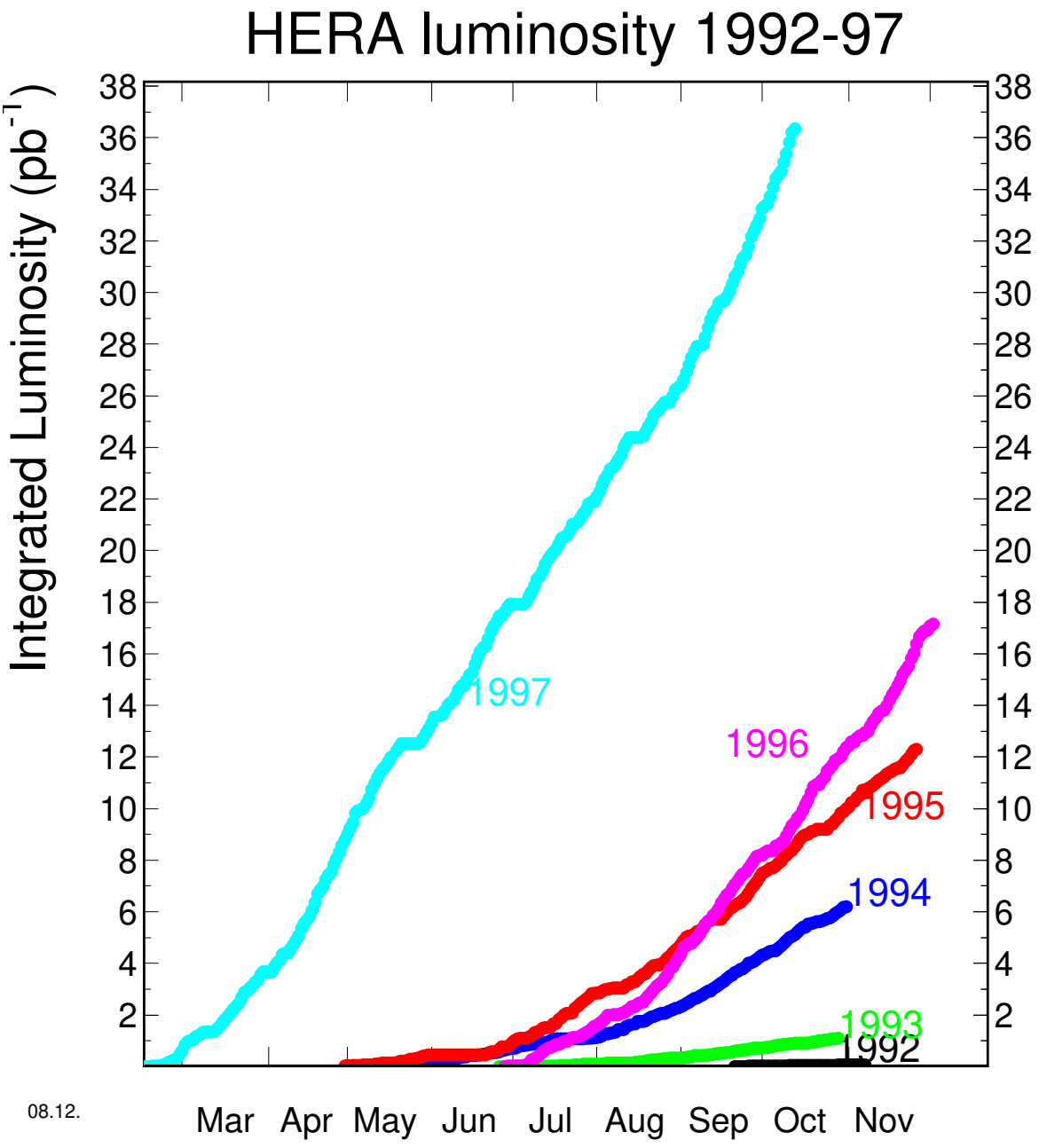
$$r_{ik}^{04} = \frac{\rho_{ik}^{0} + \epsilon R \rho_{ik}^{4}}{1 + \epsilon R}$$

$$r_{ik}^{\alpha} = \begin{cases} \dfrac{\rho_{ik}^{\alpha}}{1+\epsilon R} & \alpha = 1-3 \\ \dfrac{\sqrt{R}\,\rho_{ik}^{\alpha}}{1+\epsilon R} & \alpha = 5-8 \end{cases}$$

Conclusions

These results show preliminary evidence for the hard scale to be given by either Q^2, M_V^2, or $|t|$

The H1 and ZEUS experiments are sensitive to the transition region in *EACH* of these variables

These studies are statistics-limited

HERA Integrated Luminosity