ZEUS Diffractive Physics Group
Review Meeting

DESY
9.12.98

Helicity Conservation in Diffraction and the Contribution by ZEUS

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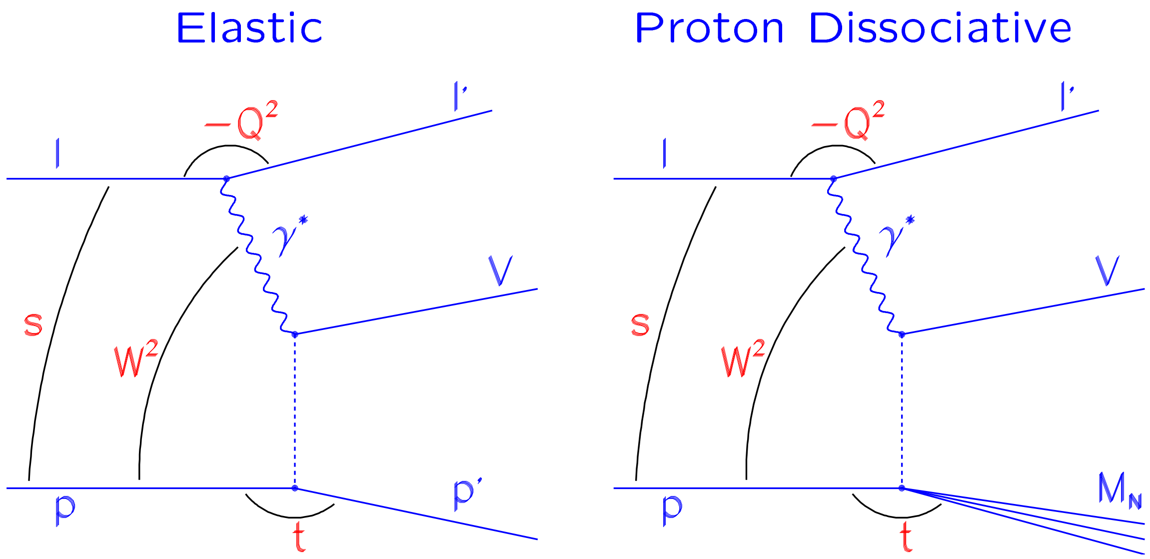
Diffractive Leptoproduction of Vector Mesons



$\sqrt{s}$: Center–of–mass energy of e–p system
HERA (ep, H1/ZEUS): 300 GeV
FNAL (μp, E665): $\simeq$30 GeV

W: Center–of–mass energy of γ^*–p system
(HERA: 20 – 240 GeV FNAL: 6 – 27 GeV)

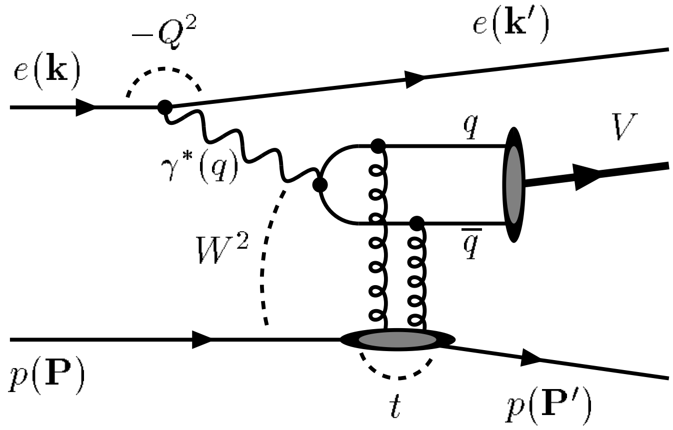
Q^2: Photon Virtuality
(HERA: 10^{-10} – 60 GeV^2 FNAL: 0.15 – 20 GeV^2)

t: Square of Momentum Transfer at the Proton Vertex
(HERA: $|t| < 13$ GeV^2 FNAL: $|t| < 1$ GeV^2)

$$|t|_{\mathrm{min}} = m_{\mathrm{p}}^2 \frac{(M_{\mathrm{V}}^2 + Q^2)^2}{W^4}$$

Perturbative QCD for Diffraction (?!)

☞ Exchange of a gluon "ladder"



Brodsky, Frankfurt, Gunion, Mueller, Strikman, PRD50 (1994) 3134

Only longitudinal photons have point-like interactions !

$$\left.\frac{d\sigma^L_{\gamma^* p \to Vp}}{d|t|}\right|_{t=0} = A_V \frac{\alpha_s^2(\bar{Q}^2)}{\alpha \bar{Q}^6} \left| \left[1 + \frac{i\pi}{2} \frac{d}{d(\ln x)}\right] xG(x, \bar{Q}^2) \right|^2$$

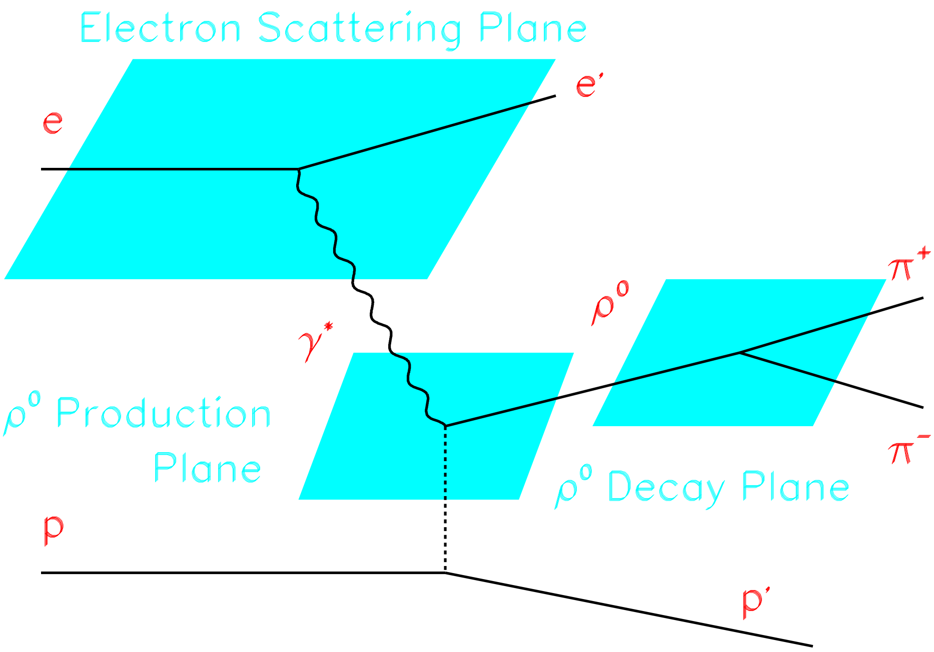
Energy dependence determined by $G(x, \bar{Q}^2)$, $x \approx Q^2/W^2$

Ryskin, Z.Phys. C57 (1993) 89 (J/ψ Photoproduction)

$$\bar{Q}^2 = \frac{Q^2 + M_V^2 - t}{4} \; (?)$$

Can the hard scale necessary for perturbative QCD calculations be set by either Q^2, M_V^2, or $|t|$??

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: $\vec{\epsilon_\gamma} = \pm P^c_\gamma \, (0, 0, 1)$
- Linear polarization: $\vec{\epsilon_\gamma} = P^l_\gamma \, (-\cos\Phi, \sin\Phi, 0)$

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

1. Unpolarized: $W(\theta,\phi) = W^0(\theta,\phi)$
2. Circularly polarized:
   $W(\theta,\phi) = W^0(\theta,\phi) \pm P^c_\gamma \; W^3(\theta,\phi)$
   Need long. pol. initial-state lepton→E665(μ),HERMES(e)
3. Linearly polarized:
   $W(\theta,\phi,\Phi) = W^0(\theta,\phi) - P^l_\gamma \cos 2\Phi \;\; W^1(\theta,\phi)$
   $- P^l_\gamma \sin 2\Phi \;\; W^2(\theta,\phi)$

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

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

Define linear combinations of the matrix elements:

(Helicity states $i, k = +1, 0, -1$)

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

The angular distributions do not distinguish unpolarized transverse photons from longitudinally polarized photons!

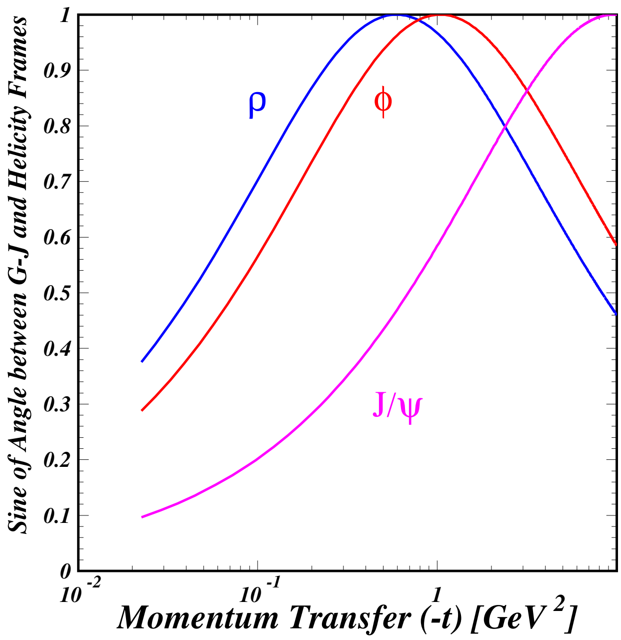
$$r_{ik}^{\alpha} = \begin{cases} \dfrac{\rho_{ik}^{\alpha}}{1+\epsilon R} & \alpha = 1-3 \text{ (Trans.)} \\ \dfrac{\sqrt{R}\,\rho_{ik}^{\alpha}}{1+\epsilon R} & \alpha = 5-8 \text{ (L/T int.)} \end{cases}$$

Constraints from hermiticity, parity conservation

The Choice of Frame

- Gottfried-Jackson frame
  Spin quantized along photon direction (t-channel)
- Helicity frame
  Spin quantized along meson direction (s-channel)

The angle χ between the two frames: $\cos\chi = \left(\frac{m_\rho^2 + t}{m_\rho^2 - t}\right)$



$\Longrightarrow$ ρ^0 most sensitive to a violation of helicity conservation in the s-channel amplitudes (SCHC)

Gilman et al., Phys. Lett. B31 (1970) 387

3-D Decay-Angle Distribution

(15 linearly independent parameters)

$$W(\cos\theta_h, \phi_h, \Phi_h) =$$

$$\frac{3}{4\pi}\Big[\Big(\frac{1}{2}\big(1 - r^{04}_{00}\big) + \frac{1}{2}\big(3r^{04}_{00} - 1\big)\cos^2\theta_h$$
$$- \sqrt{2}\,\mathrm{Re}\, r^{04}_{10}\ \sin 2\theta_h \cos\phi_h - r^{04}_{1-1}\sin^2\theta_h \cos 2\phi_h \Big)$$

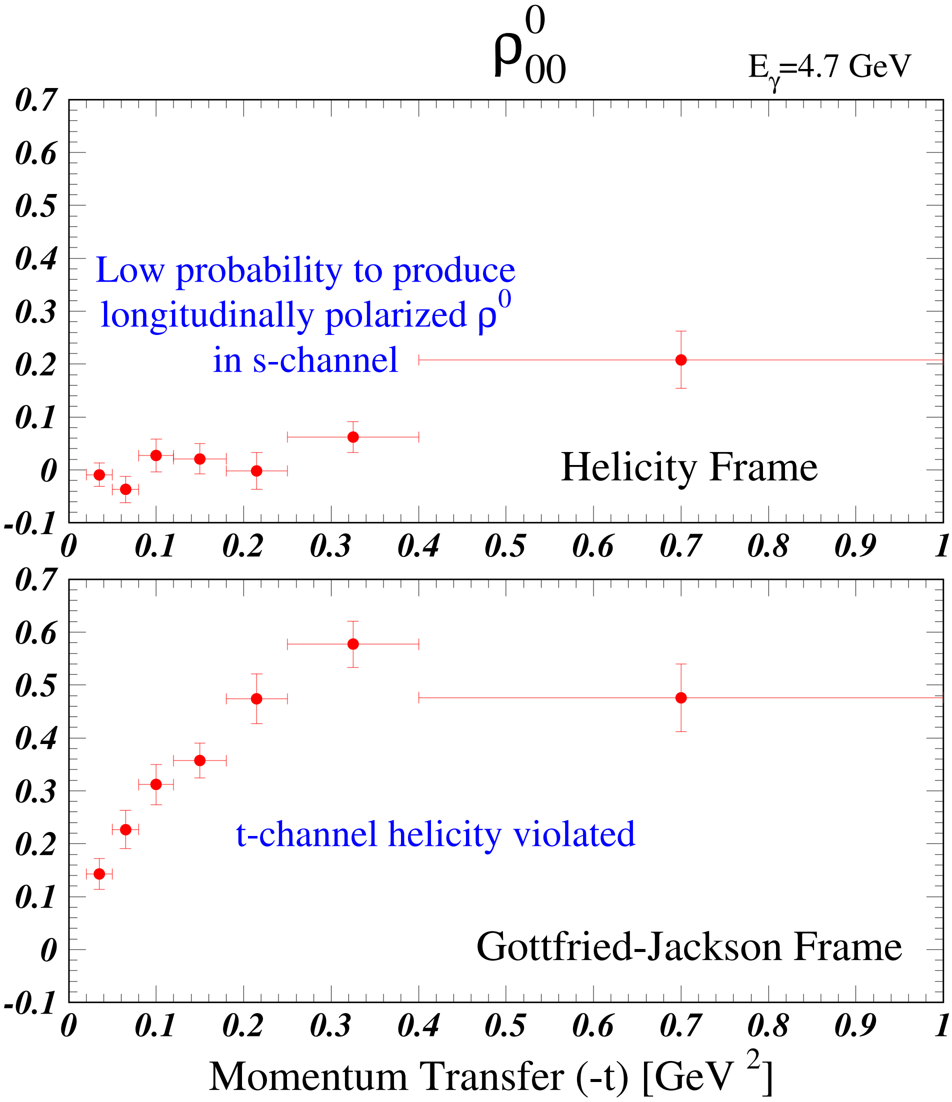
$$-\varepsilon \cos 2\Phi_h\big(\ r^1_{11}\sin^2\theta_h + r^1_{00}\cos^2\theta_h$$
$$-\sqrt{2}\,\mathrm{Re}\, r^1_{10}\ \sin 2\theta_h \cos\phi_h$$
$$-r^1_{1-1}\sin^2\theta_h\cos 2\phi_h\ \big)$$
$$-\varepsilon \sin 2\Phi_h\big(\ \sqrt{2}\,\mathrm{Im}\, r^2_{10}\ \sin 2\theta_h \sin\phi_h$$
$$+\mathrm{Im}\, r^2_{1-1}\sin^2\theta_h \sin 2\phi_h\ \big)$$

$$+\sqrt{2\varepsilon(1+\varepsilon)}\cos\Phi_h\big(\ r^5_{11}\sin^2\theta_h + r^5_{00}\cos^2\theta_h$$
$$-\sqrt{2}\,\mathrm{Re}\, r^5_{10}\ \sin 2\theta_h\cos\phi_h$$
$$-r^5_{1-1}\sin^2\theta_h\cos 2\phi_h\ \big)$$
$$+\sqrt{2\varepsilon(1+\varepsilon)}\sin\Phi_h\big(\ \sqrt{2}\,\mathrm{Im}\, r^6_{10}\ \sin 2\theta_h\sin\phi_h$$
$$+\mathrm{Im}\, r^6_{1-1}\sin^2\theta_h\sin 2\phi_h\big)\Big]$$

SCHC in ρ^0 Photoproduction

Ballam et al., Phys. Rev. D5, 545 (1972)

- Backscattered laser beam at SLAC
- Linear polarization measured to be greater than 90%
- 3k $\rho^0 \to \pi^+\pi^-$ reconstructed in bubble chamber



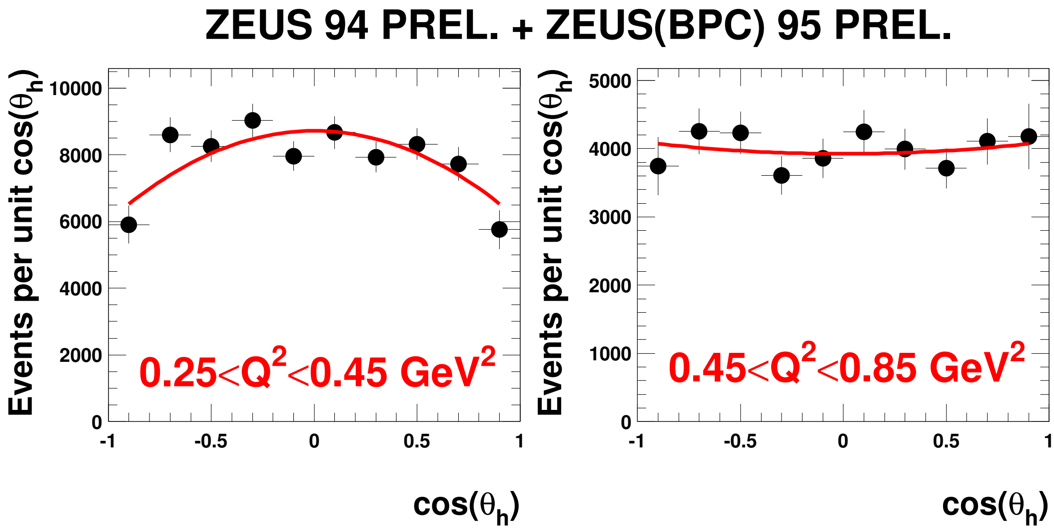
Inconsistent with t-channel exchange of spin 0 object

Gilman et al PL B31 (1970) 387

$\Longrightarrow$ Conclude SCHC holds for $|t| < 0.4$ GeV^2

ρ^0 Electroproduction at HERA

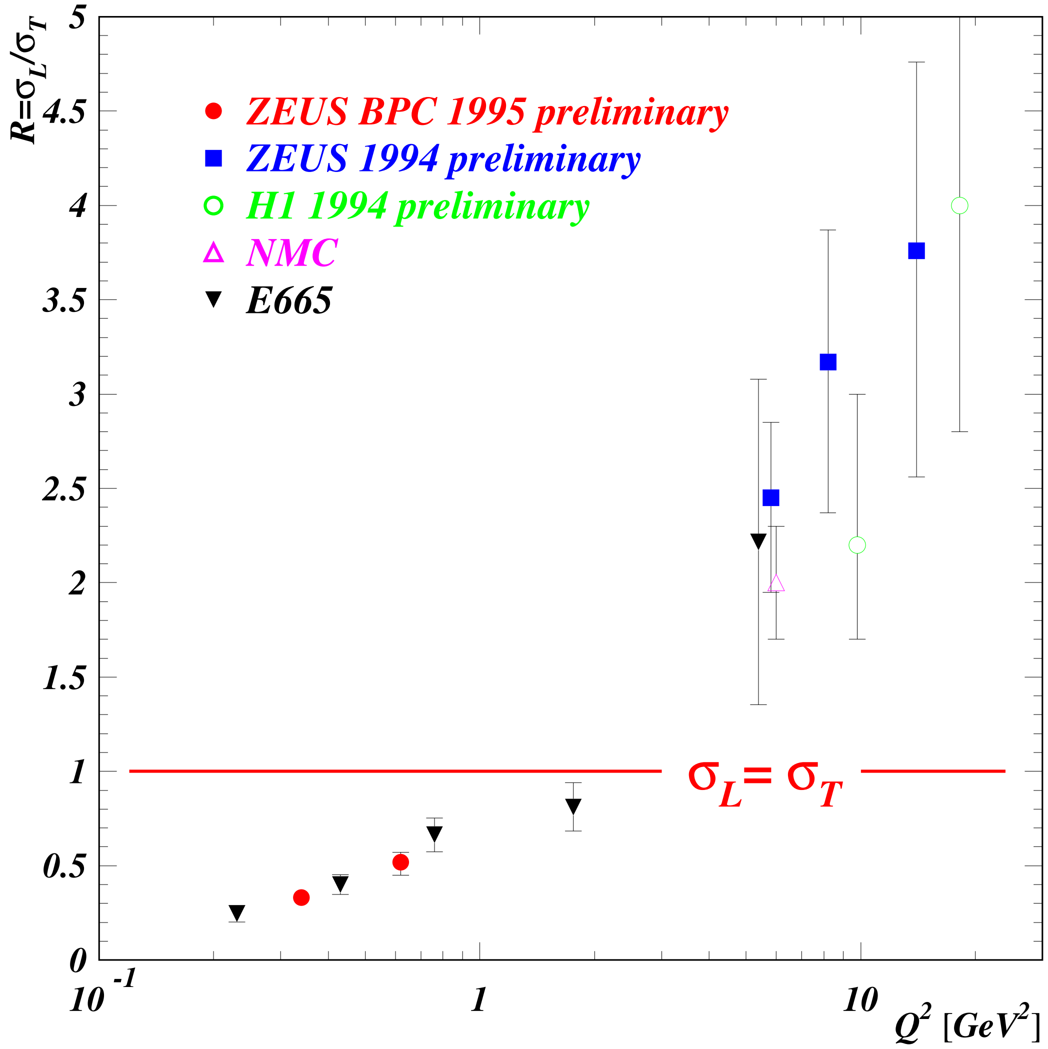
$$\frac{dN}{d\cos\theta_h} \propto 1 - r^{04}_{00} + (3r^{04}_{00} - 1)\cos^2\theta_h$$



Q^2 (GeV^2)	r^{04}_{00}
0.34	0.24 ±0.02(stat)
0.62	0.34 ±0.03(stat)
5.8	$0.71^{+0.03}_{-0.04}$(stat)$^{+0.01}_{-0.01}$(sys)
8.2	$0.76^{+0.04}_{-0.04}$(stat)$^{+0.00}_{-0.02}$(sys)
14	$0.79^{+0.04}_{-0.05}$(stat)$^{+0.02}_{-0.01}$(sys)

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

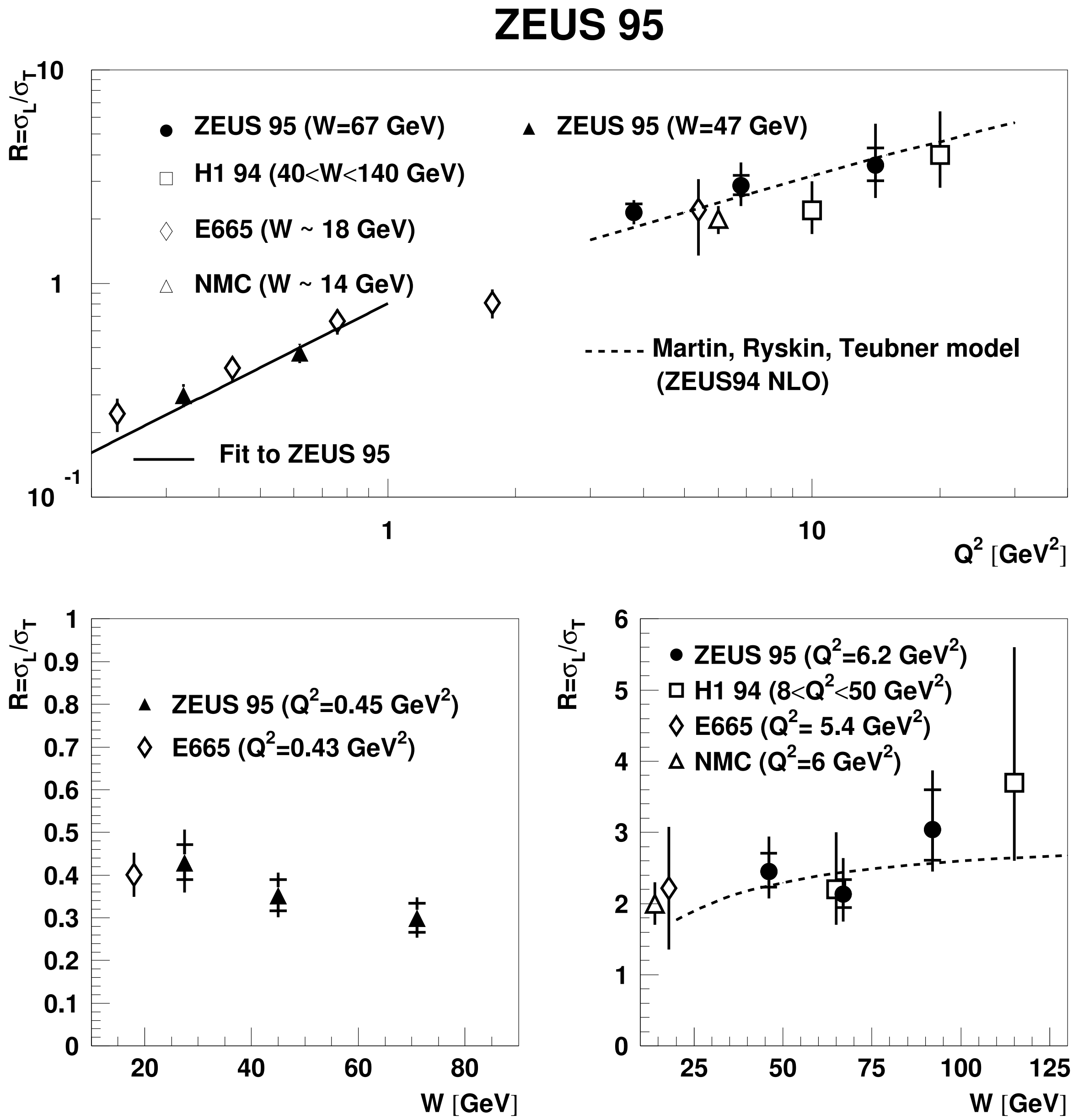
Assuming SCHC: $R = \frac{1}{\epsilon} \frac{r^{04}_{00}}{1-r^{04}_{00}}$



$\Rightarrow$ σ_L increases and becomes dominant

R vs Q^2 and W for ρ^0

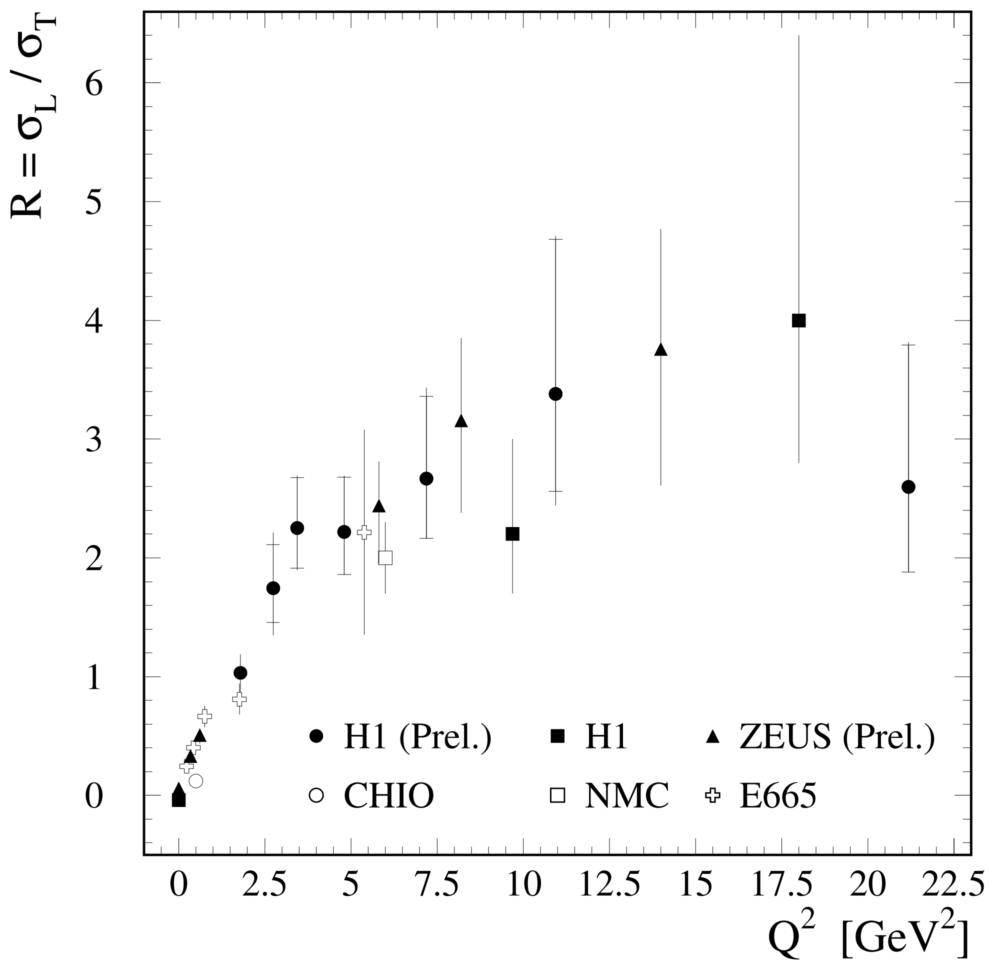
ZEUS: hep-ex/9808020



$\Rightarrow$ Do σ_T and σ_L have similar W dependence ?

R vs Q^2 (H1 DIS ρ^0 prel.)

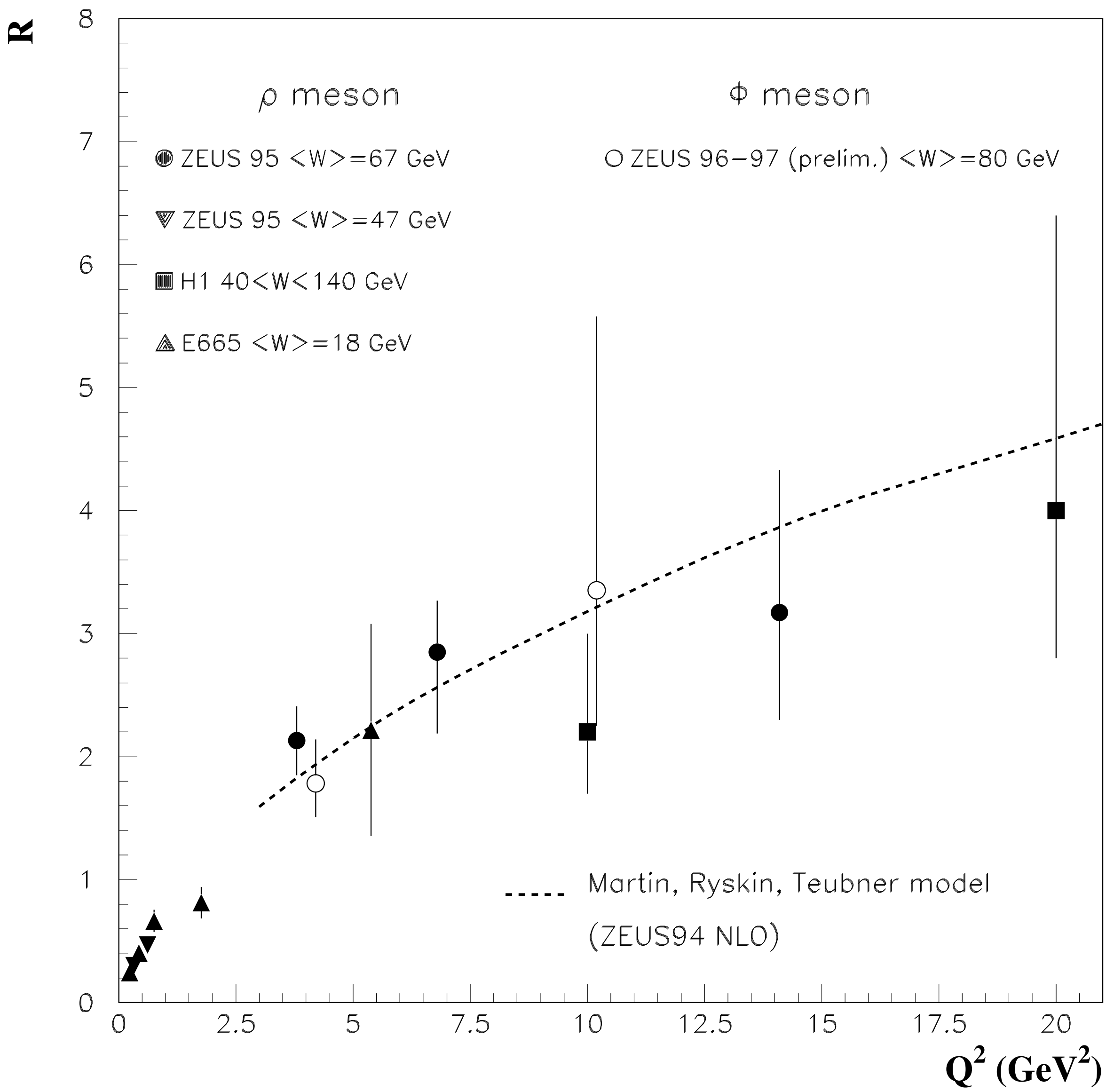
H1 ICHEP Abstract 564



$\Rightarrow$ σ_L/σ_T levelling off ??

R vs Q^2 (ZEUS DIS ϕ prel.)

ZEUS ICHEP Abstract 793

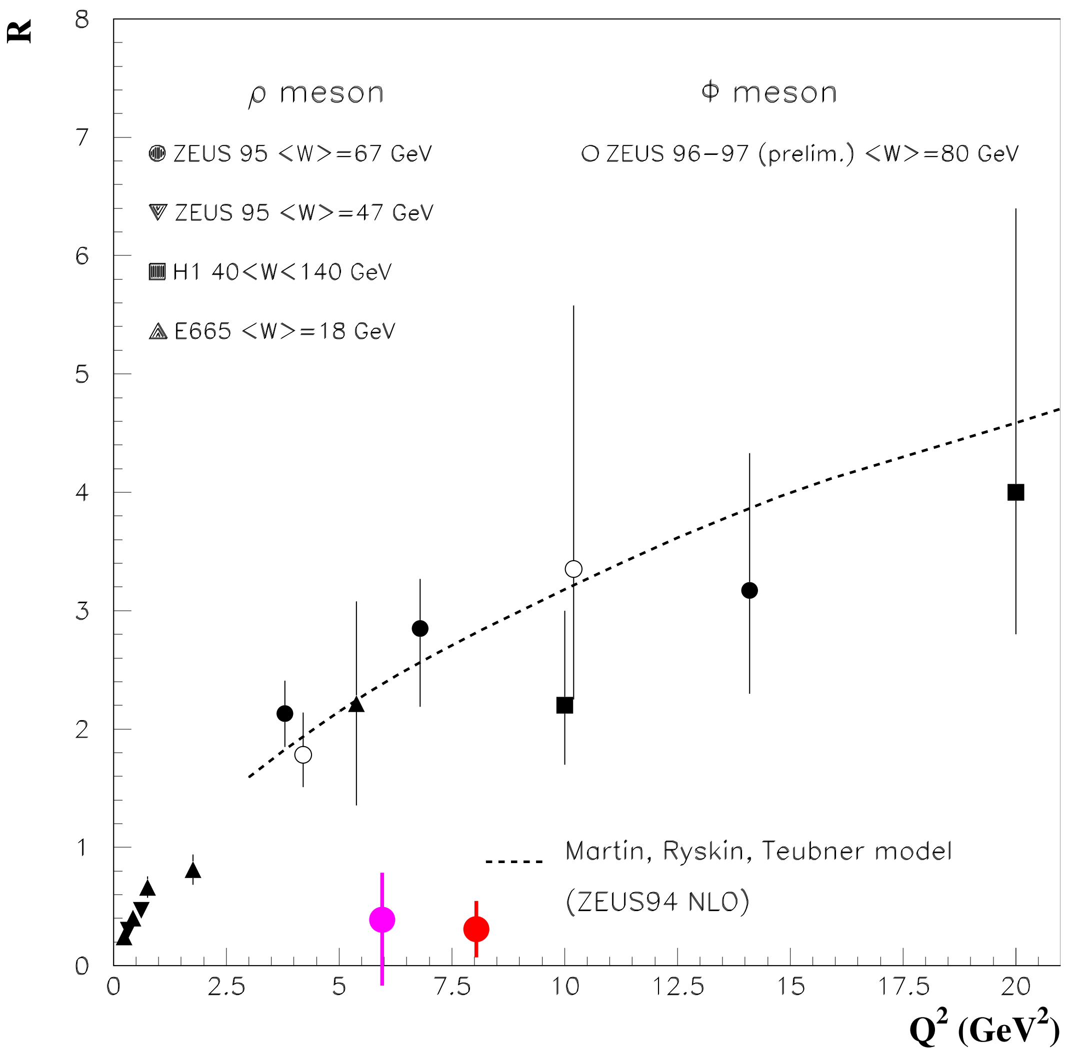


$\Rightarrow$ ϕ behaves like ρ^0 !!

R vs Q^2 for J/ψ

H1 ICHEP Abstract 572

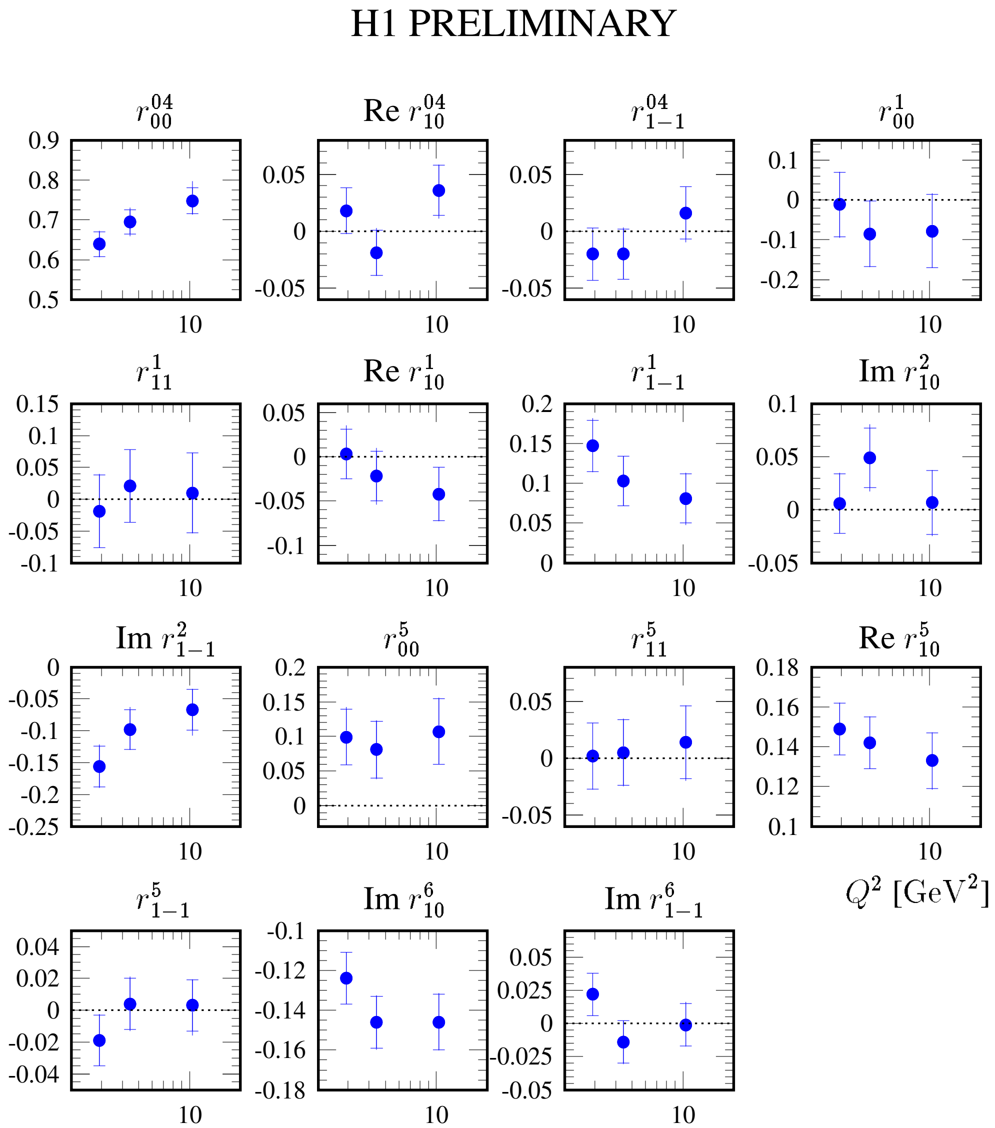
ZEUS hep-ex/9808020



$\Rightarrow$ R for J/ψ lower !!

15-Parameter Helicity-Angle Fit (I)

H1 ICHEP Abstract 564

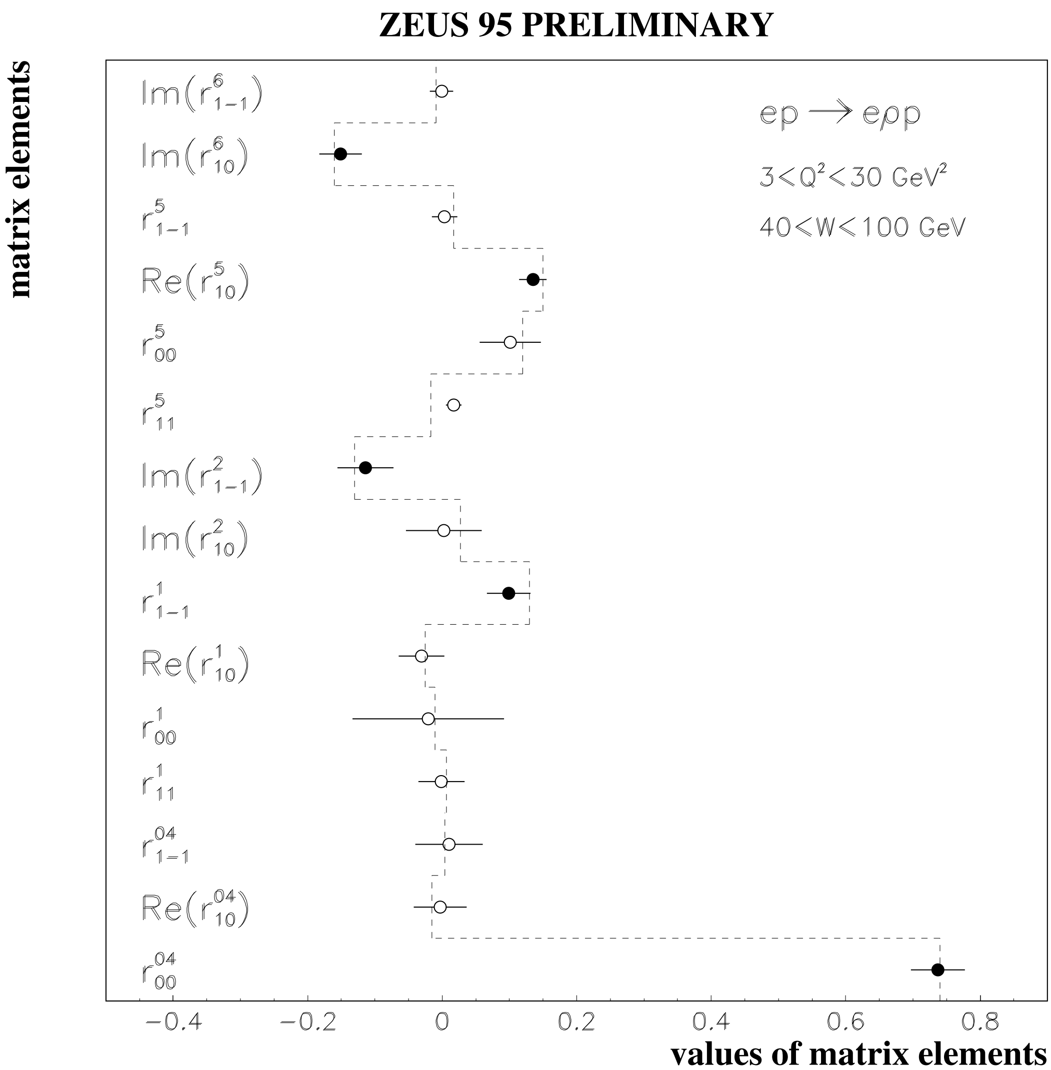


Dotted lines are SCHC values

$\Rightarrow$ SCHC violated ($r^5_{00} > 0$)

15-Parameter Helicity-Angle Fit (II)

ZEUS ICHEP Abstract 792/792b



$\Rightarrow$ Agreement with Ivanov and Kirschner (hep-ph/9807324)

$\Rightarrow$ Results also obtained for low Q^2 and ϕ

Ivanov and Kirchner

hep-ph/9807324

- Strong Q^2 dependence of $G(x, Q^2)$ at low x predicted by pQCD results in convergent integrals for transverse photons, overcoming endpoint divergences

  $\Longrightarrow$ A là Martin, Ryskin, Teubner

- Five helicity amplitudes: two helicity-conserving
  two single-flip
  one double-flip

- Amplitude to produce longitudinal ρ's from transverse photons rendered experimentally accessible via its interference with the dominant helicity-conserving longitudinal amplitude

- This single-flip amplitude is higher twist and proportional to $\sqrt{t}$

- The single-flip amplitudes *vanish* if $z = 1/2$ i.e. they vanish in the nonrelativistic approximation for the ρ wave function

Status of Paper Draft

- Contact person: Michele (also wise person)
  Editorial board: Jim W., Allen, Malcolm,
  Halina, me, Sasha, Sergey,
  Krzysztof, Michele
  A ZEUS note by Sasha is available
- The basic idea of the paper is to publish the determination of the 15 parameters characterizing the three-dimensional angular distributions for the data samples of the VM95 paper (hep-ex/9808020) which has been accepted by EJP after some minor modifications. These are the BPC (5.3k events) and DIS (2.5k events) rho samples from 1995
- Significant deviations from SCHC expectations are observed in both samples
- Comparisons are made to earlier observations of helicity nonconservation in photoproduction (PL B113 (1976) 53) and in muoproduction (PRD 26 (1982) 26)
- There has been one meeting of the Editorial Board (23 Oct 98)
- A new draft is now circulating in the Editorial Board, which expects to hold its next meeting in January