ON BEHALF OF
THE ZEUS COLLABORATION

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Proton-Dissociative Diffractive Photoproduction of Vector Mesons at Large $|t|$ at HERA

- Physics Motivation
- Event Kinematics
- Results
  - Differential Cross Section $d\sigma/dt$
  - Decay Angular Analysis
- Summary and Conclusions

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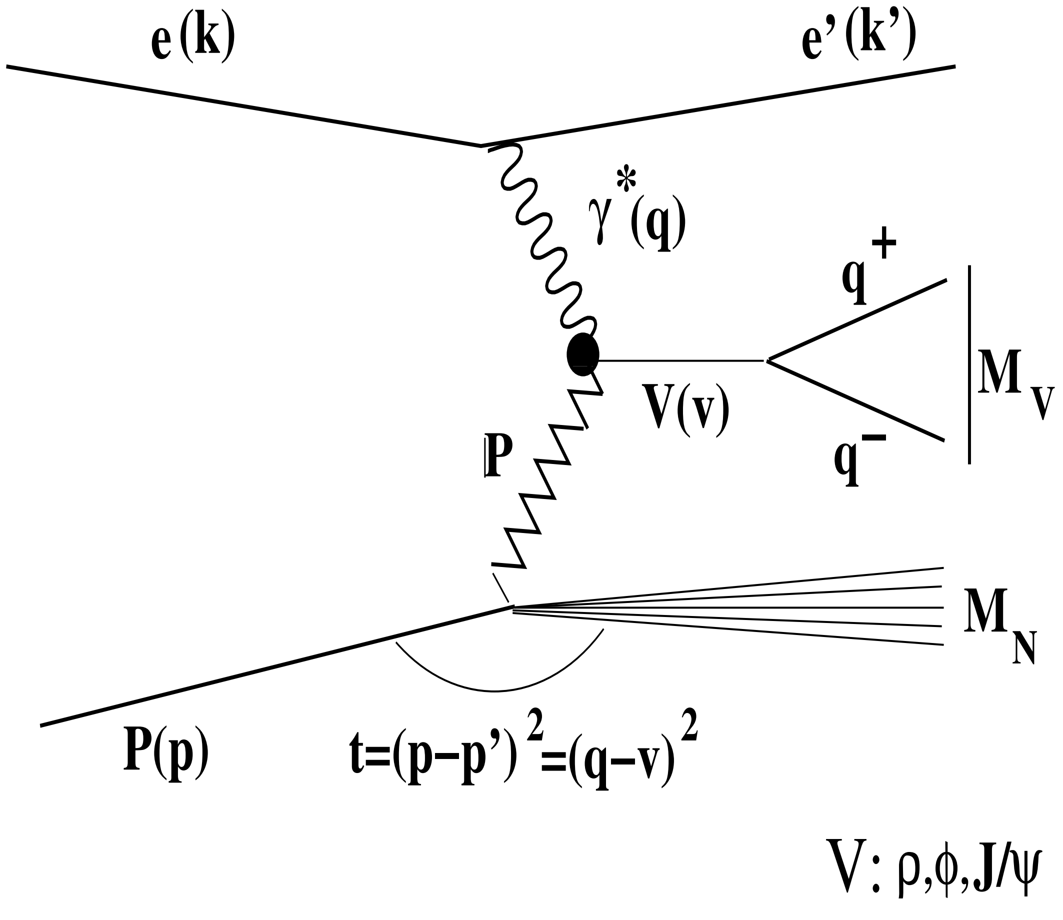
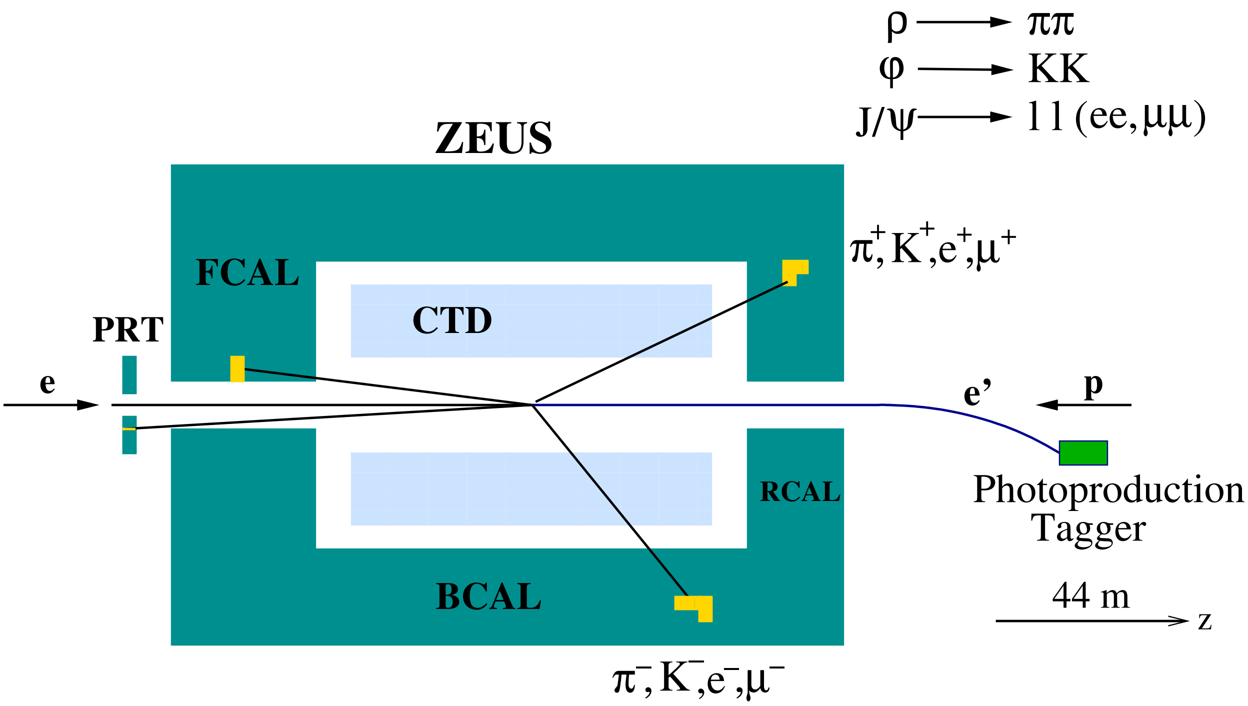
PHYSICS MOTIVATION



- Does $|t|$ provide a hard scale?
- At which $|t|$ is the pQCD description valid?
- Do the mesons retain photon helicity?

EVENT RECONSTRUCTION



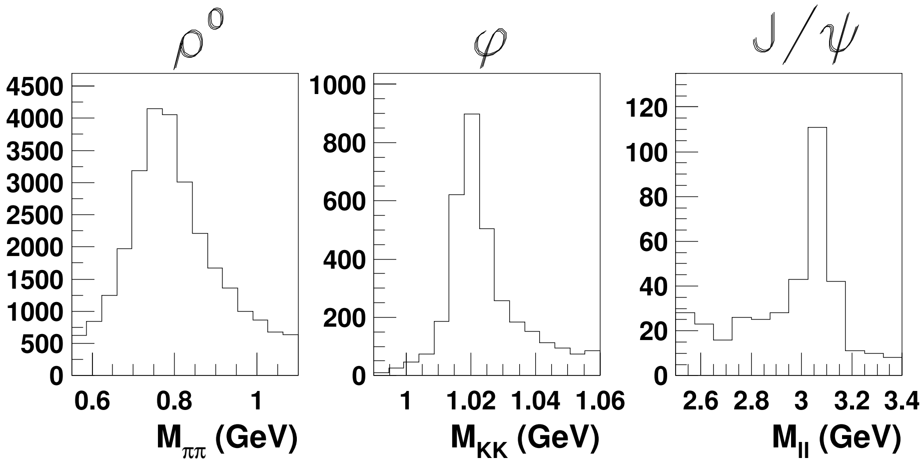
- Two tracks of opposite charge registered in the **C**entral **T**racking **D**etector
- Energy deposits in **RCAL** and **BCAL** only from the two tracks
- Energy deposits in **FCAL** and the **P**roton **R**emnant **T**agger from the proton fragments
- Scattered positron registered in the Photoproduction Tagger

All kinematical variables like $W_{\gamma p}$, t and the helicity angles $cos(\theta_h)$ and ϕ_h are reconstructed from the four-momenta of the meson decay products.

KINEMATIC RANGE AND EVENT SELECTION

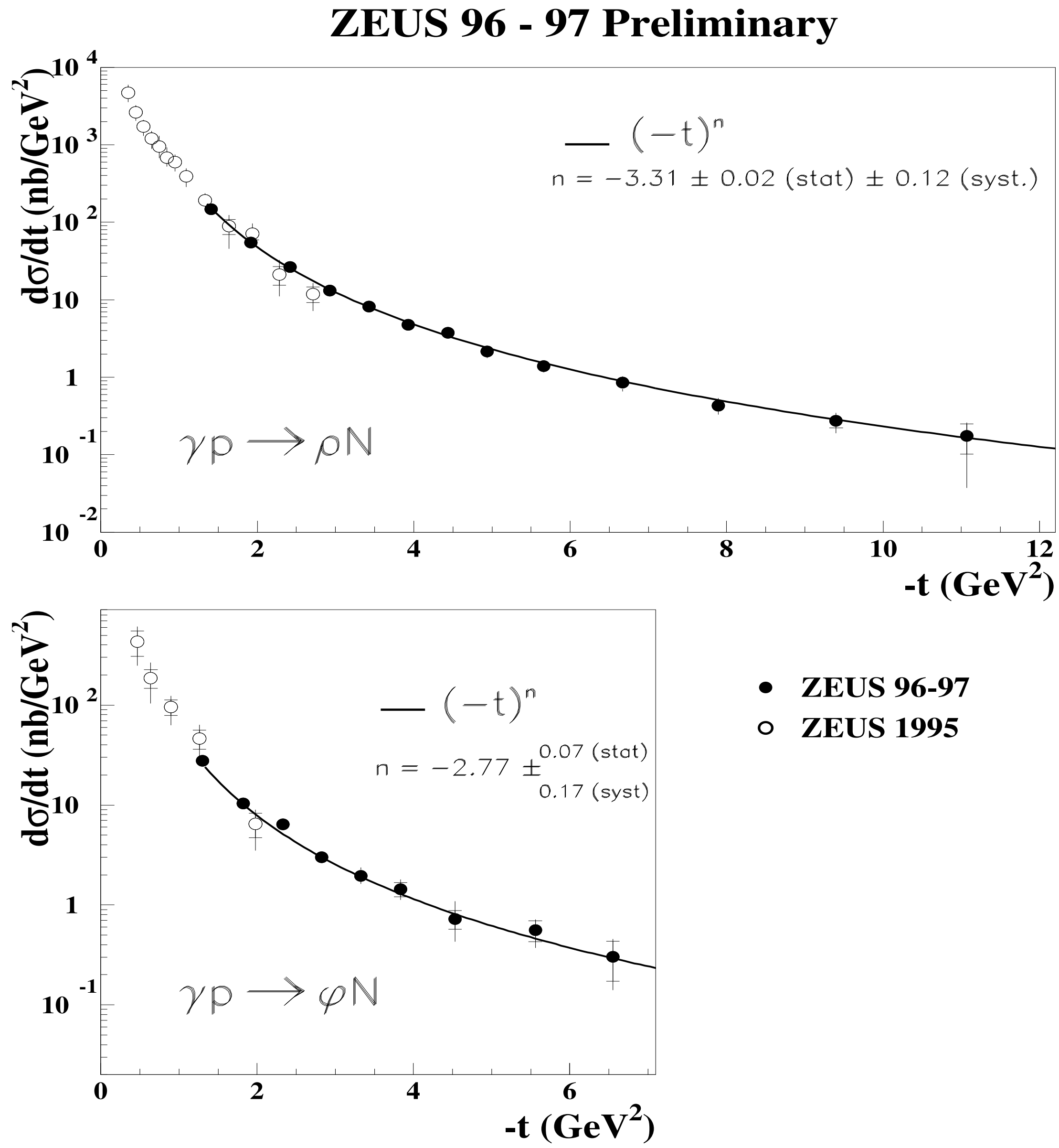
data analyzed: 1996-97 (24 pb^{-1})

- photoproduction: $Q^2 < 0.02\ \mathrm{GeV}^2$
- $|t|$ range: $1.1 - 12\ \mathrm{GeV}^2$
- average: $\langle W_{\gamma p} \rangle \simeq 100$ GeV
  $W_{\gamma p}$ range : $80 < W_{\gamma p} < 120$ GeV
- the invariant mass range for 3 vector mesons:
  $0.55 < M_{\pi\pi} < 1.1$ GeV for ρ^0
  $0.99 < M_{KK} < 1.06$ GeV for φ
  $2.98 < M_{ll} < 3.13$ GeV for J/ψ



Final Sample: 24400 ρ^0
3300 φ
180 J/ψ

$\frac{d\sigma}{dt}$ RESULTS for ρ^0 and φ



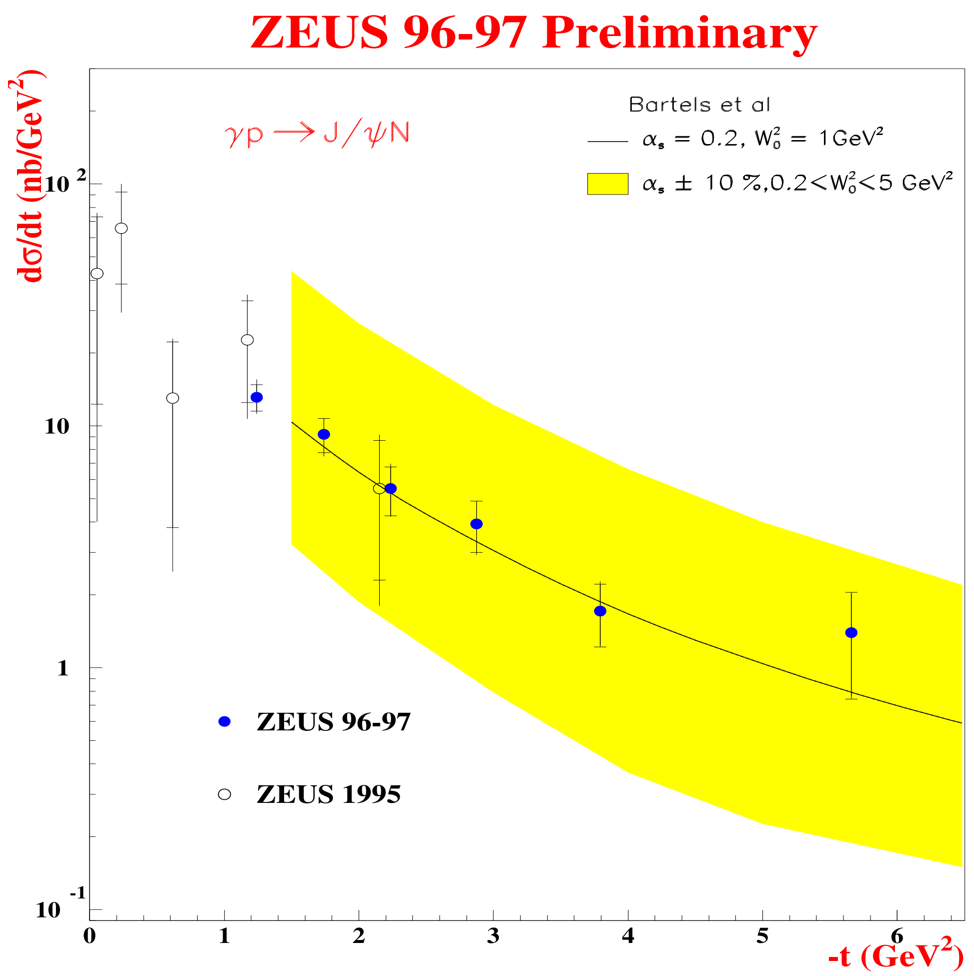
- pQCD predicts power-like behavior of cross sections with $|t|$

$$\frac{d\sigma}{dt} \propto |t|^n$$

- Fitted powers for $|t| > 1.2$ GeV^2:

$$n = -3.31 \pm 0.02(\text{stat}) \pm 0.12(\text{syst}) \text{ for } \rho^0$$
$$n = -2.77 \pm 0.07(\text{stat}) \pm 0.17(\text{syst}) \text{ for } \varphi$$

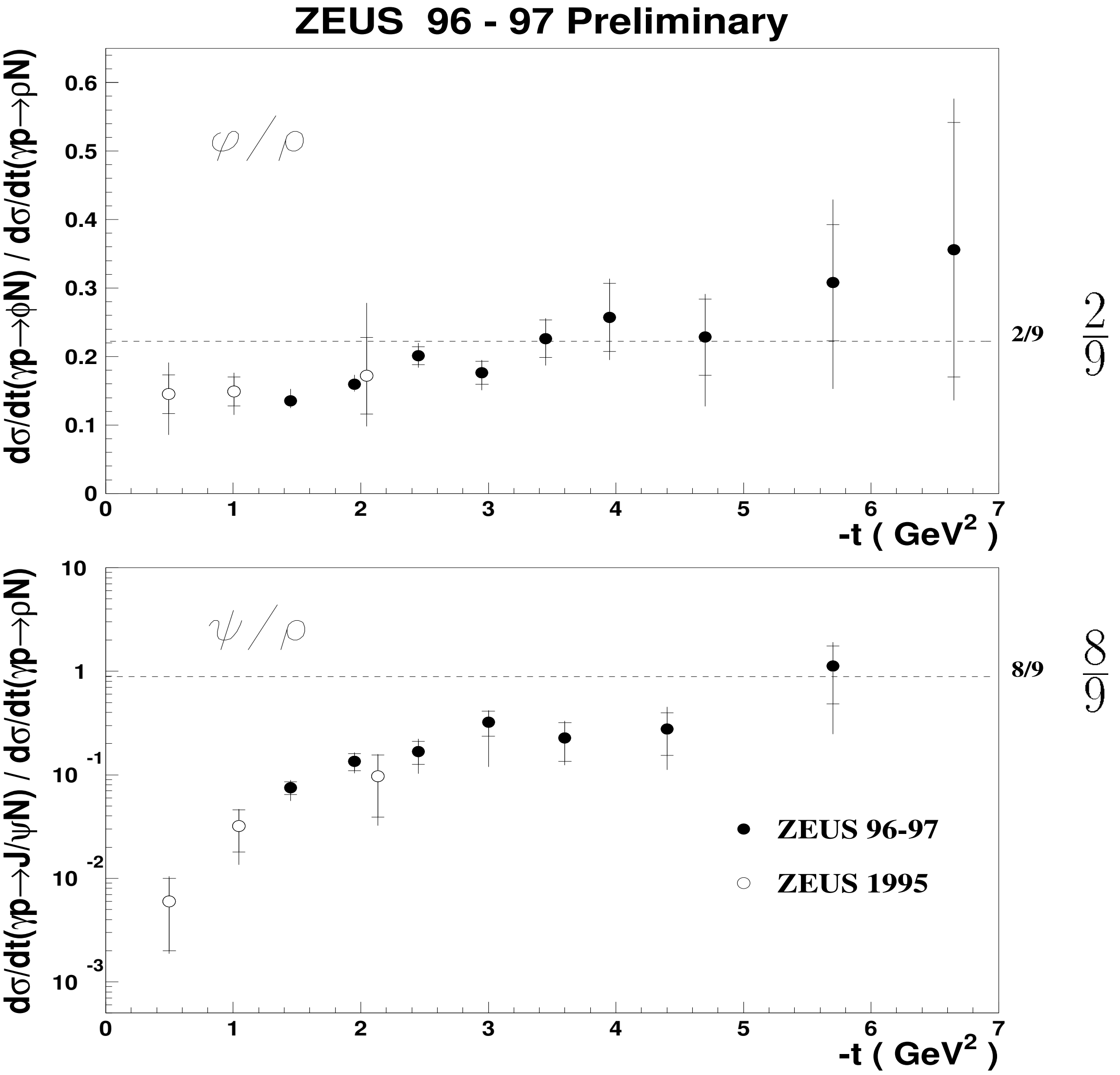
$\frac{d\sigma}{dt}$ RESULTS for J/ψ



- BFKL calculations describe J/ψ cross section
  J.Bartels et al., Phys. Lett. B 375 (1996) 301.
- very large uncertainties due to model parameters
- power-like behavior $\frac{d\sigma}{dt} \propto |t|^n$

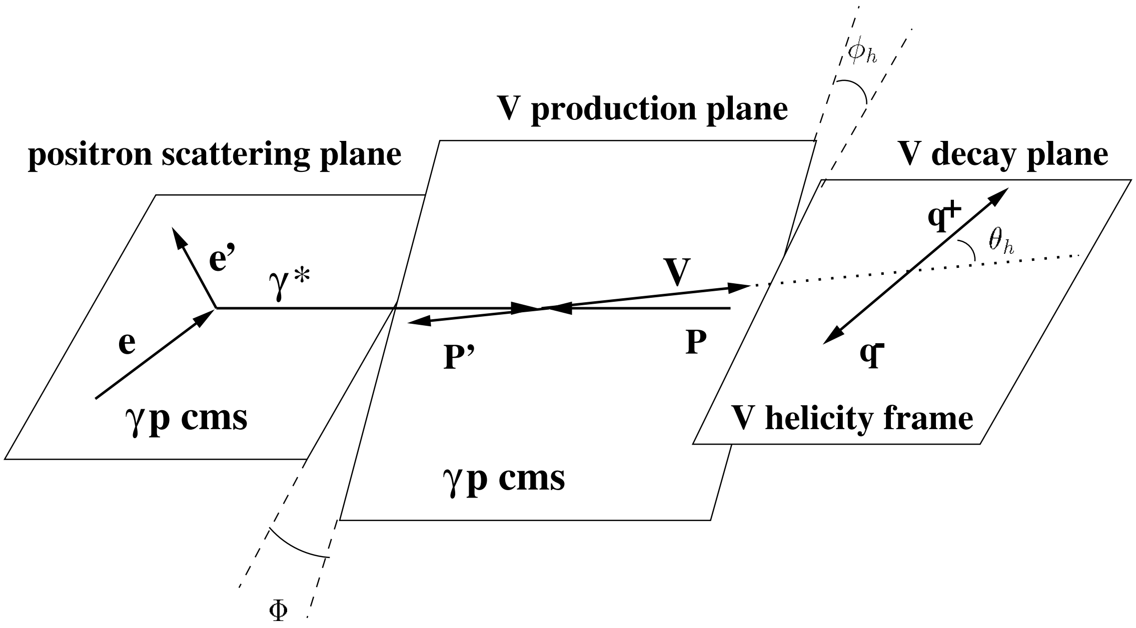
$$n = -1.7 \pm 0.2(stat.) \pm 0.2(syst.)$$

RESULTS for Cross Section Ratios



- φ/ρ ratio increases with $|t|$ and approaches SU(4) value at $|t| \simeq 3.5$ GeV^2
- ψ/ρ ratio also increases with $|t|$ but is much below the SU(4) prediction up to $|t| \approx 4$ GeV^2

DECAY ANGULAR ANALYSIS



- Two-dimensional angular distribution (for ρ and φ):

$$W\left(cos\theta_h, \phi_h\right) = \frac{3}{4\pi}\left[\frac{1}{2}\left(1 - r_{00}^{04}\right) + \frac{1}{2}\left(3r_{00}^{04} - 1\right)cos^2\theta_h - \sqrt{2}Re\left(r_{10}^{04}\right)sin2\theta_h cos\phi_h - r_{1-1}^{04}sin^2\theta_h cos2\phi_h\right]$$

- One-dimensional distributions (for J/ψ):

$$W\left(cos\theta_h\right) = \frac{3}{8}\left[1 - r_{00}^{04} + \left(3r_{00}^{04} - 1\right)cos^2\theta_h\right]$$

$$W\left(\phi_h\right) = \frac{1}{2\pi}\left(1 - r_{1-1}^{04}cos2\phi_h\right)$$

- determination of the VM spin-density matrix elements

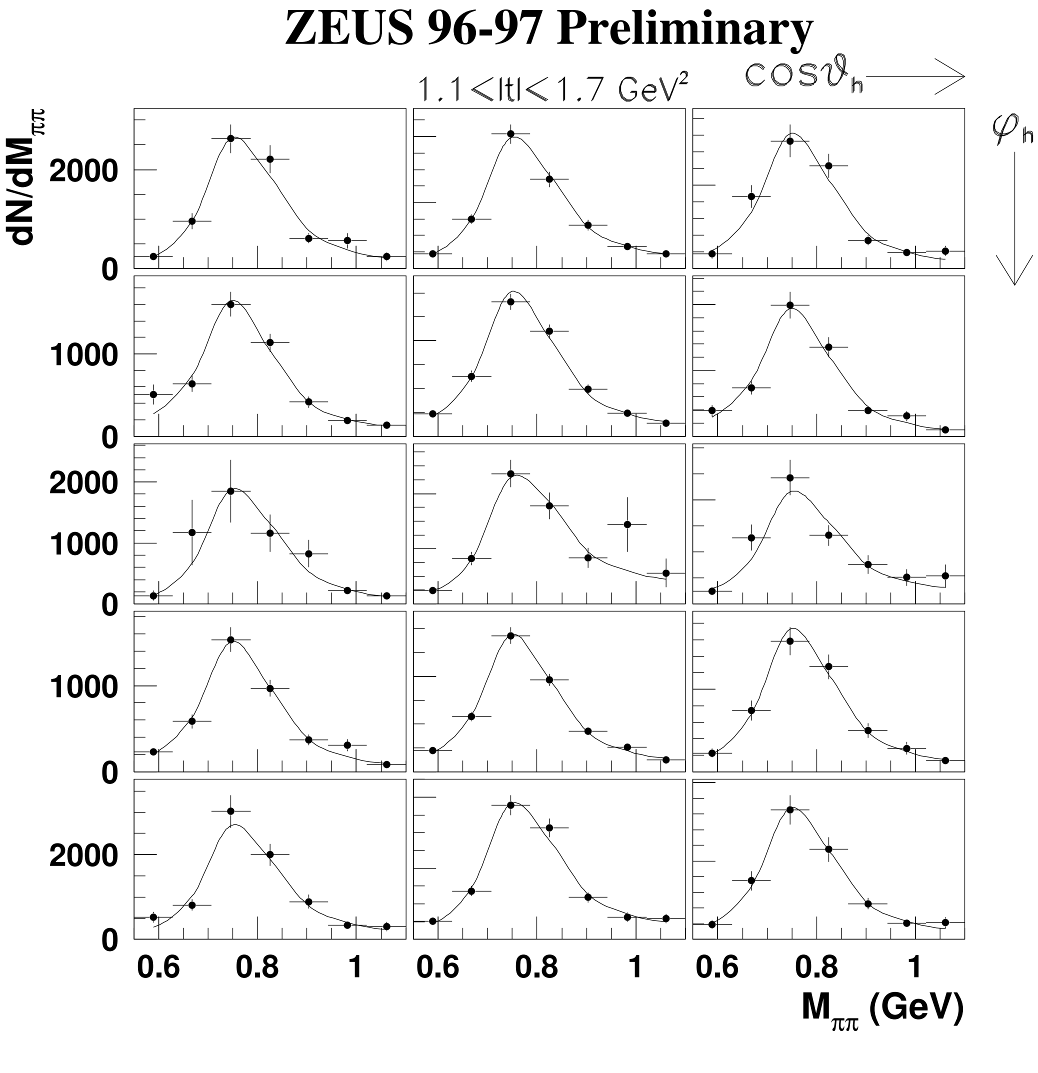
If SCHC holds : $r_{00}^{04} = r_{1-1}^{04} = Re(r_{10}^{04}) = \mathbf{0}$

2-dim Helicity Analysis for ρ^0

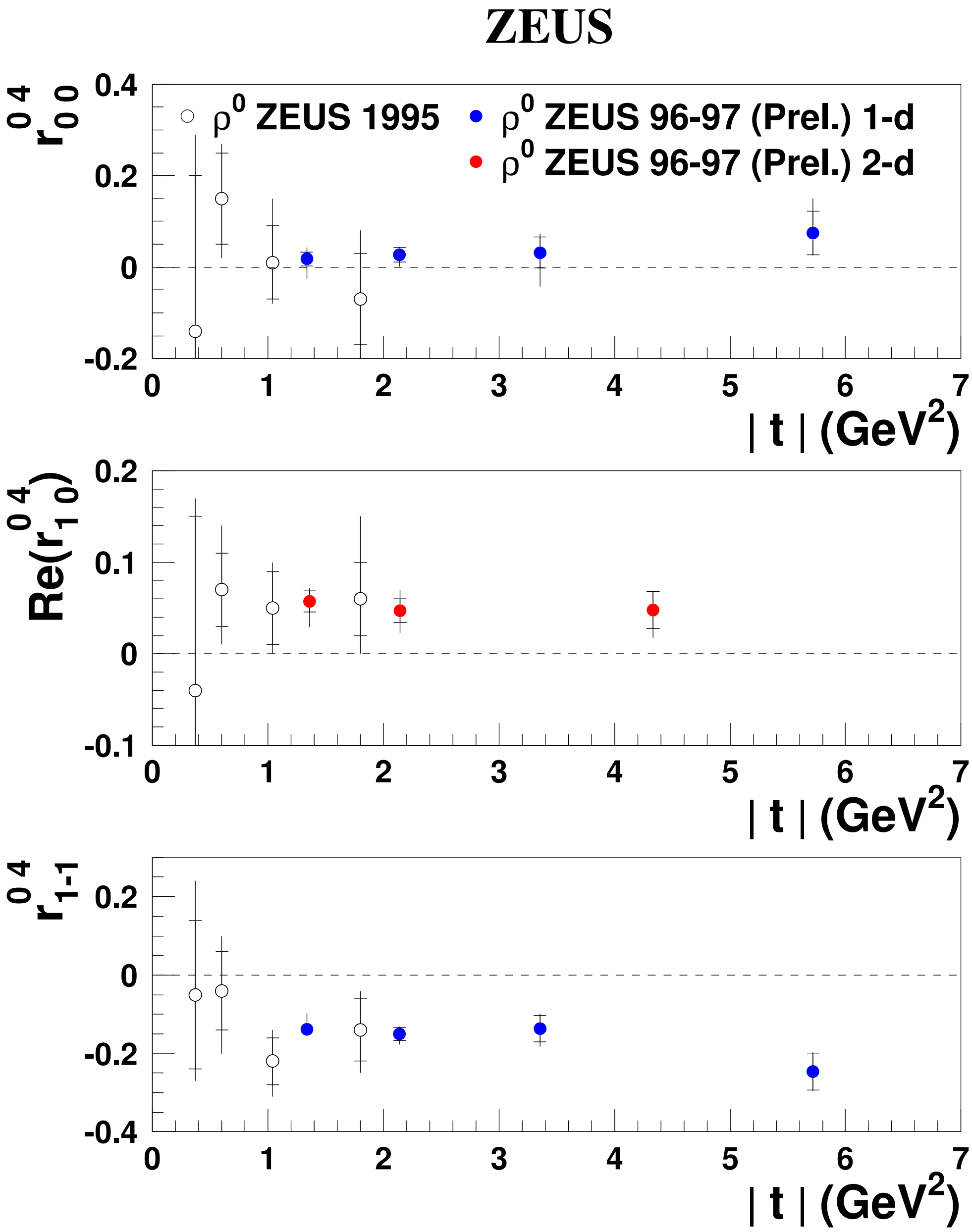
- in 3 bins of $|t|$ and $5\phi_h \times 3cos(\theta_h)$ bins
- acceptance corrected $M_{\pi\pi}$ distributions fitted according to the **Söding model** in the mass range:
  $$0.55 < M_{\pi\pi} < 1.1 \text{ GeV}$$

$$\frac{d\sigma}{dM_{\pi\pi}} = A^2 \left[\left| \frac{\sqrt{M_{\pi\pi} M_\rho \Gamma_\rho}}{M_{\pi\pi}^2 - M_\rho^2 + iM_\rho \Gamma_\rho} + B/A \right|^2 + f \right]$$

$$f = A_f \, (1 + 1.5 M_{\pi\pi})$$

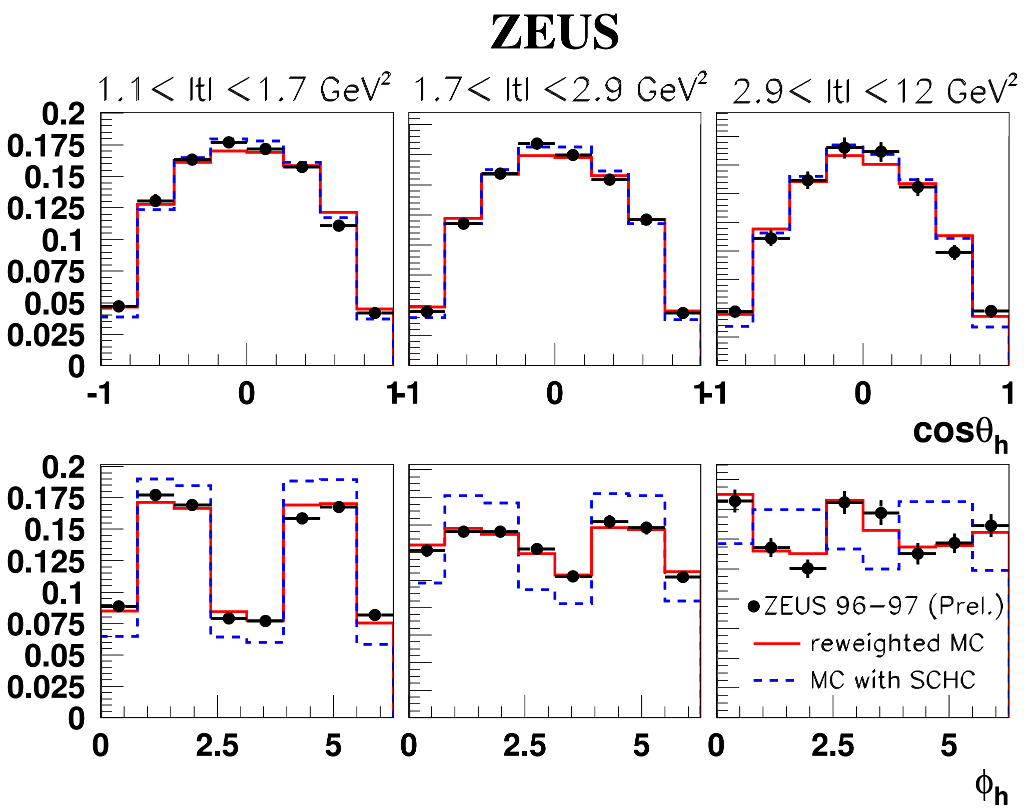


RESULTS for ρ^0



- production of transversly polarized ρ's dominates in this process
- **NEW** result for $Re(r^{04}_{10})$ from the 2-dim angular fit
- $Re(r^{04}_{10})$ is significantly different from zero $\Rightarrow$ longitudinal ρ's produced from transverse photons
- non-zero helicity double-flip amplitude

RESULTS for ρ^0 DATA-MC Comparison

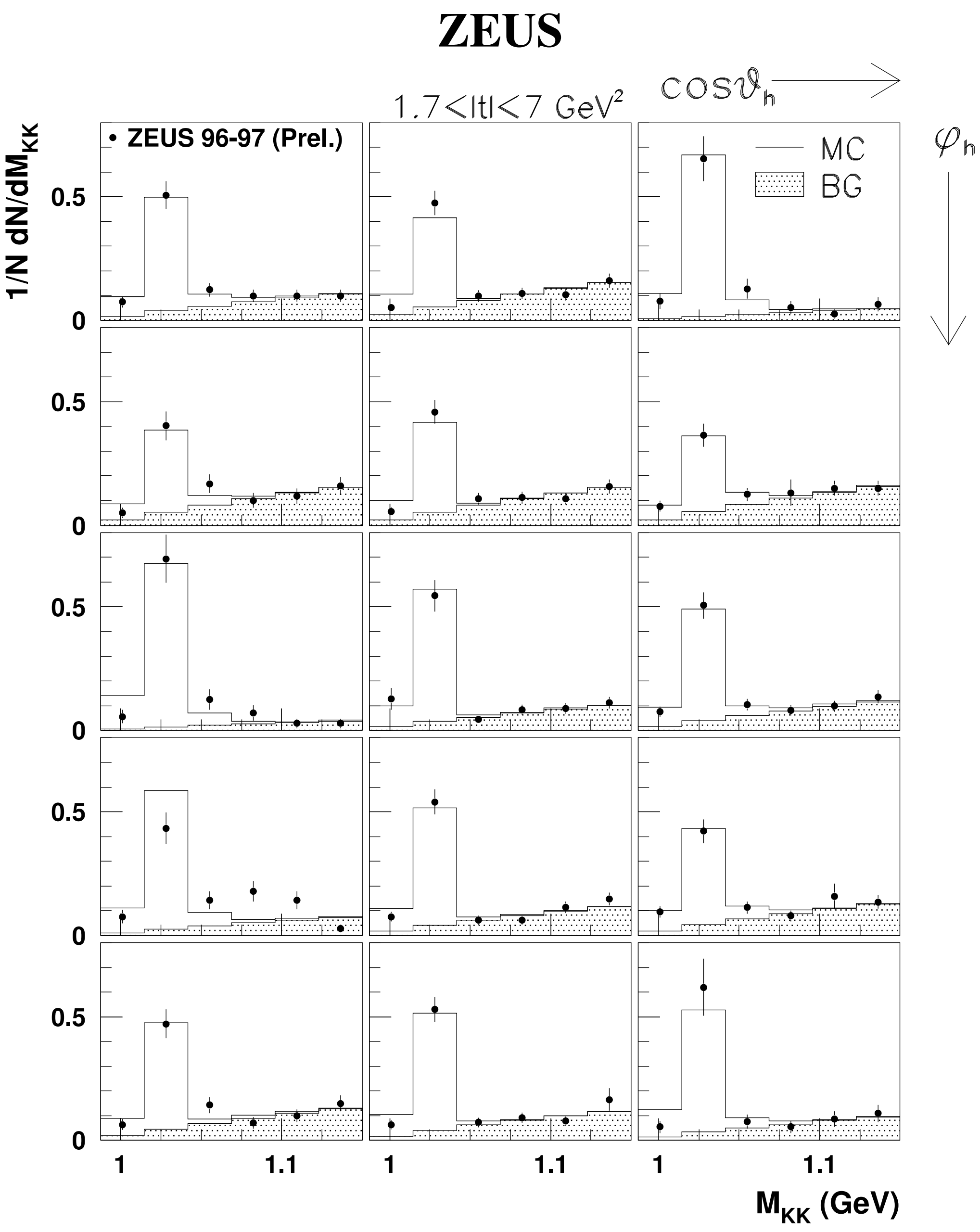


- MC with SCHC does not describe decay angle distributions
- after including the results from this analysis - good agreement

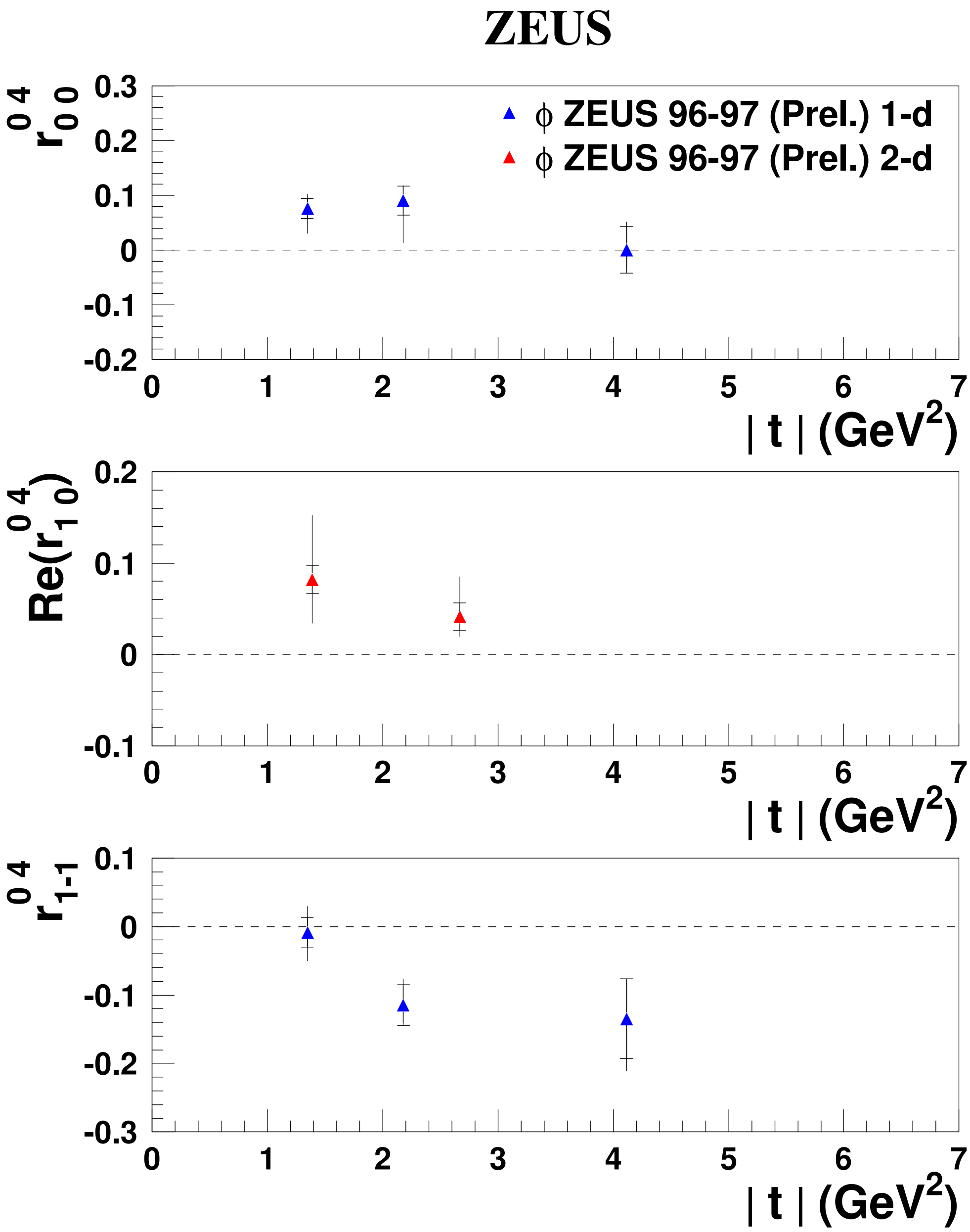
2-dim Helicity Analysis for φ

- in 2 bins of $|t|$ and $5\phi_h \times 3cos(\theta_h)$ bins
- the relative signal to background normalization is fitted in the mass range: $0.99 < M_{KK} < 1.15$ GeV
- background parametrized with a polynomial function

$$BG = A_{BG} \cdot (M_{KK} - 2M_K)^{\Delta}$$

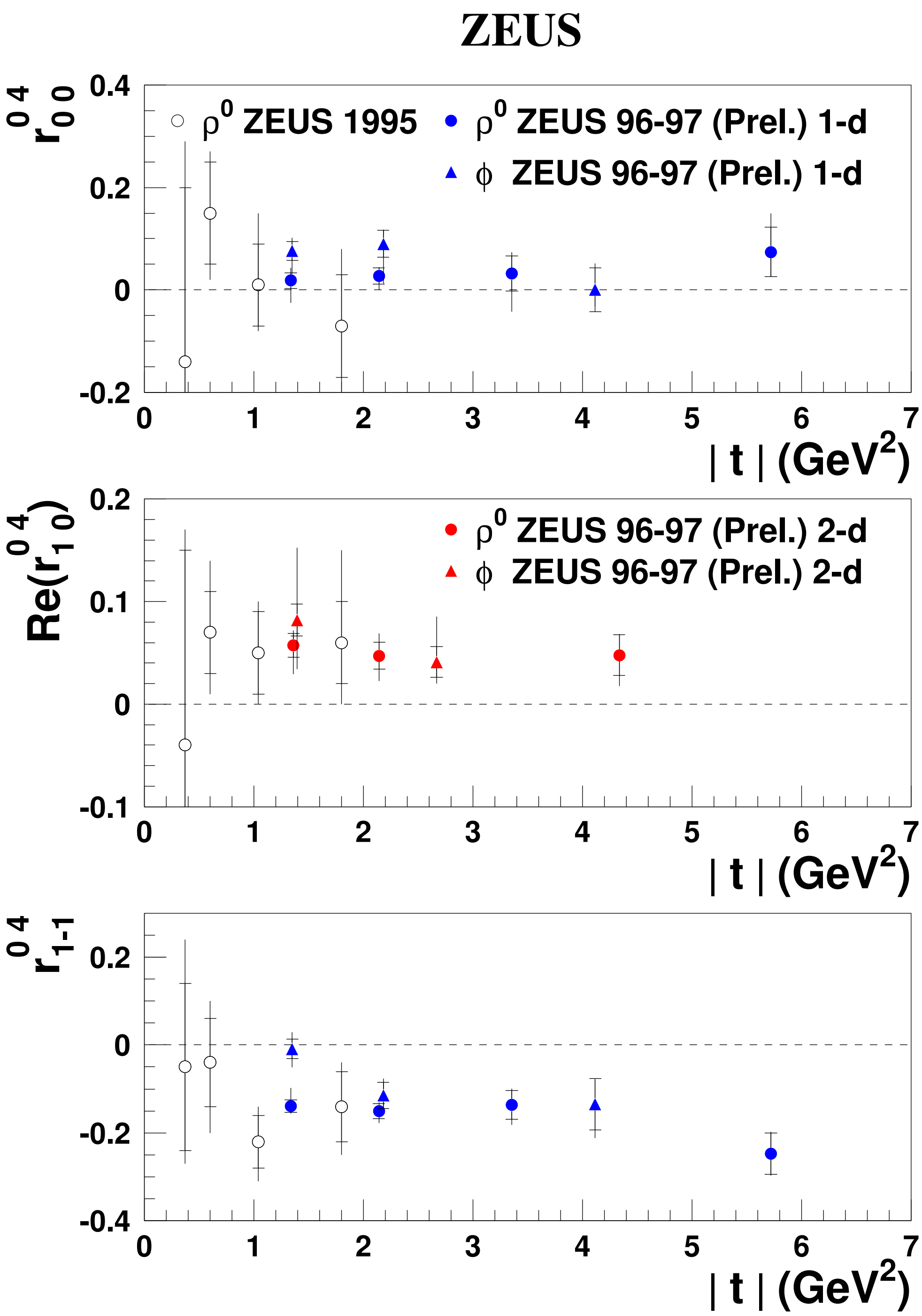


RESULTS for φ



- production of transversly polarized φ's dominates in this process
- **NEW** result for $Re(r^{04}_{10})$ from the 2-dim angular fit
- $Re(r^{04}_{10})$ is different from zero $\Rightarrow$ longitudinal φ's produced from transverse photons
- indication of non-zero helicity double-flip amplitude

RESULTS for ρ^0 and φ

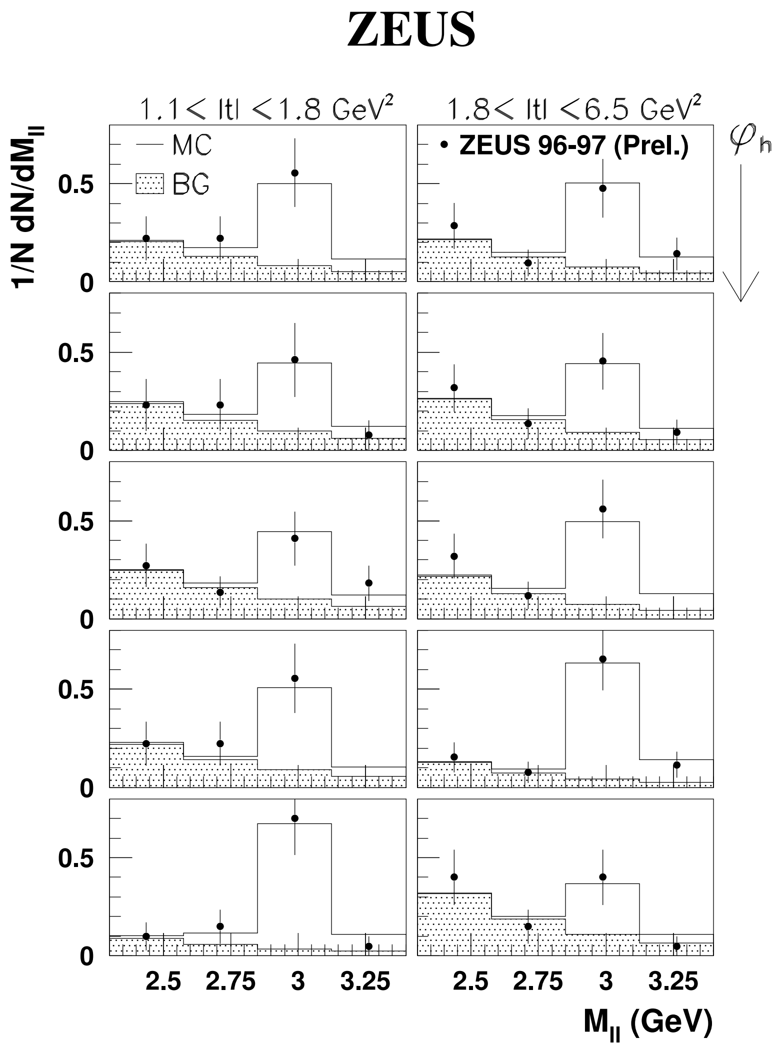


- clear deviation from SCHC expectations at large $|t|$ for both mesons
- spin-density matrix elements are the same for ρ^0 and φ
- pQCD predictions: hep-ph/0001255 (Ivanov et al.)

1-dim Helicity Analysis for J/ψ

- in 2 bins of $|t|$ and 5 ϕ_h and 4 $cos(\theta_h)$ bins
- the relative signal to background normalization is fitted in the mass range: $2.3 < M_{ll} < 3.4$ GeV
- background parametrization by an exponential function

$$BG = A_{BG} \cdot exp\,(\Delta \cdot M_{ll})$$



J/ψ RESULTS

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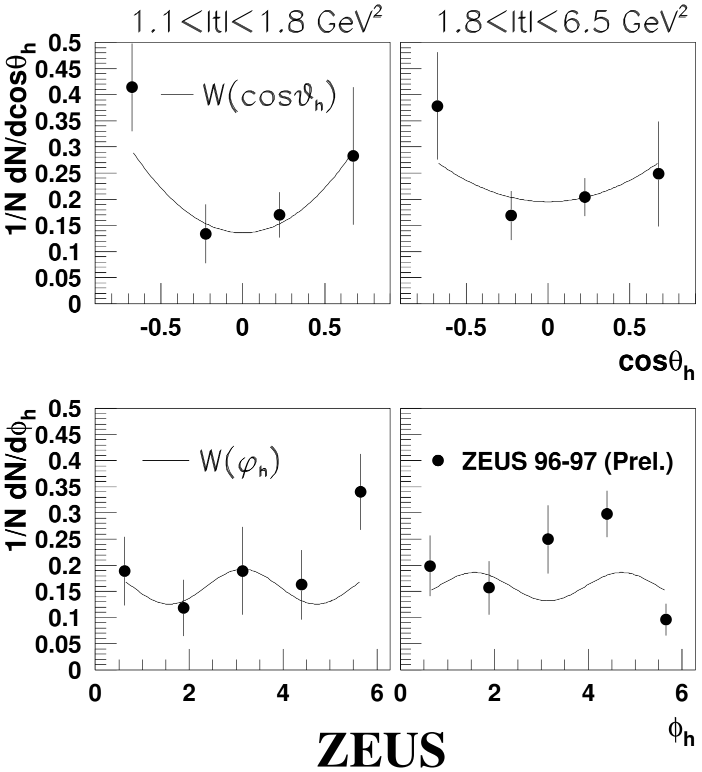

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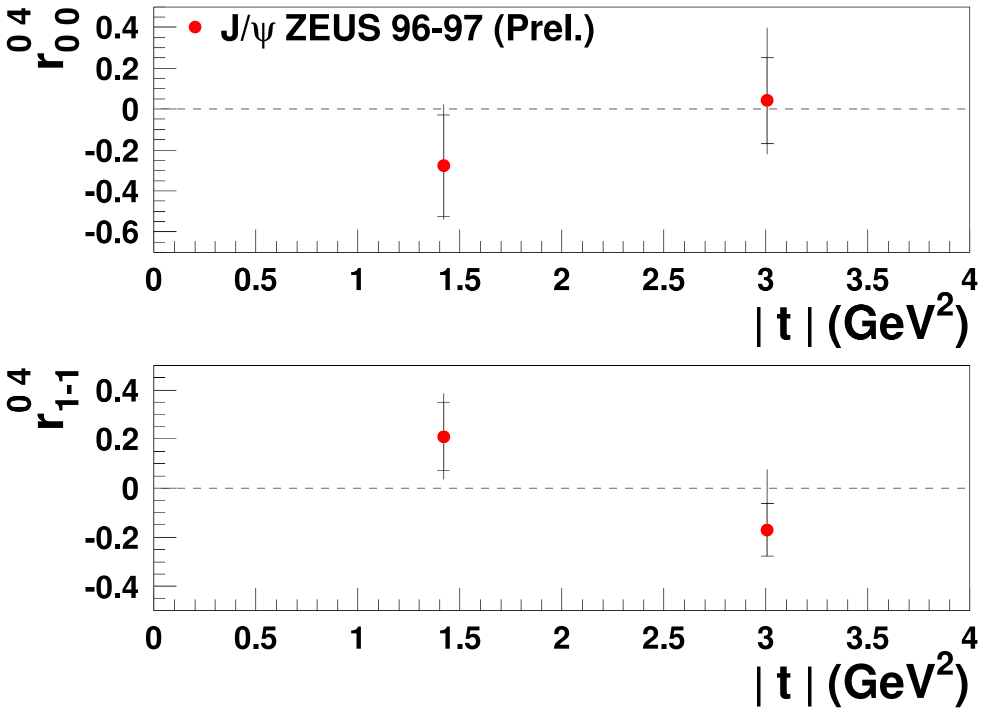

- J/ψ results consistent with SCHC expectations

SUMMARY AND CONCLUSIONS

- diffractive photoproduction of ρ^0, φ and J/ψ with proton dissociation has been measured at $W_{\gamma p} \approx 100$ GeV for $|t|$ up to 12 GeV^2

- $\frac{d\sigma}{dt} \propto |t|^n$ measured for $|t| > 1.2$ GeV^2
  $n = -3.31 \pm 0.02(\mathrm{stat}) \pm 0.12(\mathrm{syst})$ for ρ^0
  $n = -2.77 \pm 0.07(\mathrm{stat}) \pm 0.17(\mathrm{syst})$ for φ
  $n = -1.70 \pm 0.2(\mathrm{stat}) \pm 0.2(\mathrm{syst})$ for J/ψ
- J/ψ cross section agrees with BFKL
- φ/ρ ratio increases with $|t|$: SU(4) at $|t| \simeq 3.5$ GeV^2
  ψ/ρ ratio below SU(4) value up to $|t| \approx 4$ GeV^2

- clear deviation from SCHC expectations measured for ρ^0 and φ
- NON-zero helicity double and single-flip amplitudes for ρ^0 and φ
- longitudinally polarized light VM's produced from transverse photons
- J/ψ decay-angle results consistent with SCHC expectations