# Exclusive $\phi$ production in DIS at HERA

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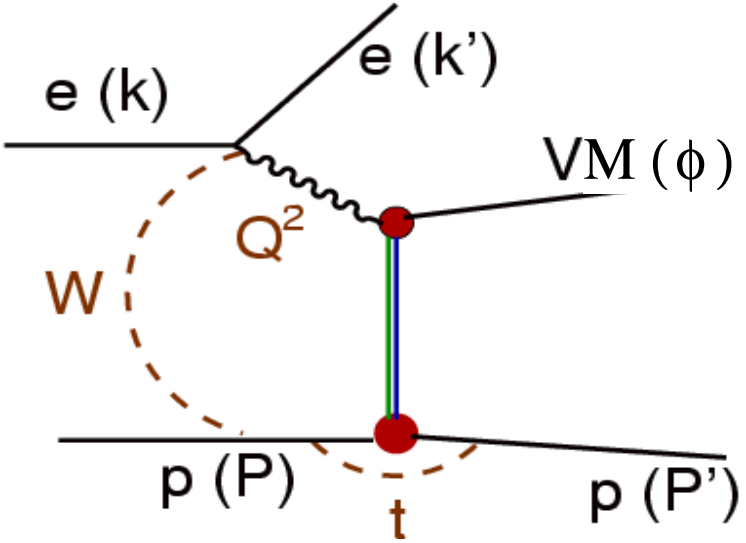
- Introduction
- Data selection
- Results
  - t-dependence: b-slope vs $Q^2$
  - W dependence
  - $Q^2$ dependence
  - Helicity analysis
- Summary

# Exclusive $\phi$ production in DIS

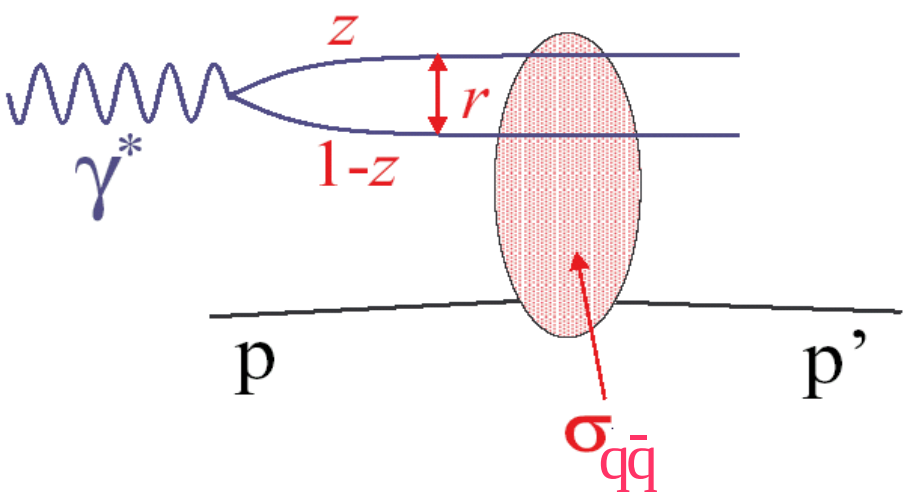



| | | |
|---|---|---|
| Virtuality of exchanged photon | $Q^2 = -q^2 = (k-k')^2$ | = 2 - 70 GeV$^2$ |
| $\gamma^*$p centre of mass energy | $W = (q+p)^2$ | = 35 - 145 GeV |
| 4-momentum transfer squared at proton vertex | $t = (P-P')^2$ | = 0 -0.6 (1) GeV$^2$ |

VM: **$\varphi$ (1019)**, $\rho$ (770), J/$\psi$ (3096))

- $\rho$ and J/$\psi$ show different behaviour
- $\varphi$ mass in between => how does it behave?

# Theoretical models for VM production : dipole model




Dipole picture in proton rest frame:

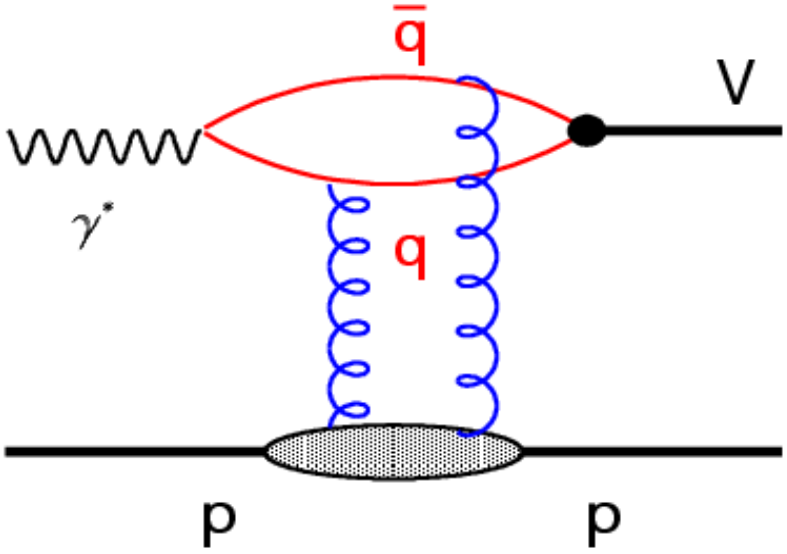
- $\gamma^* \rightarrow q\bar{q}$
- $q\bar{q}$ scattering on the proton
- VM is formed (after interaction)

r : transverse separation of $q\bar{q}$ $r \sim [z(1-z)Q^2 + m_q^2]^{1/2}$ , $z = p_q/p_{\gamma^*}$

small dipoles (large $Q^2$ or $m_q^2$) => pQCD

large dipoles (small $Q^2$ for light VM) => soft interactions

# Theoretical models for VM production




## pQCD

- leading order: 2 gluon exchange
- $\sigma \propto [x^{-0.2}]^2$, $(x \approx Q^2/W^2) \Rightarrow \sigma \propto W^{0.8}$
- $d\sigma/dt \propto e^{bt}$, $b = b_{2g} \approx 4\ GeV^{-2}$ (const.)
- b - constant with W => $\alpha' = 0\ GeV^{-2}$

## What is the hard scale?

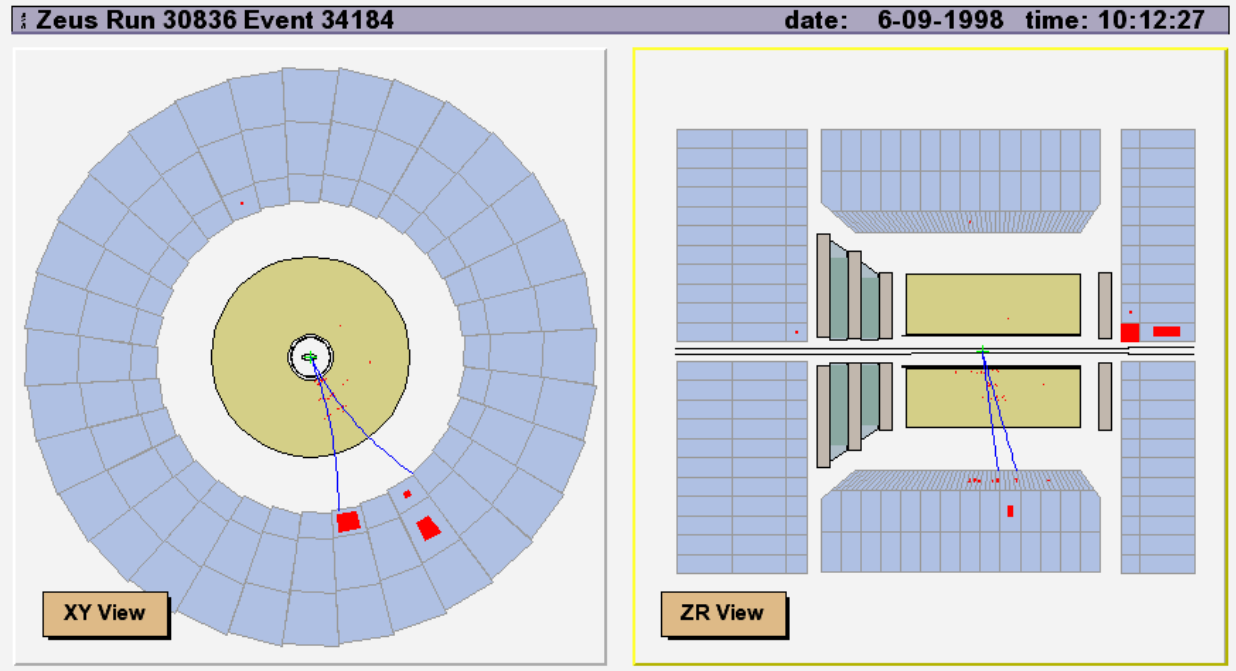
- Ryskin: $Q_{eff}^2 = 1/4\,(Q^2 + M_{VM}^2 + |t|)$

## Soft physics

- $d\sigma/dt \propto e^{bt}\,(W/W_0)^{4(\alpha t - 1)}$
- $\alpha(t) = \alpha_0 + \alpha' t$, $\alpha = 1.08$ $\alpha' = 0.25\ GeV^{-2}$
- $\sigma \propto W^{0.22}$

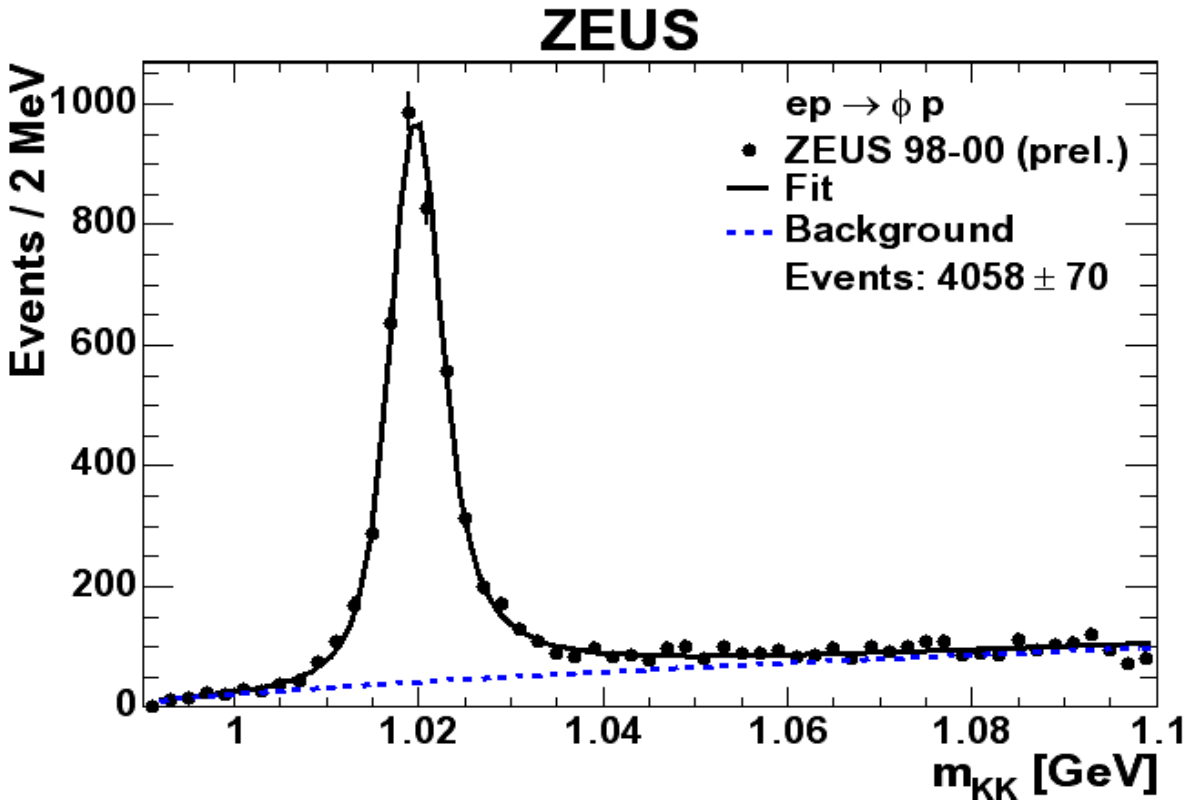
# Event selection

- 2 good quality primary vertex tracks of opposite charges
  allow for extra primary tracks associated with electron
- Electron with E>10 GeV in a well measured region of detector
- No cluster with E>300MeV not associated with electron or Kaons



# Data set

- 98-00 $e^{\pm}p$ data; $E_p$ =920GeV $E_e$ =27.5 GeV
- L = 66.4pb$^{-1}$
- ~ 4000 events in accepted kinematic range
- φ mass agrees within systematics: Fit: 1019.65GeV PDG: 1019.413± 0.008 GeV



# Cross-sections

- Extract Born-level, $\gamma^*p$ cross-sections

Normalization corresponds to :

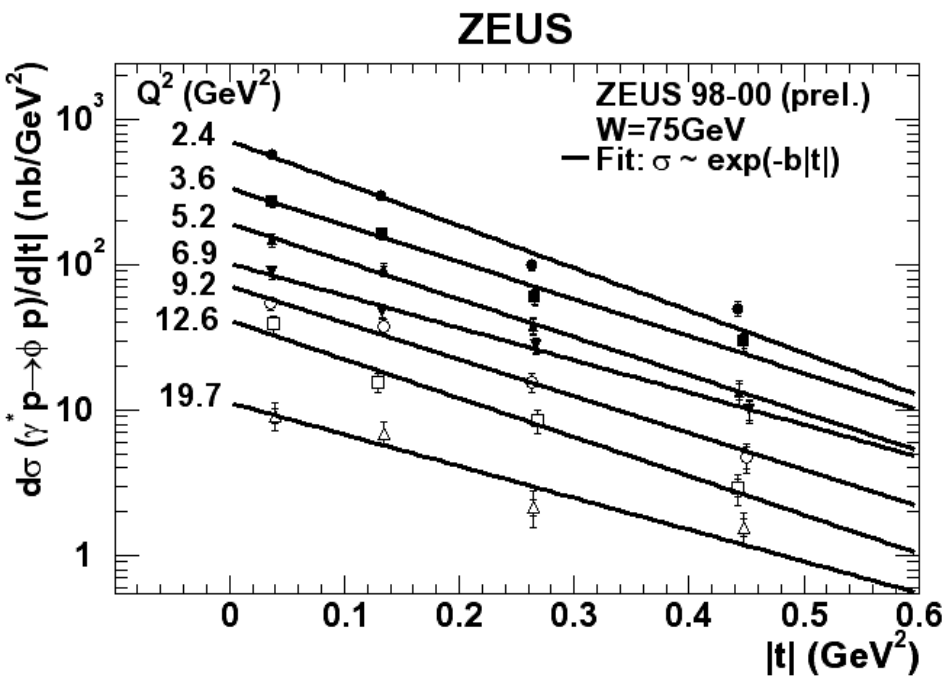
- $m_{KK} = 2m_K - (2m_K + 5\,\Gamma_\phi)$
- Extrapolate from $|t|<0.6$ GeV$^2$ to full range
- Normalization error: Lumi: 2.5% $\oplus$ BR ($\phi$ -> $K^+K^-$): 1%
- Proton dissociation background ($ep \rightarrow e\phi N$)

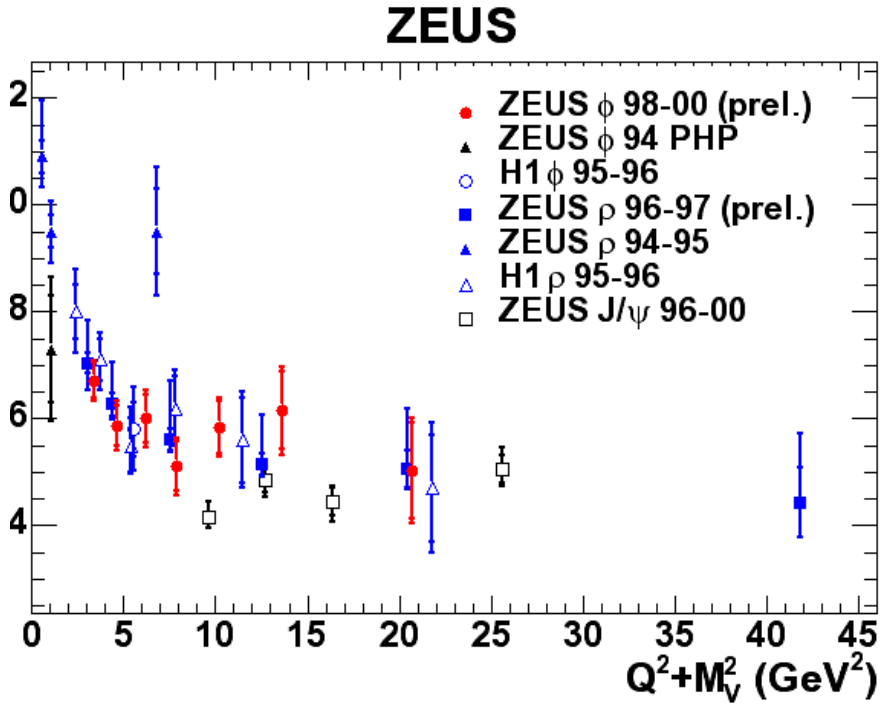
$f = 7\,^{+10}_{-6}$ % independent of $Q^2$, W, helicity angles; increasing with $|t|$

- Largest systematics: detector alignment for electron position measurement

# t-dependence

- $d\sigma/dt \sim \exp(-b|t|)$
- $\sqrt{|t|}$ is Fourier conjugate of impact parameter
  => b is related to transverse size of interaction $b \sim 1/4\,(r^2_p + r^2_{VM})$
- Data suggest scaling with $Q^2+M_V^2$
- Decrease of b with $Q^2$ => high $Q^2$ = small dipole size



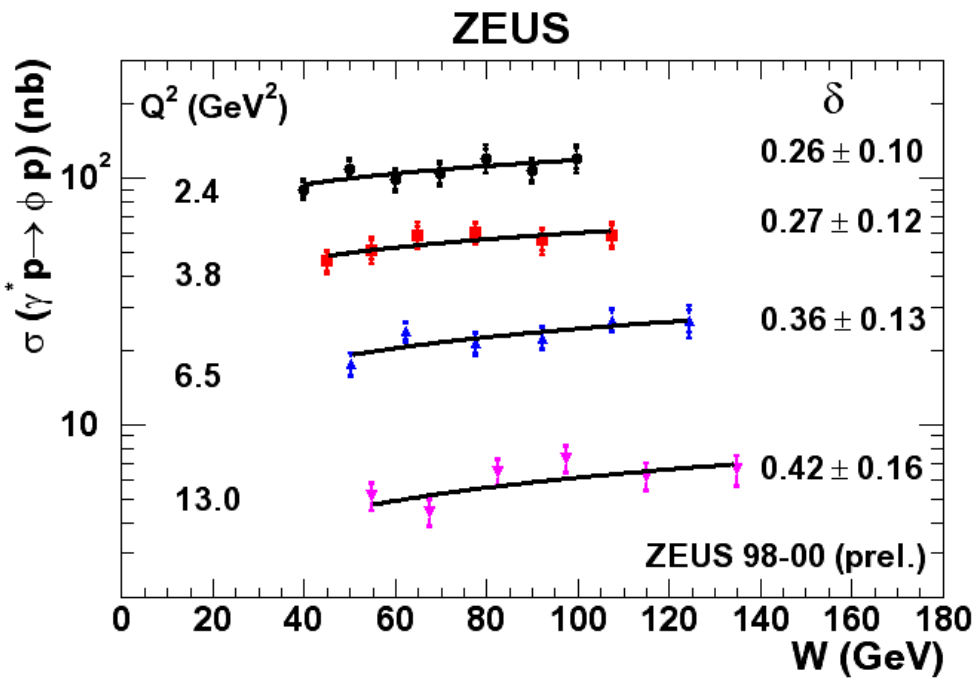



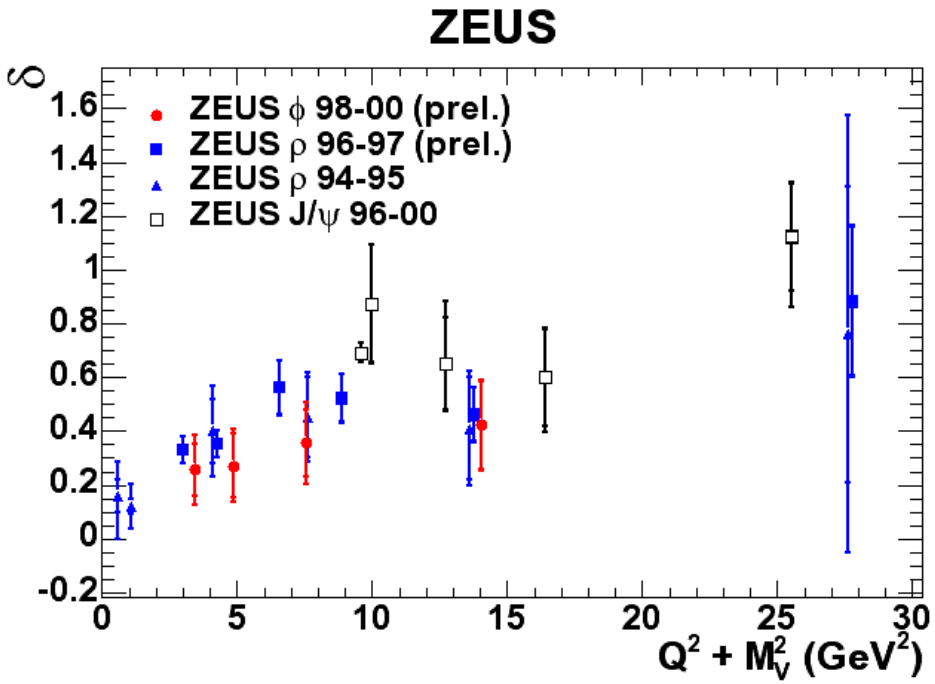
# W dependence as function of $Q^2$

- Fit to $\sigma \sim W^{\delta}$ - $\delta$ is a function of $Q^2$
- Measured data agree well with results from other Vector Mesons
- Rise of $\delta$ with $Q^2+M_V^2$ observed in global VM picture

  $\rho$ , $\phi$ : transition from soft to hard regime

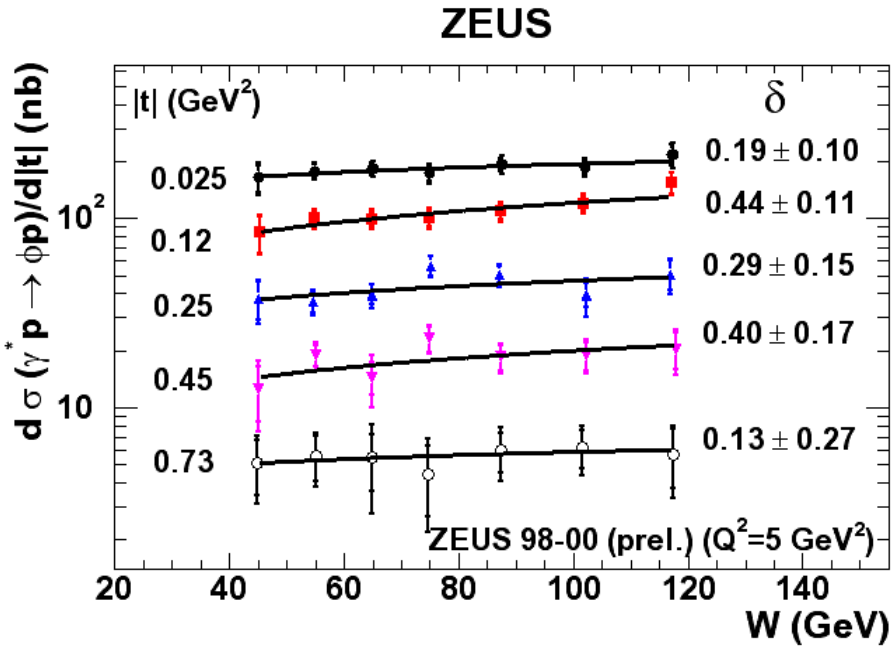
  J/$\psi$ : hard already in photo-production

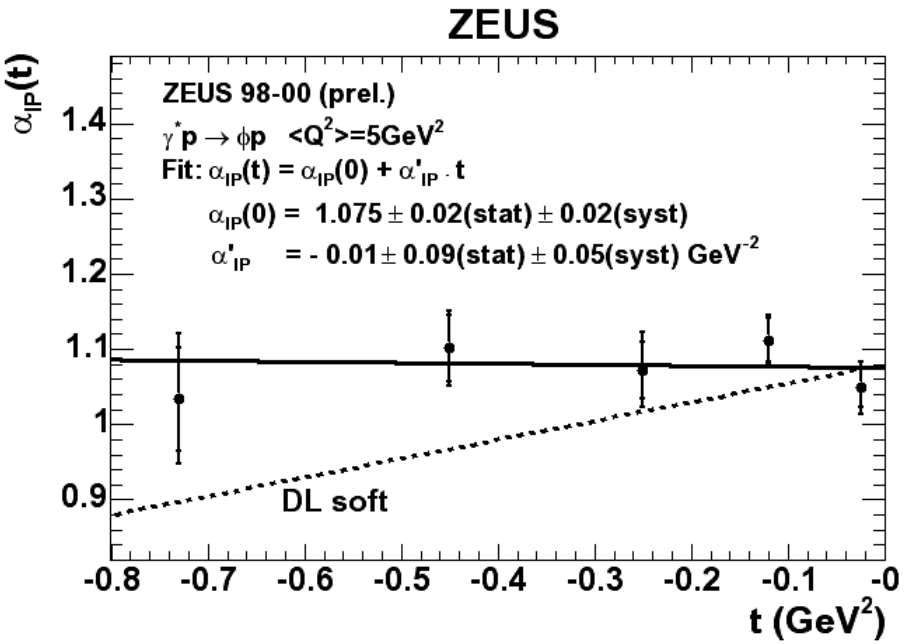


# W dependence as function of t

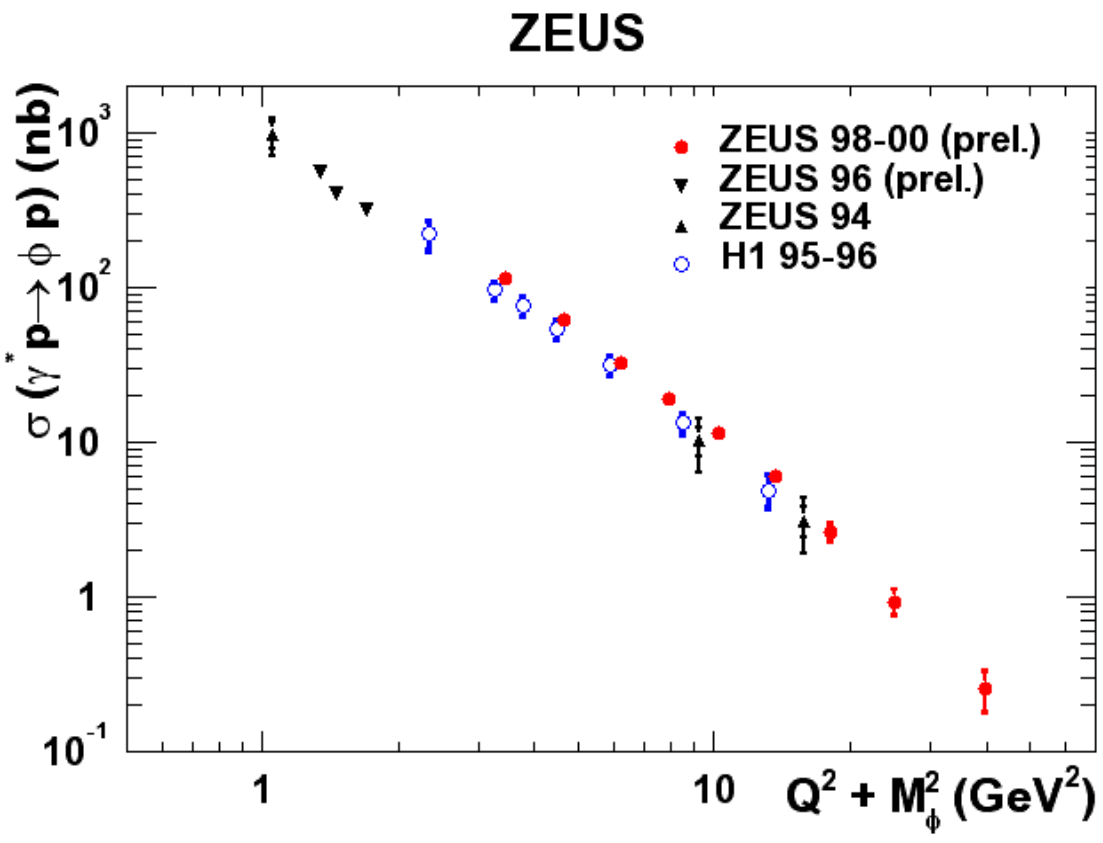
- Fit to $\sigma \sim W^{\delta}$
- $\delta$ related to "Pomeron" trajectory $\delta = 4(\alpha_{IP}-1)$ $\alpha_{IP} = \alpha_0 + \alpha' t$
- $\alpha'$ extracted from W dependence in bins of t
- Data are consistent with no t-dependence of $\delta$
- ZEUS $\rho$ 96-97 (prel.) $\alpha' = 0.04 \pm 0.07\,(stat)\,^{+0.13}_{-0.04}\,(syst)$
- ZEUS J/$\psi$ 98-00 (DIS): $\alpha' = 0.07 \pm 0.05\,(stat) \pm 0.03(syst)$



# $Q^2$- dependence

- $Q^2$ dependence for W=75 GeV
- Fit to $(Q^2+M^2)^{-n}$ - data suggest that n rises with $Q^2$ (observed previously for ρ )
- $n=2.1 \pm 0.05(stat) \pm 0.05(syst)$ for $Q^2=2.4$ - 9.2 $GeV^2$
- $n=2.75 \pm 0.13(stat) \pm 0.07(syst)$ for $Q^2=9.2$-70 $GeV^2$



# Helicity analysis

- $\sigma = \sigma_T + \varepsilon \sigma_L$
- $\gamma^*_T$, $\gamma^*_L$ :different wave functions => interactions
- Expect rise of $R=\sigma_L/\sigma_T$ with $Q^2$

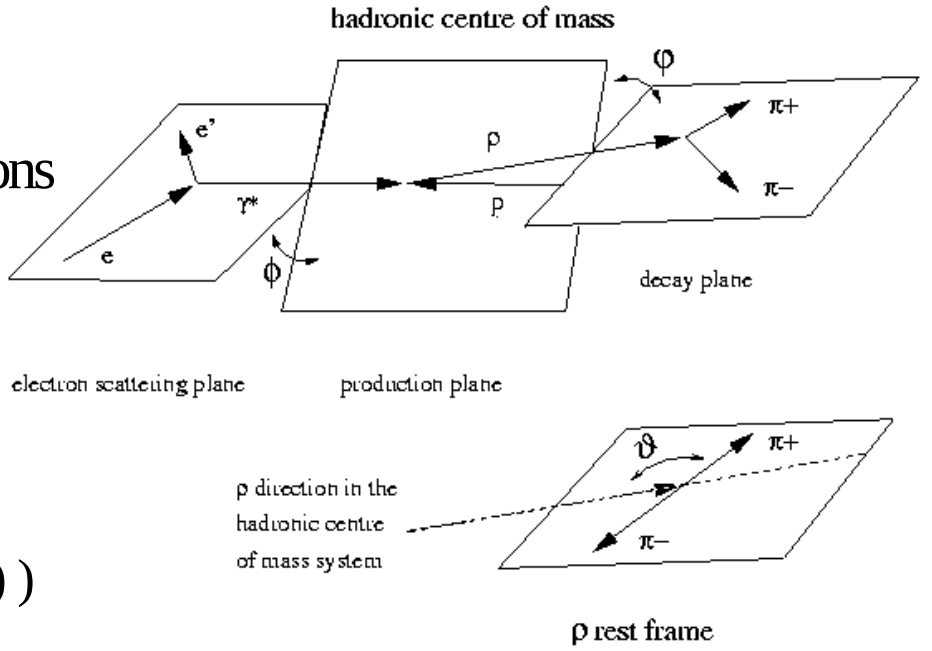
  Photo-production: $\sigma_L=0$ => R=0

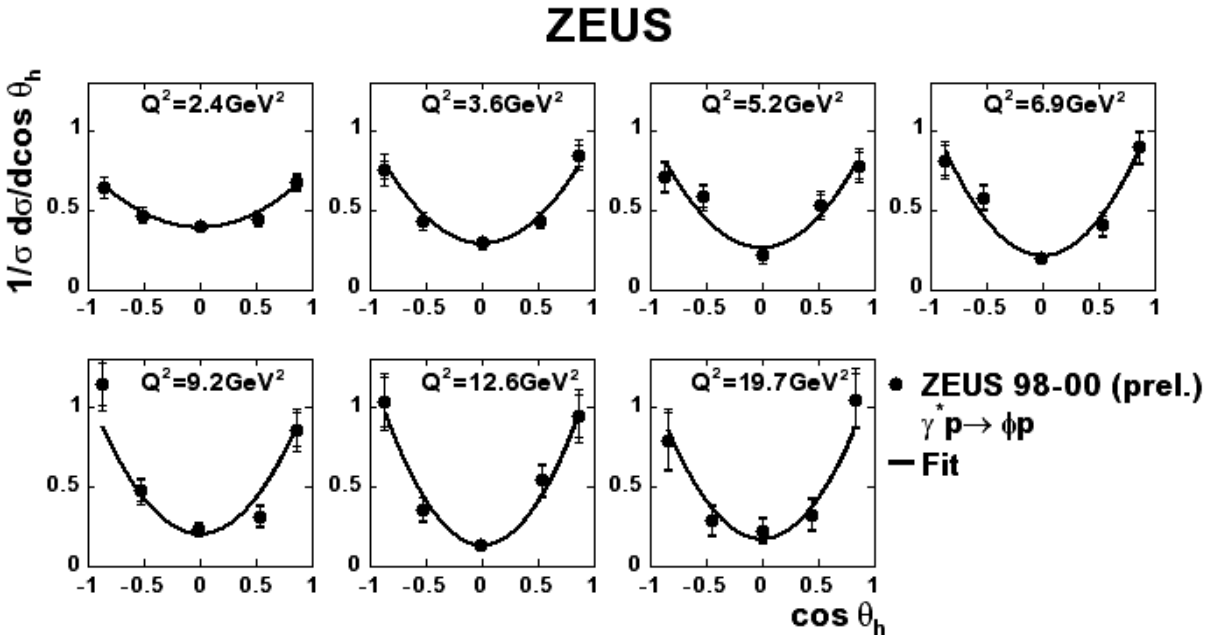
  High $Q^2$ : $\sigma_L$ dominates => R>>1

Can we separate them?

- $1/N\ dN/d\cos(\theta_h) = 3/4\ (1-r_{00}^{04} + (3r_{00}^{04}-1)\cos^2(\theta_h))$
- s-channel helicity conservation:

  $R = 1/\varepsilon\ r_{00}^{04}/(1-r_{00}^{04})$ $(\varepsilon \sim 0.99)$

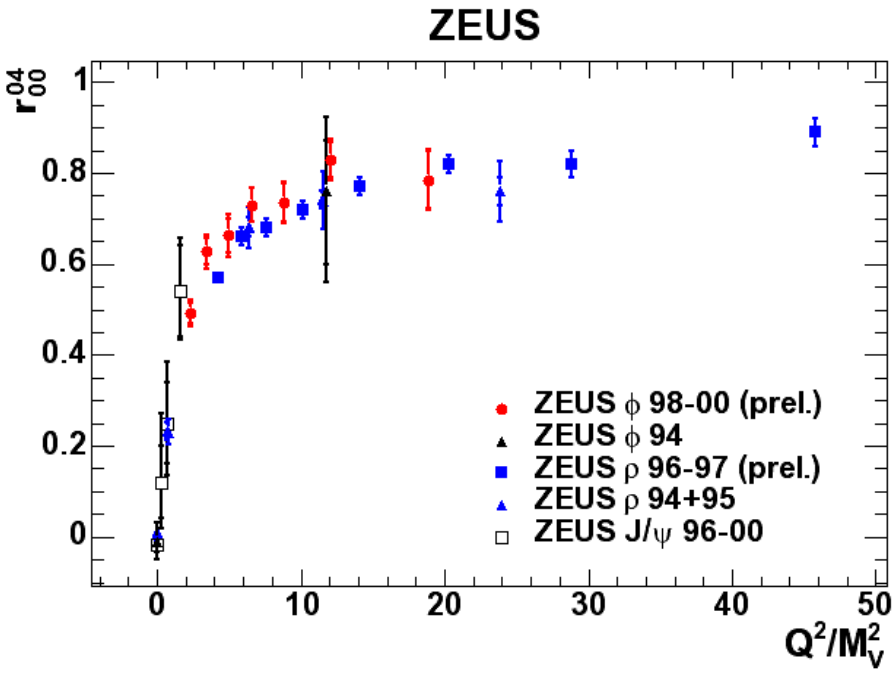


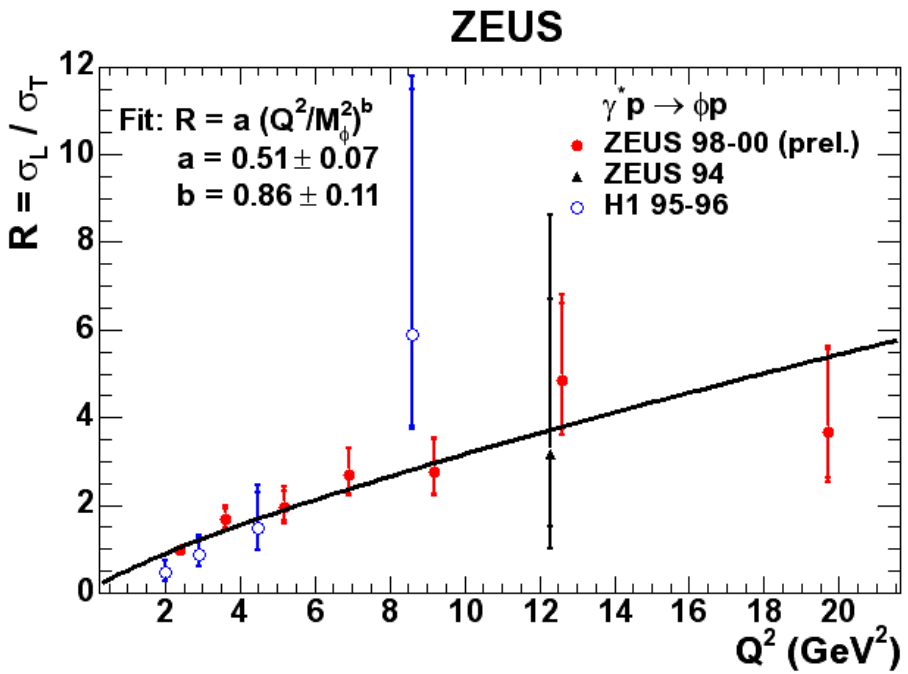



# Helicity analysis

- Agreement with previous measurements
- Scaling with $Q^2/M_V^2$ for all VM observed
- Fit to $R=a(Q^2/M_V^2)^b$ describes data well

$a = 0.51 \pm 0.07(\text{stat}) \pm 0.05(\text{syst})$
$b = 0.86 \pm 0.11(\text{stat}) \pm 0.05(\text{syst})$



# Summary

- Cross-sections for $\gamma^*p \to \phi p$ have been measured as a function of $Q^2$, W, $\cos(\theta_h)$, t
- Large increase in available statistics => precision for $\phi$
- Large impact on $\phi$ measurements as well as for global VM picture
- Data are consistent with expectations from phenomenological models