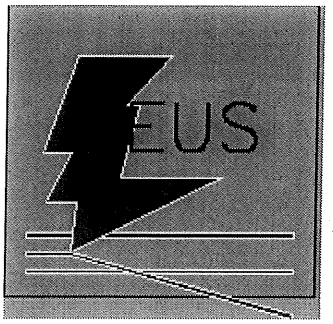
DIS2000

Elastic and proton-dissociative Vector Meson Production at high Q^2 or large $|t|$

Dirk Schmidt
DESY

For the H1 and ZEUS collaborations

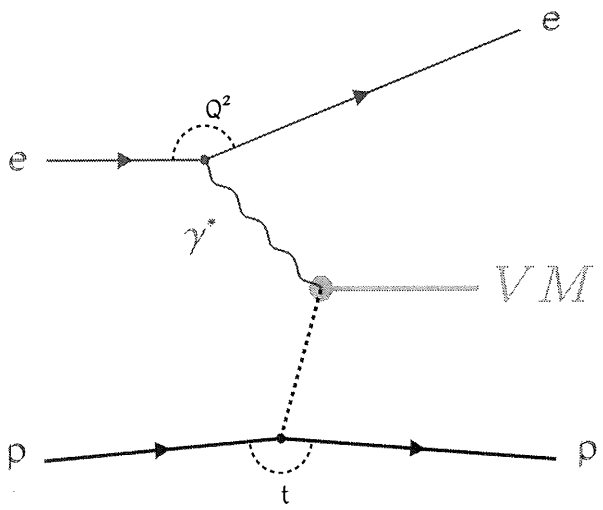


8th International Workshop on Deep Inelastic Scattering and QCD (DIS 2000)

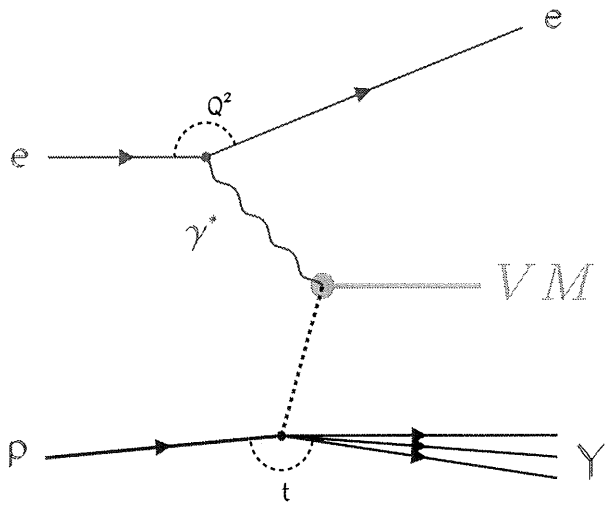
April 25 - 30, 2000
Liverpool, UK

Diffractive Vector Meson Production at HERA

$$e^{\pm} + p \rightarrow e^{\pm} + Y + VM$$



elastic process



proton dissociation:
Y = low mass system

$$VM = \rho,\ \omega,\ \phi,\ J/\psi,\ \psi',\ \Upsilon$$

What is measured?

$$Q^2 = -q^2 = -(e - e')^2$$
$$t = (p - p')^2$$
$$W^2 = (q + p)^2$$
decay angles

- physics with several scales in large range
- transition from soft to hard physics
- determine at which scale and for which reaction pQCD models can describe data

Non-perturbative Model for VM-Production

- description based on Regge theory and VDM
- W and t dependence of cross section related to
  - exchanged pomeron trajectory $\alpha(t) = \alpha_0 + \alpha' \cdot t$:
  - intercept $\alpha_0 = 1 + \epsilon$ and
  - slope α' of

$$\frac{d\sigma}{dt} \sim e^{-b|t|} \left(\frac{W}{W_0}\right)^{4\epsilon} = e^{-b_0|t|} \left(\frac{W}{W_0}\right)^{4(\alpha(t)-1)}$$

- slope b rises with W (shrinkage)

$$b = b(W) = b_0 + 4\alpha' \ln\left(\frac{W}{W_0}\right)$$

- "soft" pomeron trajectory $(\alpha_0, \alpha') = (1.08, 0.25)$

▶ predicts slow rise of cross section with:

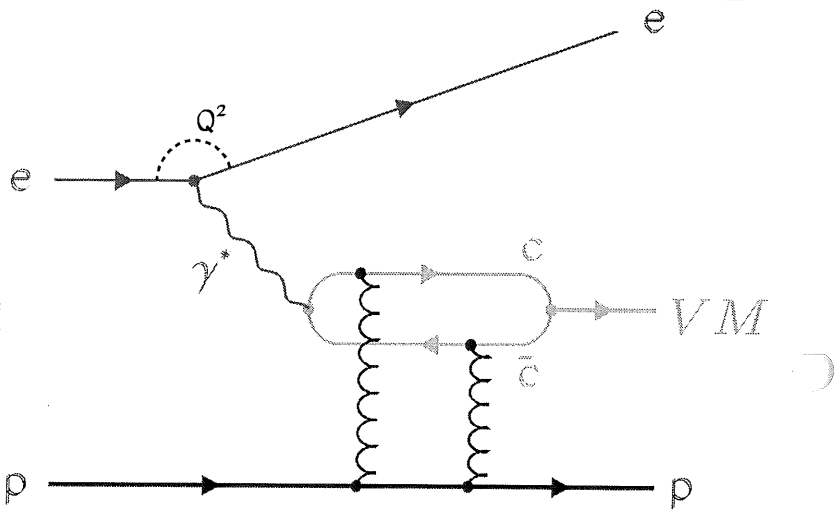
$$\sigma \sim W^{0.22} \ldots W^{0.32}$$

▶ observed e.g. in light VM γp

pQCD Models

Basic concept:
factorisation in:

1. fluctuation $\gamma \to$ VM
2. interaction with p
3. formation of VM



scale: $Q^2_{eff} = \frac{Q^2+m_V^2}{4}$

- $\sigma \sim |xg(x, Q^2_{eff})|^2$ with $x = (Q^2 + m_V^2)/(Q^2 + W^2)$

$\Rightarrow$ steeper rise with W reflects gluons at low x

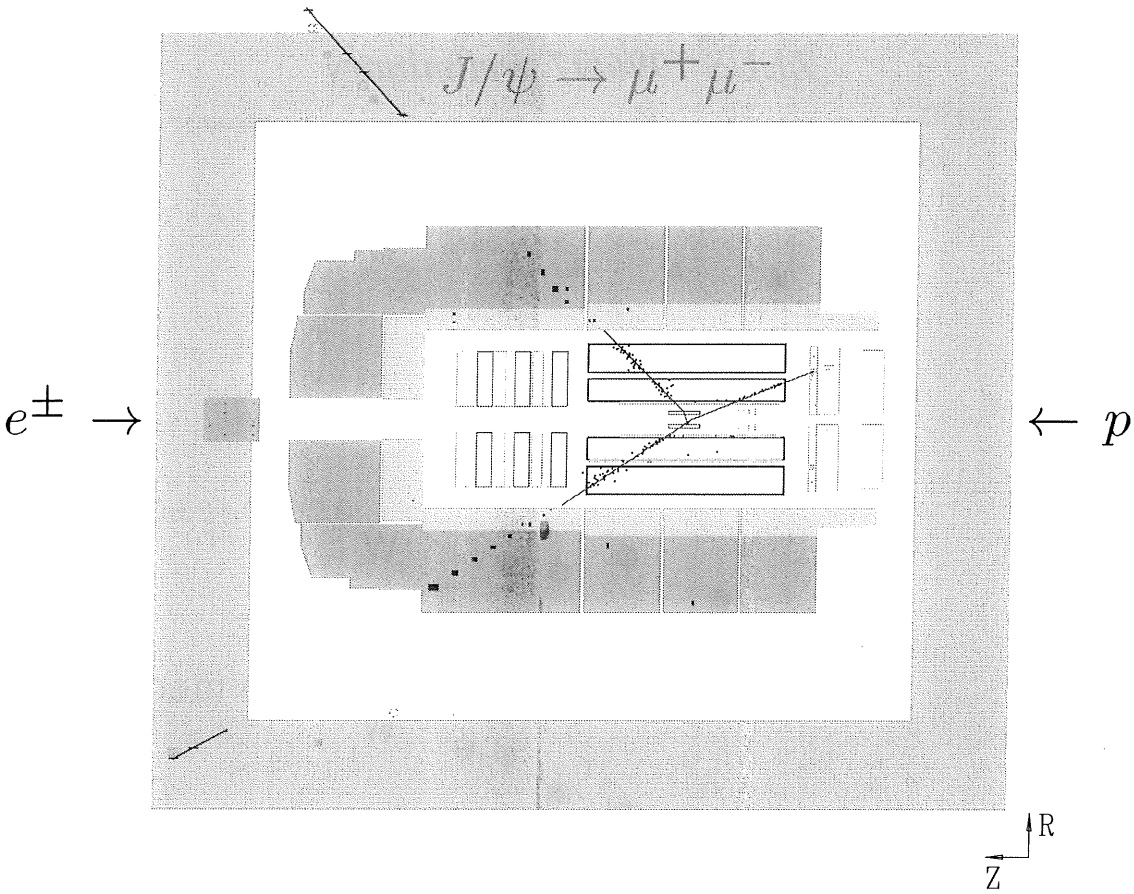
$\Rightarrow$ large sensitivity to gluon density

- absence of shrinkage
- universal t-dependence with $b \approx 4 - 5\,\text{GeV}^{-2}$

+ corrections

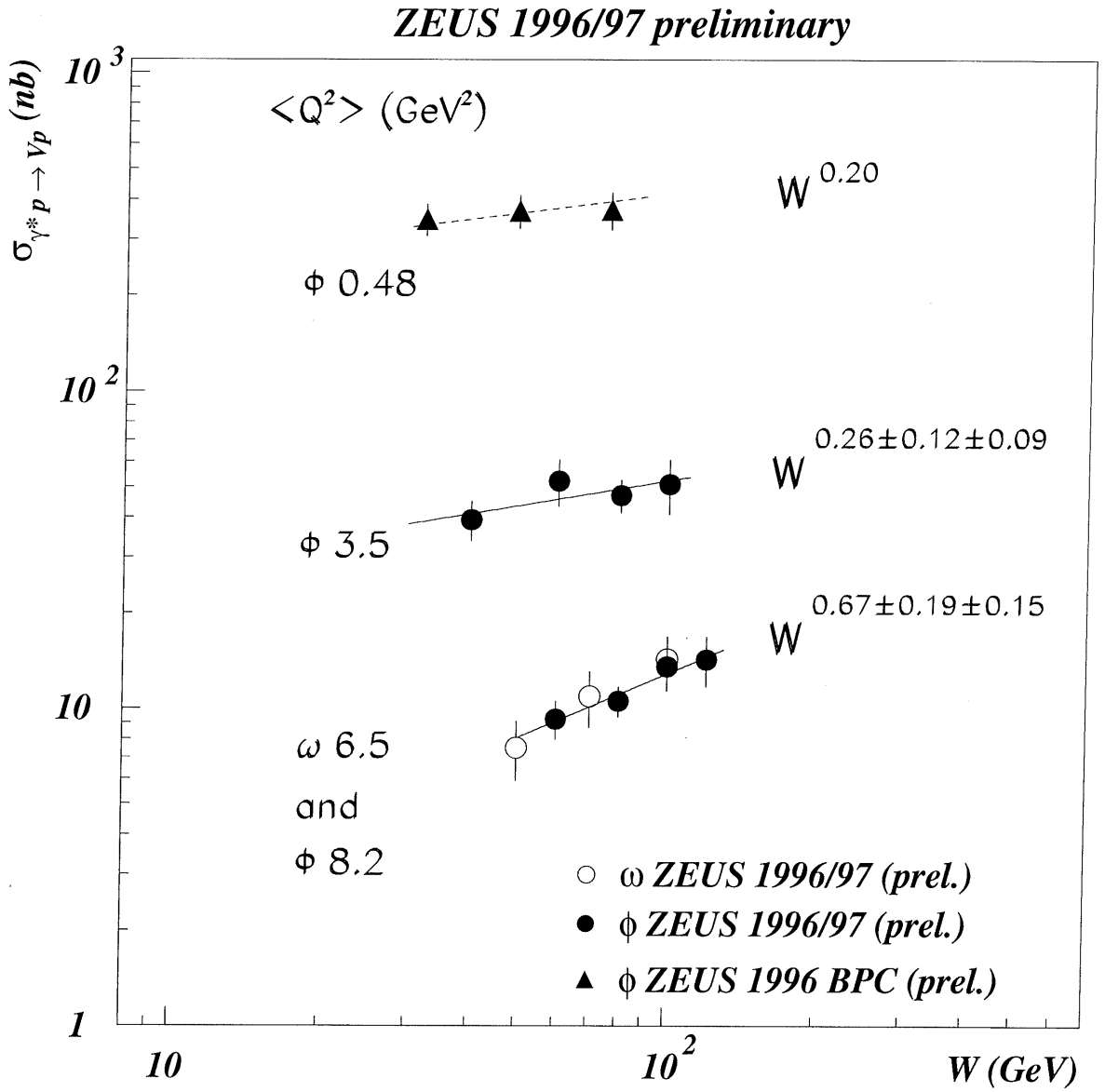
e.g. Fermi motion, skewed partons, different wave functions

Event Selection



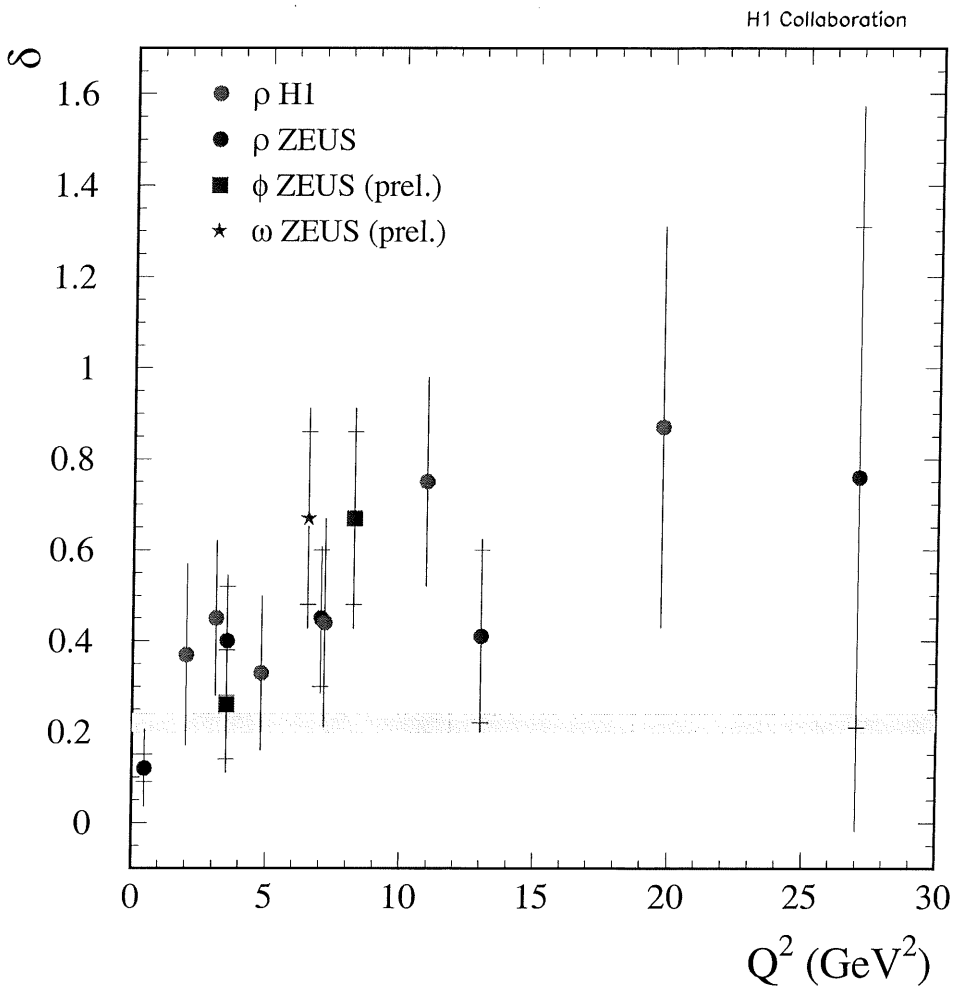
- Reconstruction of charged decay particles of VM using central tracking detectors (limits W range)
- Elastic selection: no energy deposits in main detector besides decay products
- Proton dissociative selection: energy in forward detectors
- DIS: scattered e observed in main detector ($Q^2 > 1\,\mathrm{GeV}^2$)

W dependence for ω and ϕ



- parametrisation: $\sigma \propto W^{\delta}$
- ω, ϕ comparable slopes at similar Q^2
- steeper behaviour than in γp

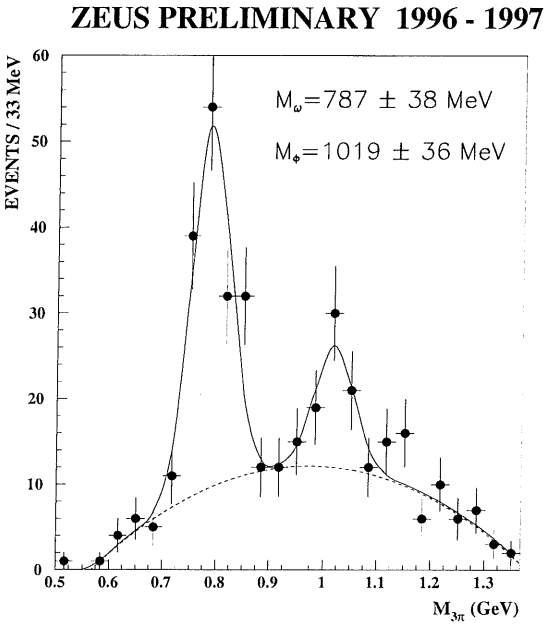
W dependence for VM



- J/ψ γp for comparison: $\delta \approx 0.8$
- values of δ increasing with Q^2
- in agreement with pQCD predictions: $\sigma \propto |xg(x, Q^2_{eff})|^2$

▶ indication for Q^2 providing hard scale

Q^2 dependence for ω



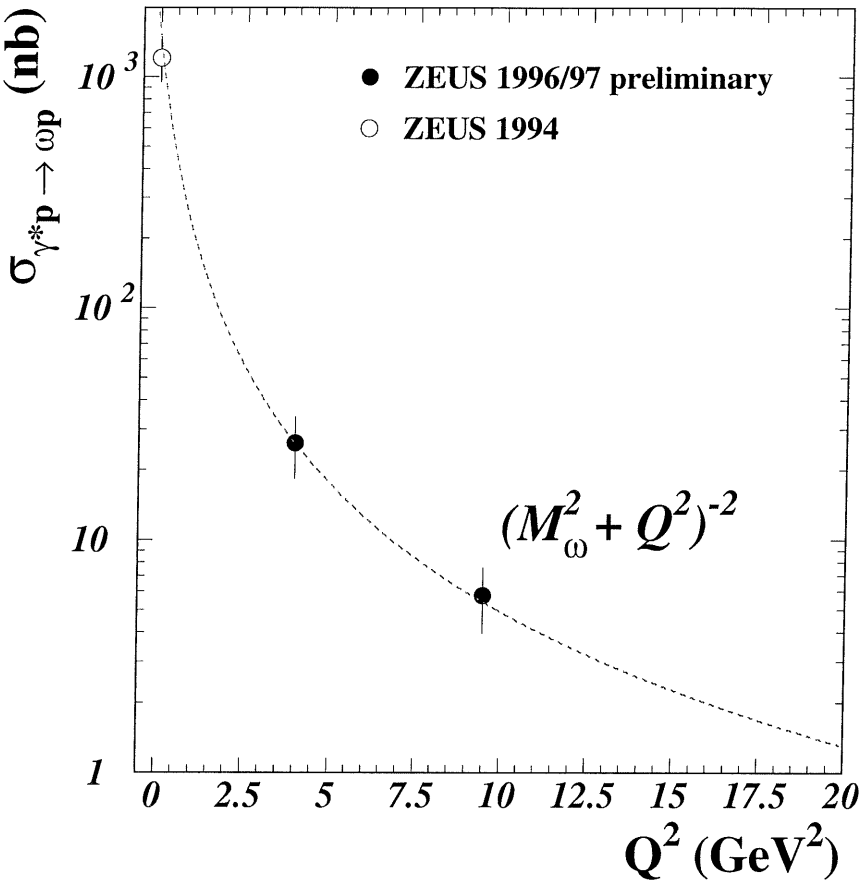
$\omega \to \pi^+\pi^-\pi^0$

kinematic range:

$3 < Q^2 < 20\,\mathrm{GeV}^2$

$40 < W < 120\,\mathrm{GeV}$

$|t| < 1\,\mathrm{GeV}^2$

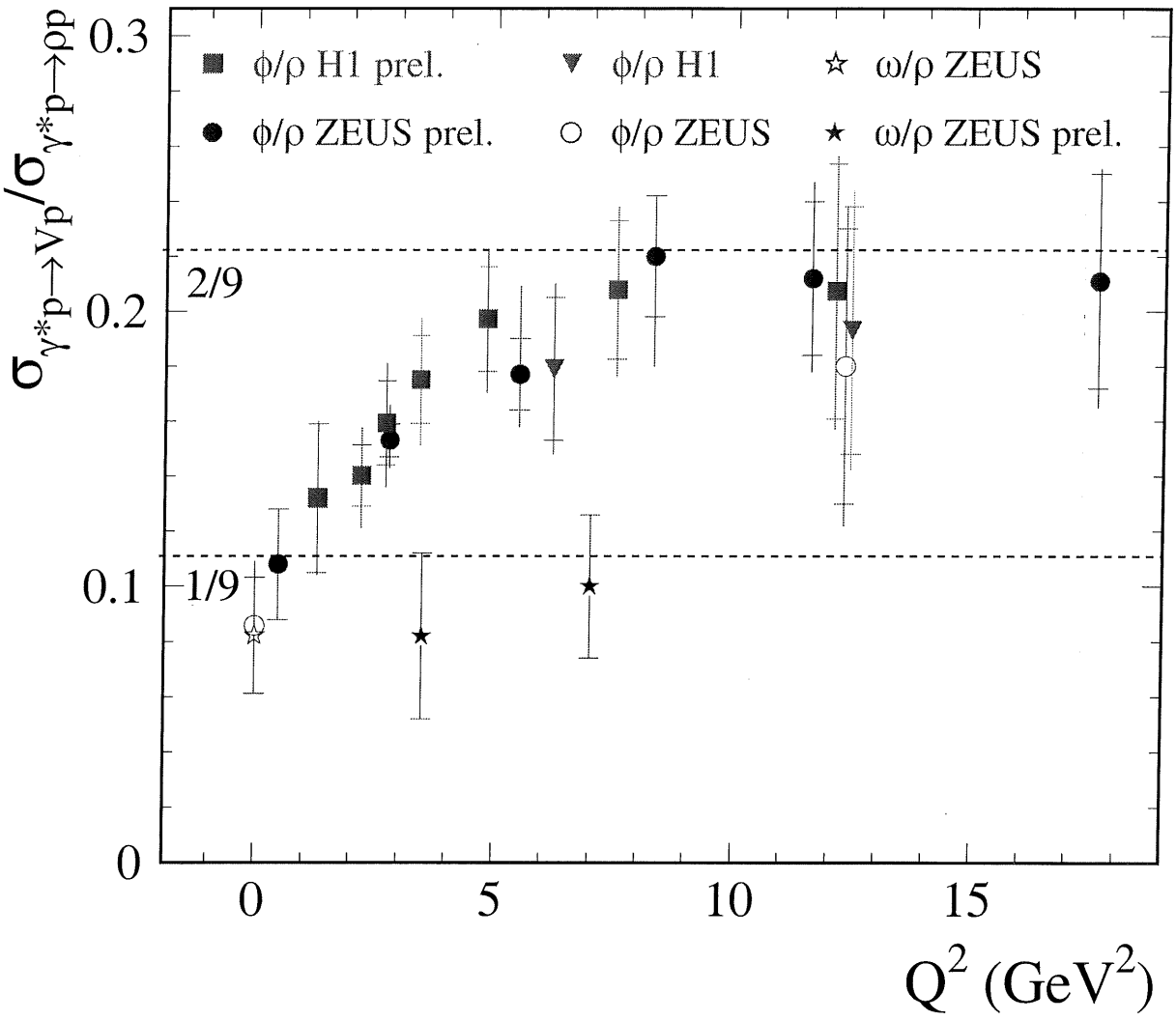


Q^2 dependence similar to ρ and J/ψ

VM production ratios

if γ^* couples directly to quarks:

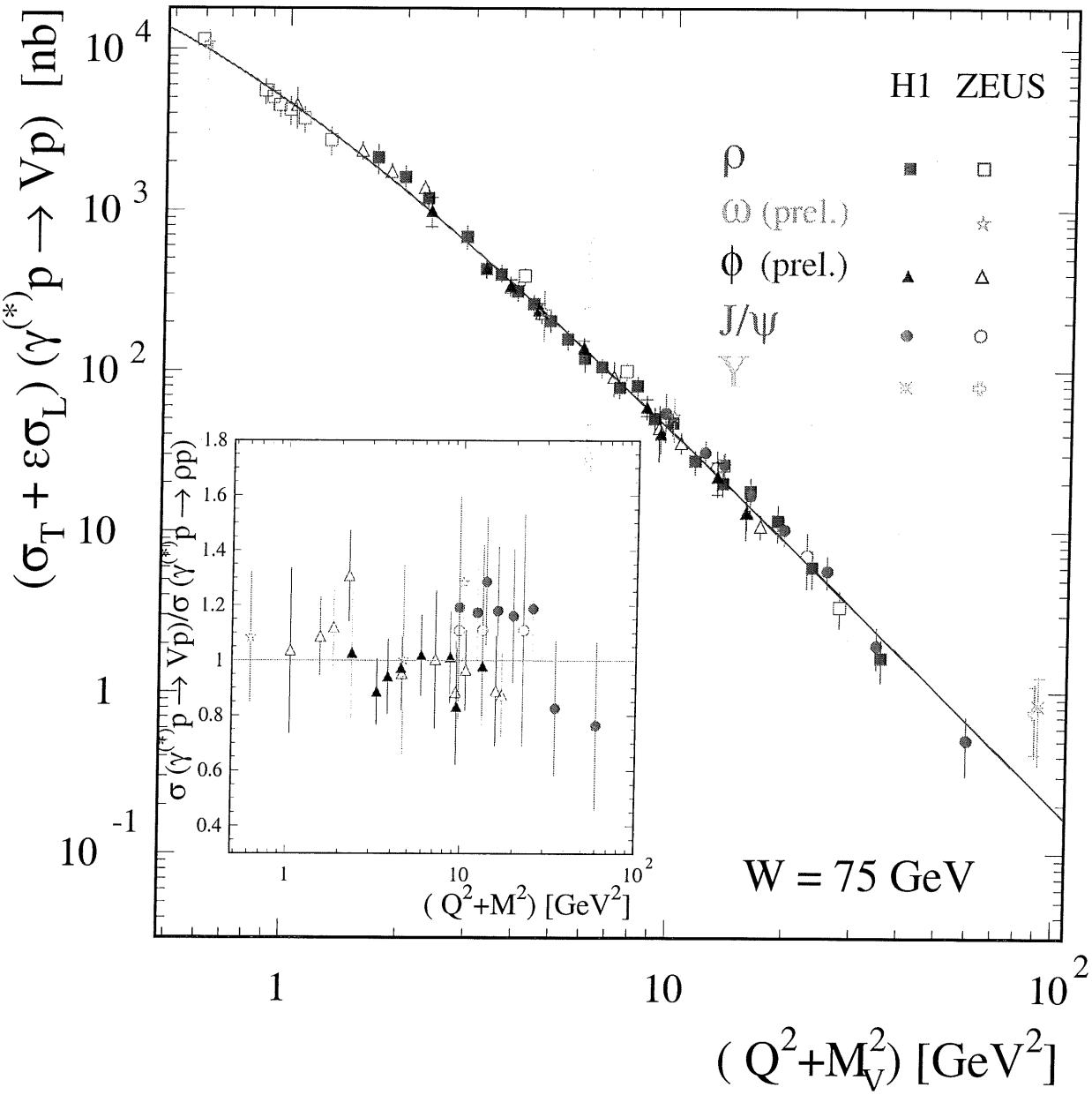
SU(4) : $\rho : \omega : \phi : J/\psi : \Upsilon = 9 : 1 : 2 : 8 : 2$



increasing $Q^2 \Rightarrow$ flavour independence

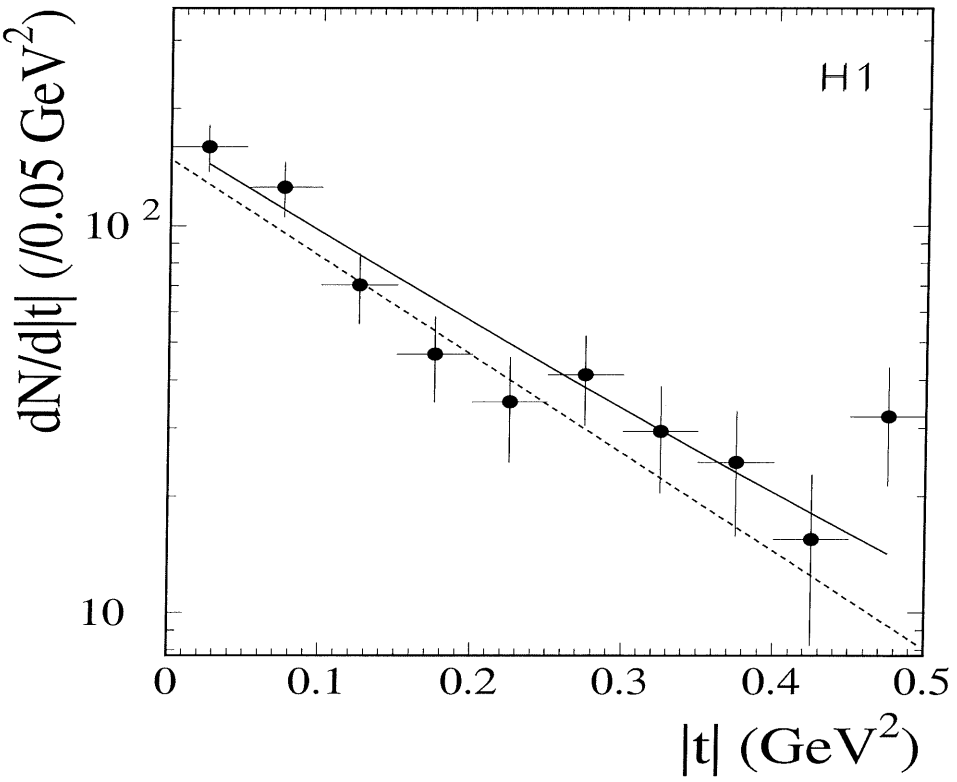
Flavour independence

- scale cross section by SU(4) factors and down to $W = 75\,\mathrm{GeV}$
- Υ cross section scaled assuming W^{δ} with $\delta = 1.7$ (Frankfurt, Dermott, Strikman, hep-ph/9812316)



universal behaviour as function of $Q^2 + M_V^2$

t distribution for elastic ϕ



$$\frac{dN}{dt} \sim e^{-b|t|}$$

- $b = 5.8 \pm 0.5 \pm 0.6\,\text{GeV}^{-2}$ for $< Q^2 >= 4.5\,\text{GeV}^2$
- compare to :
  - $b = 7.3 \pm 1.0 \pm 0.8\,\text{GeV}^{-2}$ in γp (ZEUS)
  - $b = 5.2 \pm 1.6 \pm 1.0\,\text{GeV}^{-2}$ for $< Q^2 >= 10\,\text{GeV}^2$ (H1)

▶ consistent with decrease of slope with increasing Q^2

? decrease of transverse size of virtual γ ?

t-dependence in γp

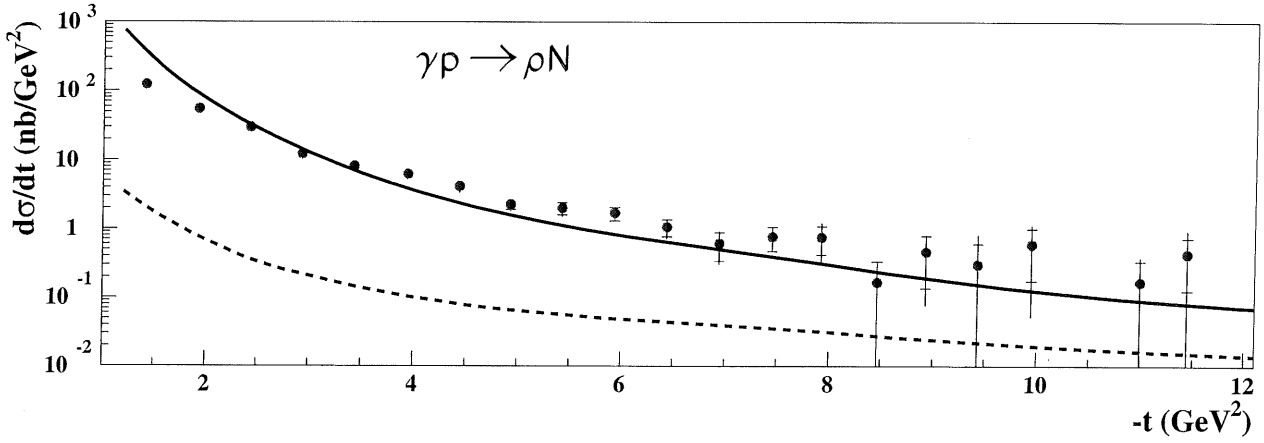
Proton dissociative sample:

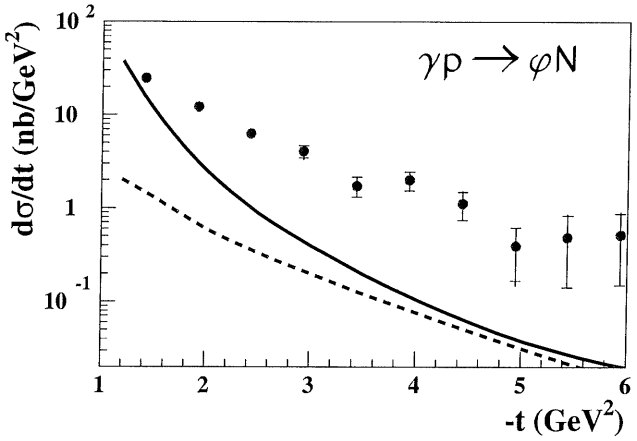
$80 < W < 120\,\text{GeV}$

$Q^2 < 0.01\,\text{GeV}^2$

t is measured by $t \approx -p^2_{t,VM}$

ZEUS Preliminary 1997

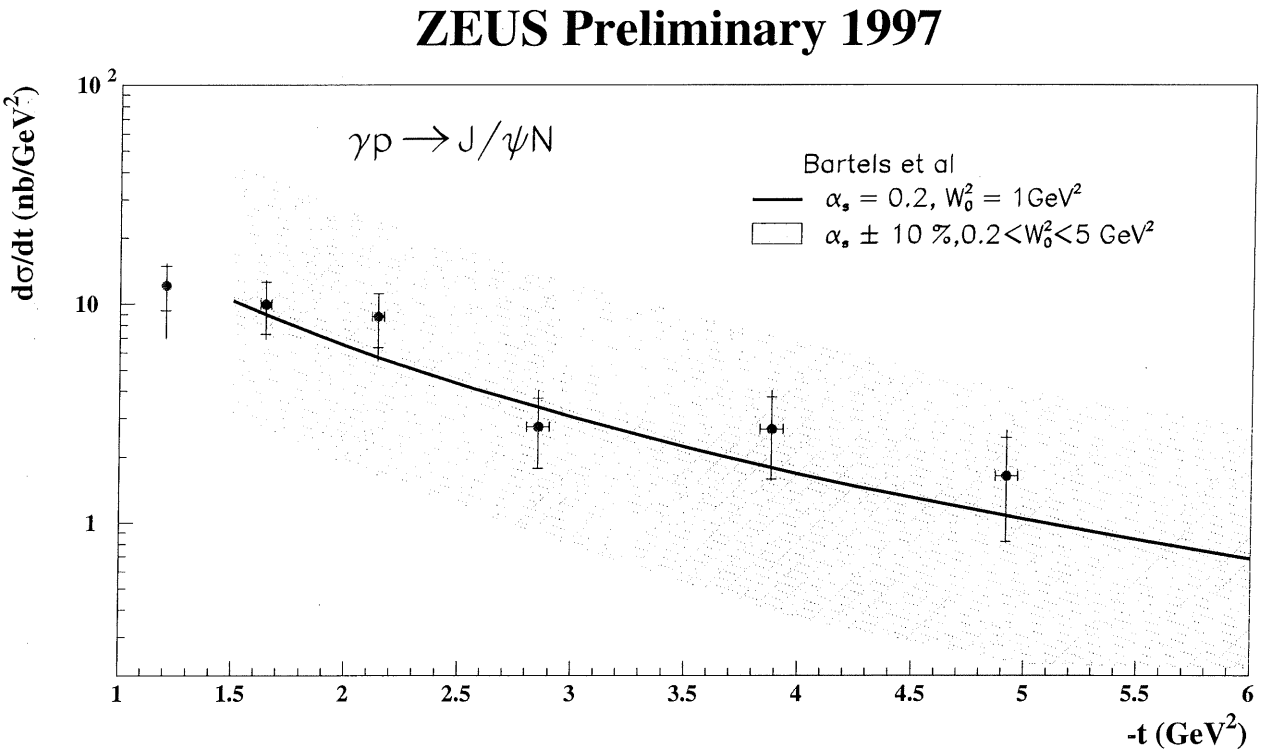




Ivanov & Ginzburg
pQCD+non−perturbative
pQCD only

- ρ: nonperturbative contribution dominates
- ϕ: shape described by pQCD only

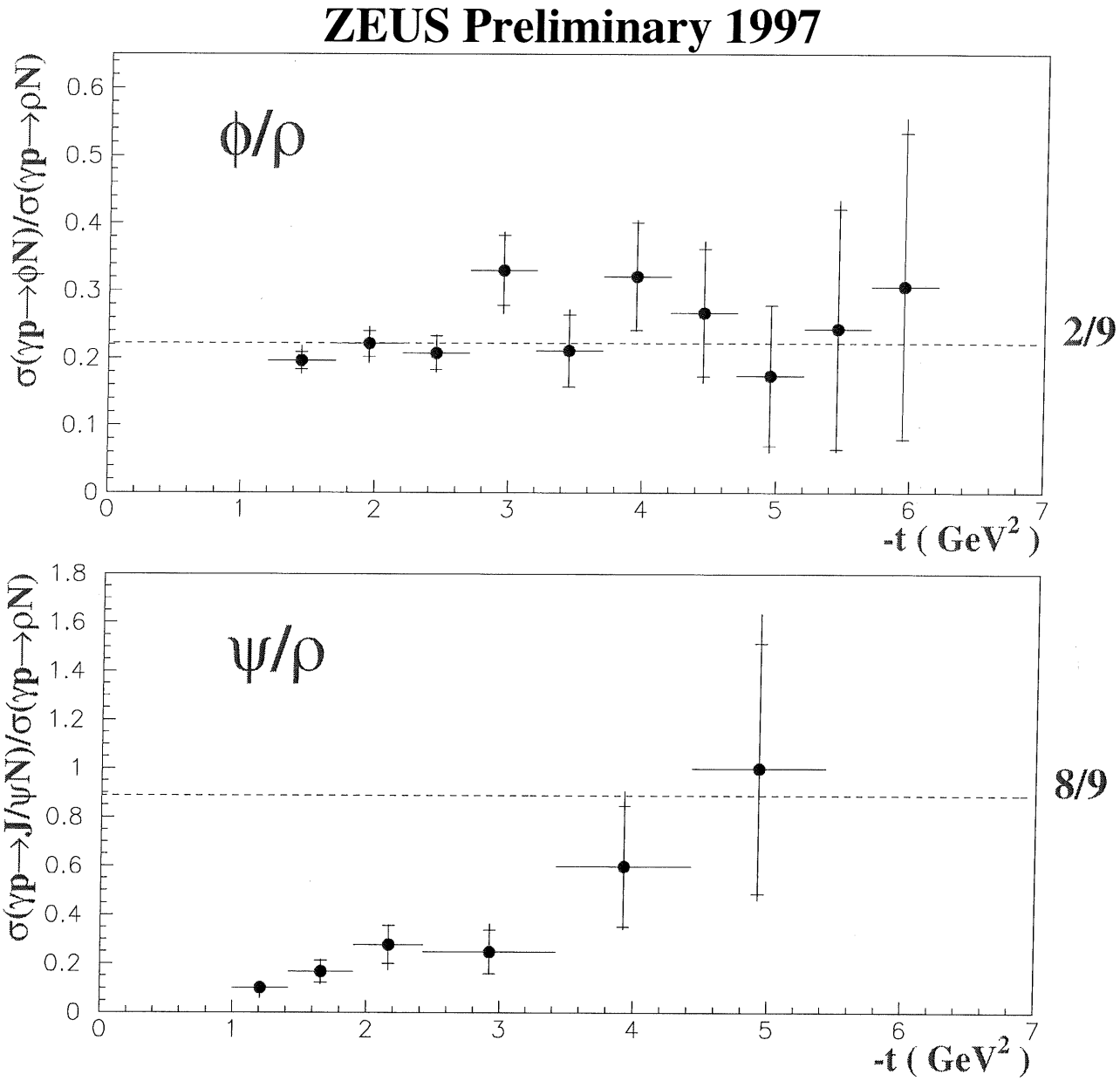
t-dependence for J/ψ in γp



- calculation based on BFKL-formalism
- good agreement in normalisation

? reduced uncertainties in NLO?

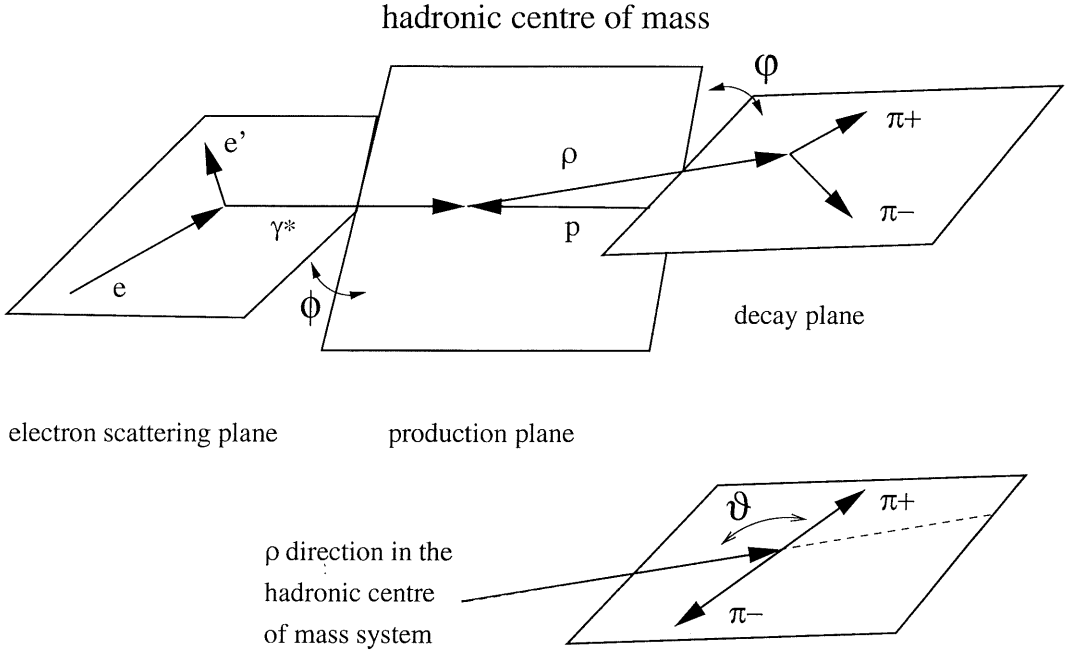
VM production ratios



Evidence for t providing a hard scale

Helicity studies

study angular distribution of production and decay of VM
information on polarisation of γ and VM



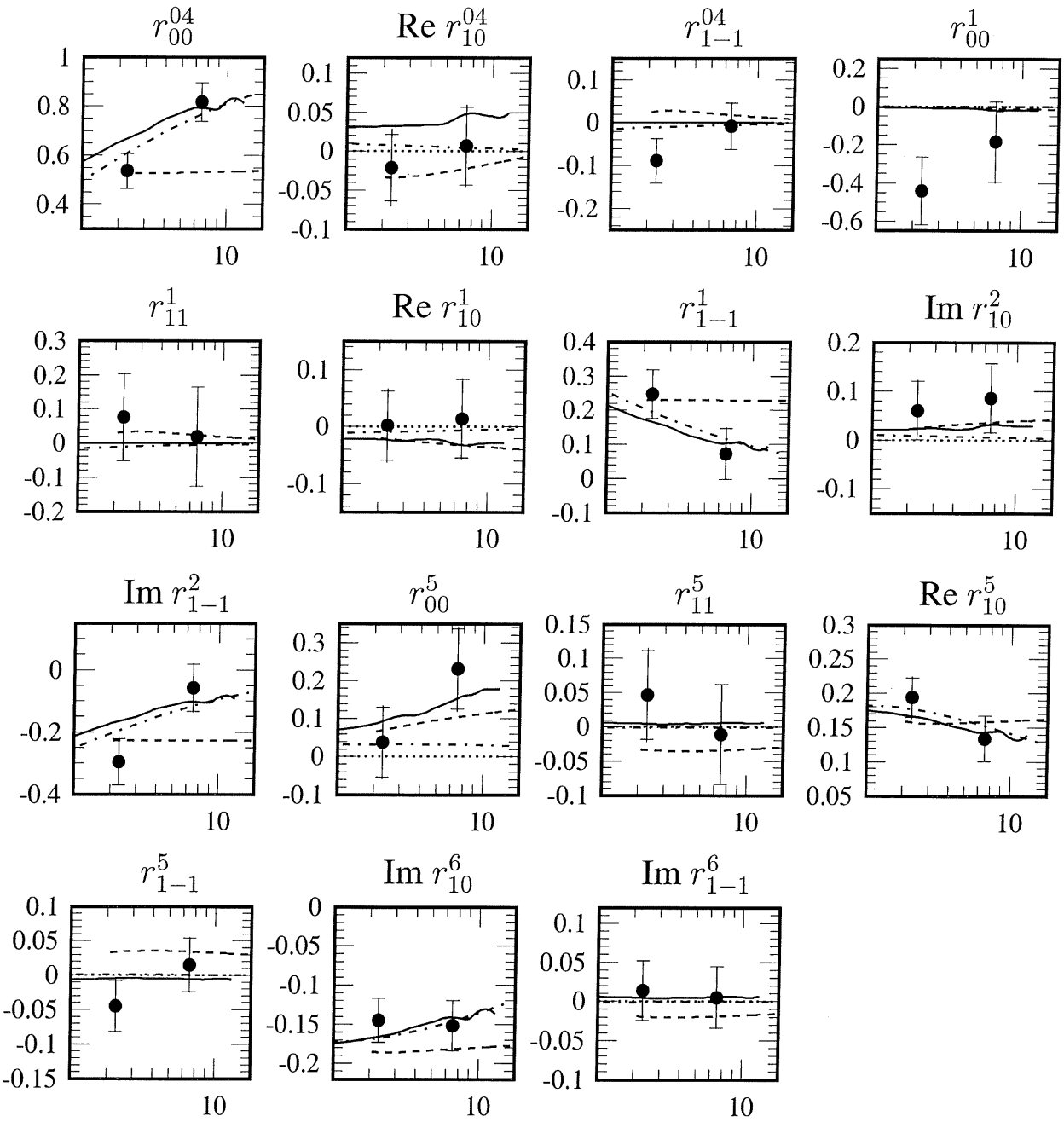
θ, ϕ polar and azimuthal angles of decay particles in helicity frame (meson rest frame)
Φ angle between scatt. and prod. plane

$W(cos\theta, \phi, \Phi)$ = decay angular distribution

- function of 15 spin density matrix elements r_{ij}^{α} and $r_{ij}^{\alpha\beta}$
- matrix elements related to helicity amplitudes $T_{\lambda_{VM},\lambda_{\gamma}}$
- SCHC: helicity of VM and γ equal
  T_{00}, T_{11} , T_{-1-1} different from zero
  10 $r_{ij}^{\alpha\beta}$ are zero

Helicity studies for ϕ

H1 data



.... SCHC

____ Royen and Cudell

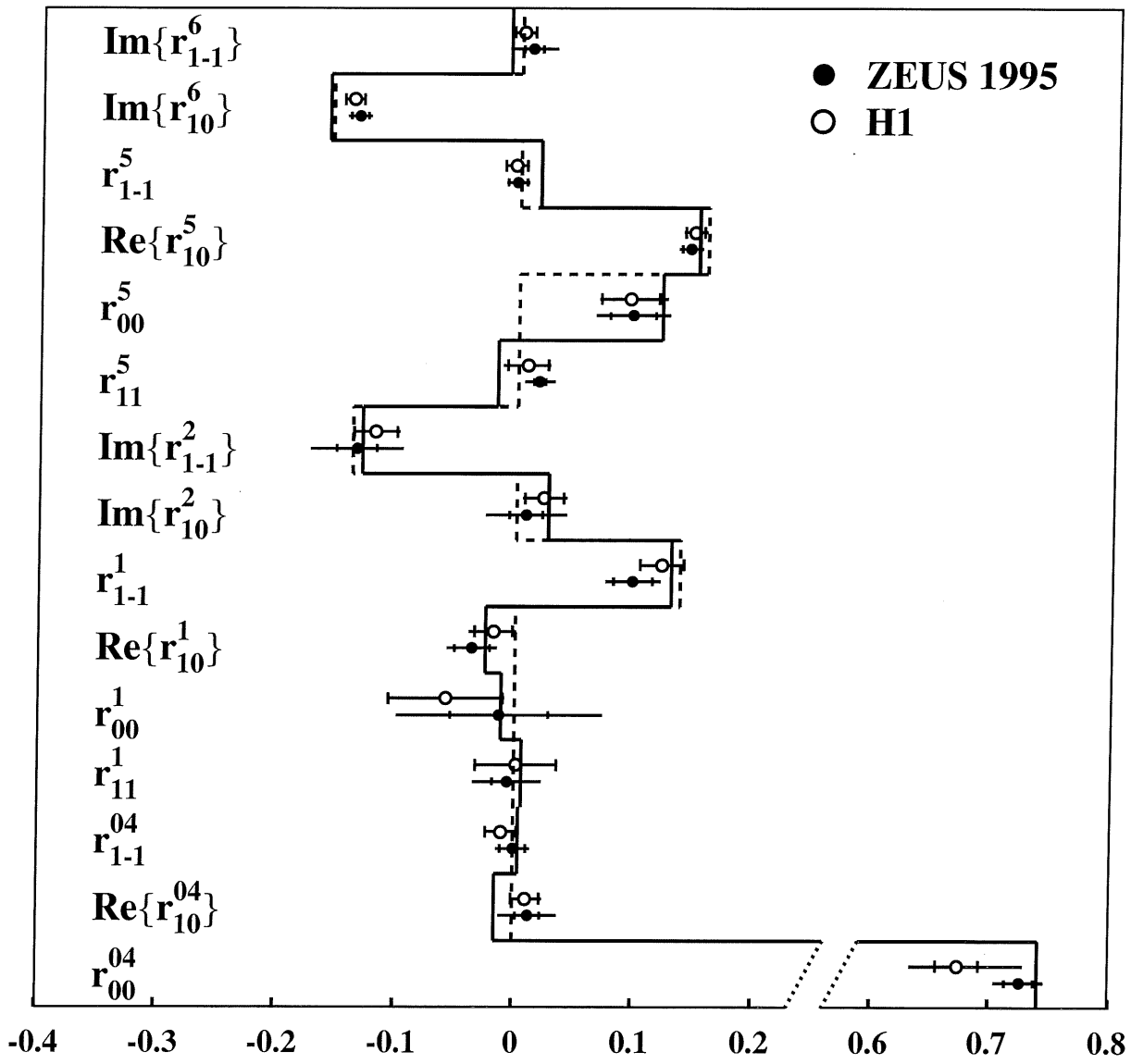
_ _ _ Ivanov and Kirschner

_ . _ Akushevich and Nikolaev

Helicity studies for ρ

comparible result for ρ meson:

matrix element r^5_{00} different from zero



.... SCHC

____ Ivanov and Kirschner

Helicity studies for ϕ

measure angular distribution $W(\Phi)$:

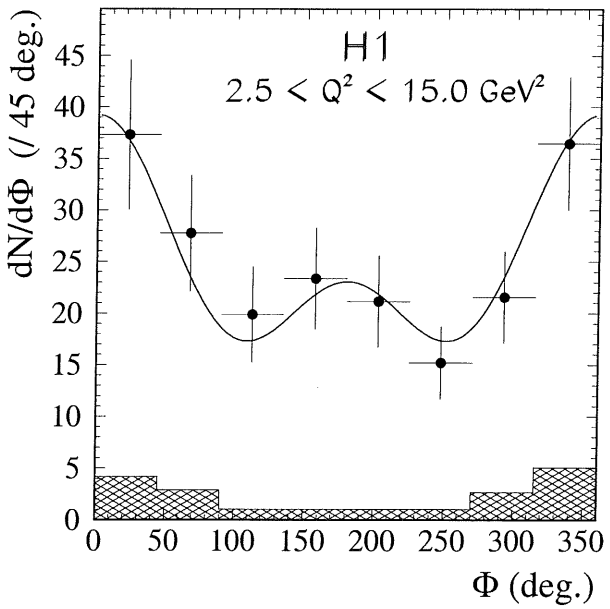
$$W(\Phi) \propto 1 - \epsilon \cos 2\Phi (2r^1_{11} + r^1_{00}) + \sqrt{2\epsilon(1+\epsilon)} \cos\Phi (2r^5_{11} + r^5_{00})$$

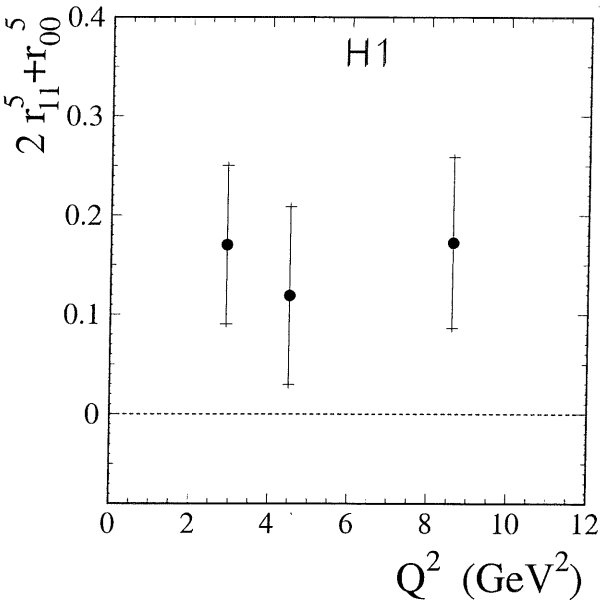
with ϵ = polarisation parameter of γ

SCHC:

- uniform behaviour of $W(\Phi)$

▶ matrix elements zero





- $2r^5_{11} + r^5_{00}$ deviates from zero (similar to elastic ρ production)

▶ violation of SCHC

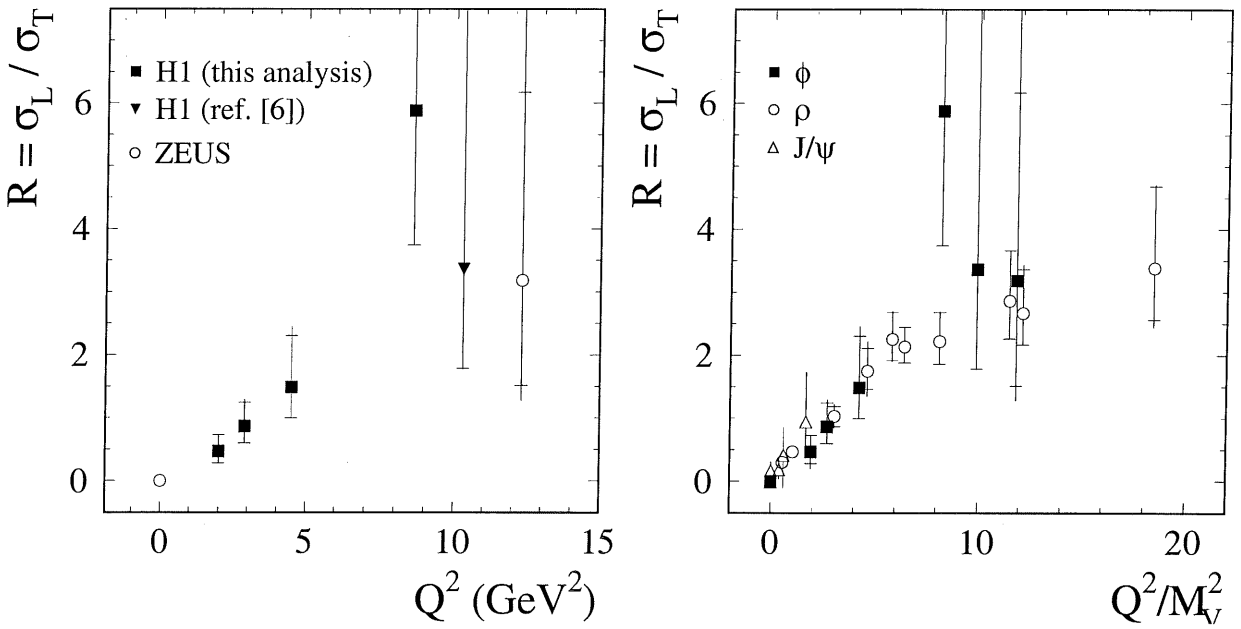
Measurement of $R = \sigma_L/\sigma_T$ for ϕ

$W(\cos\theta) \propto 1 - r_{00}^{04} + (3r_{00}^{04} - 1)\cos^2\theta$

r_{00}^{04} : probability for VM longitudinally polarised

now assume SCHC:
$|R(\text{no SCHC}) - R(\text{SCHC})| < 3\%$

$$\Rightarrow \quad R = \frac{1}{\epsilon}\frac{r_{00}^{04}}{1 - r_{00}^{04}}$$



- domination of σ_L at higher Q^2
- R increases with Q^2 and flattening at high Q^2

Summary

- Q^2 dependence of ω similar to other VM
- $\sigma \propto W^{\delta}$ δ increases with Q^2
- flavour independence for increasing Q^2
- $d\sigma/d|t|$ measured for t up to 12 GeV^2 in γp
- helicity studies of ϕ meson see small SCHC violation (same for ρ)