Vector mesons production at HERA

Dorota Szuba

INP-PAS, Cracow

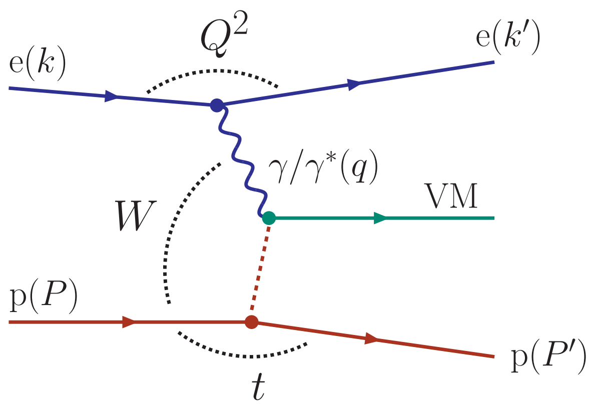
on behalf of

the ZEUS collaboration

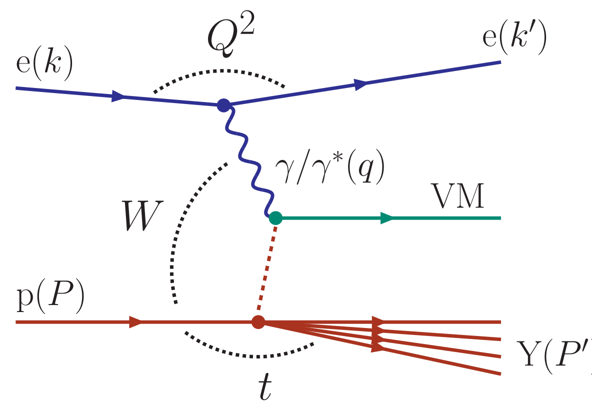
XIII International Workshop on Deep Elastic Scattering
Madison, April 27th 2005

Diffractive vector meson production at HERA

'elastic' (exclusive)



proton dissociative

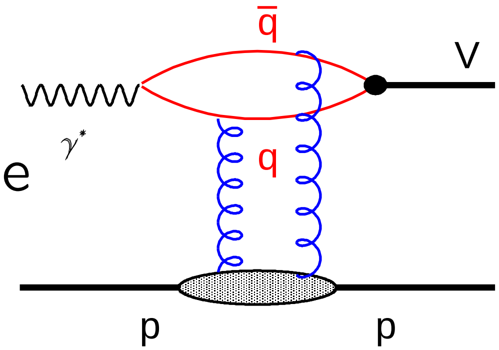


experimentally: very clean process in wide kinematic range

VM	Vector Meson	$\rho, \omega, \phi, J/\psi, \psi', \Upsilon$
Q^2	photon virtuality	$Q^2 = -q^2 = -(k-k')^2$
W	c.m. energy of γp system	$W = (q+p)^2$
t	(4-mom. transfer)^2 at p-vertex	$t = (P-P')^2$

$\longrightarrow$ VM at HERA: transition between soft and hard regime
$\longrightarrow$ simultaneous control of different scales: Q^2, $|t|$, M^2_{VM}

Diffractive VM production pQCD models



large Q^2, M^2_{VM} or $|t| \Rightarrow$ small $q\bar{q}$ and interaction size

hard interaction $\Rightarrow$ perturbative QCD applicable:

VM $= q\bar{q}$ dipol, exchange of $\geq$ 2 gluons (color singlet–QCD Pomeron)

pQCD expectation:

- steep rise of σ_L with W, $\sigma \sim \frac{\alpha_S(Q^2)}{Q^6}[xg(x,Q^2)]^2 \approx W^{0.8}$, $x \approx Q^2/W^2$
- universality of t dependence: $\sim \exp^{-b_{2g}|t|}$, $b_{2g} \sim$ 4-5 GeV^{-2}, $\alpha'_{IP} \approx 0$
- possible SCHC violation

Exclusive ϕ in DIS

"Exclusive electroproduction of ϕ mesons at HERA", hep-ex/0504010

- ϕ production: good test of pQCD in transition between soft and hard regime
- mass of heavy quarks provides a hard scale
- different QCD models: FS04 and MRT

Forshaw and Shaw, JHEP 0412, 052 (2004)

Martin, Ryskin, Teubner, Phys. Rev. D 62, 14022 (2000)

  – NLO not fully taken into account

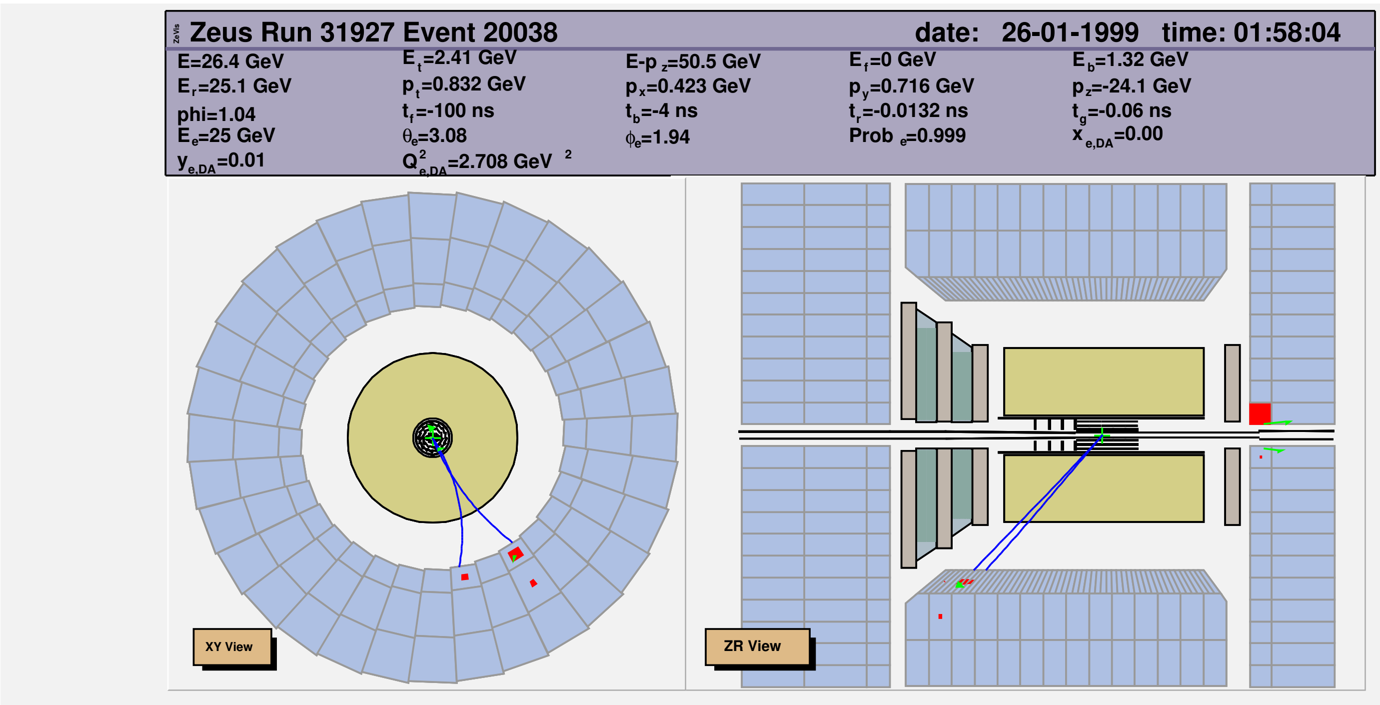
- ρ and J/ψ show different behaviour

  ϕ mass in between, how does it behave?

- large available statistics $\rightarrow$ precise mesurement in several variables

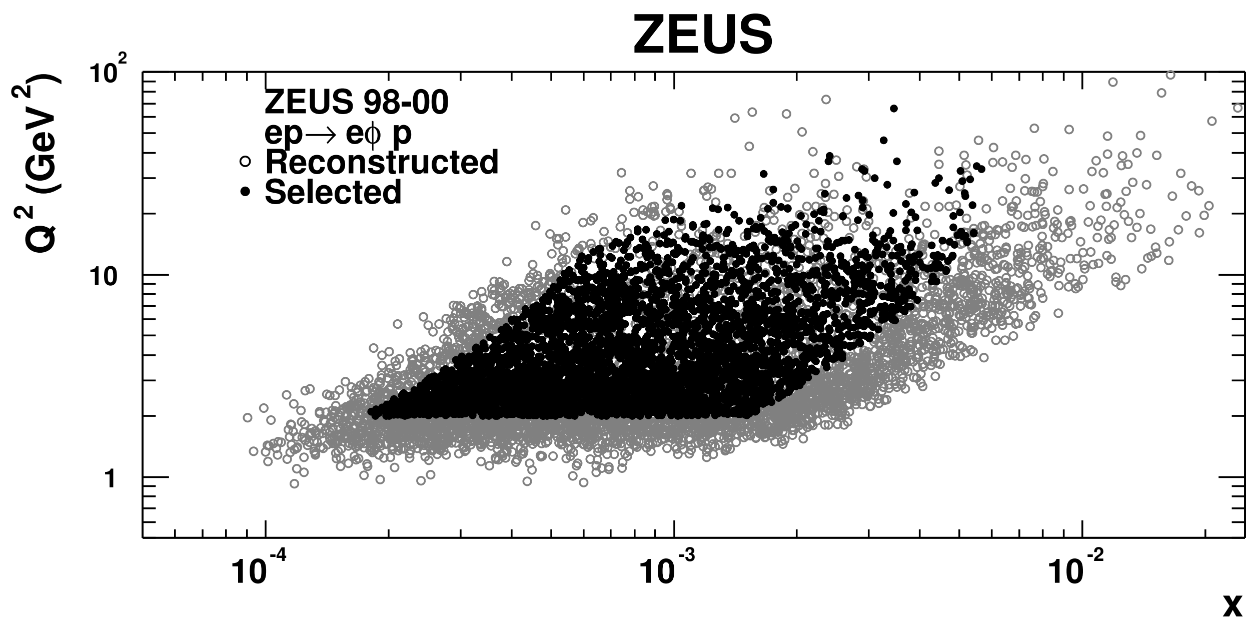
Experimental signature

- scattered e with $E > 10\,\mathrm{GeV}$ reconstructed in CAL
- scattered p undetected
- two tracks reconstructed in CTD associated to kaons
- nothing else in detector above 300 MeV



Kinematic range

- data from 1998 - 2000 runs
- $e^{\pm}p$ data, $E_p = 920$ GeV, $E_e = 27.5$ GeV



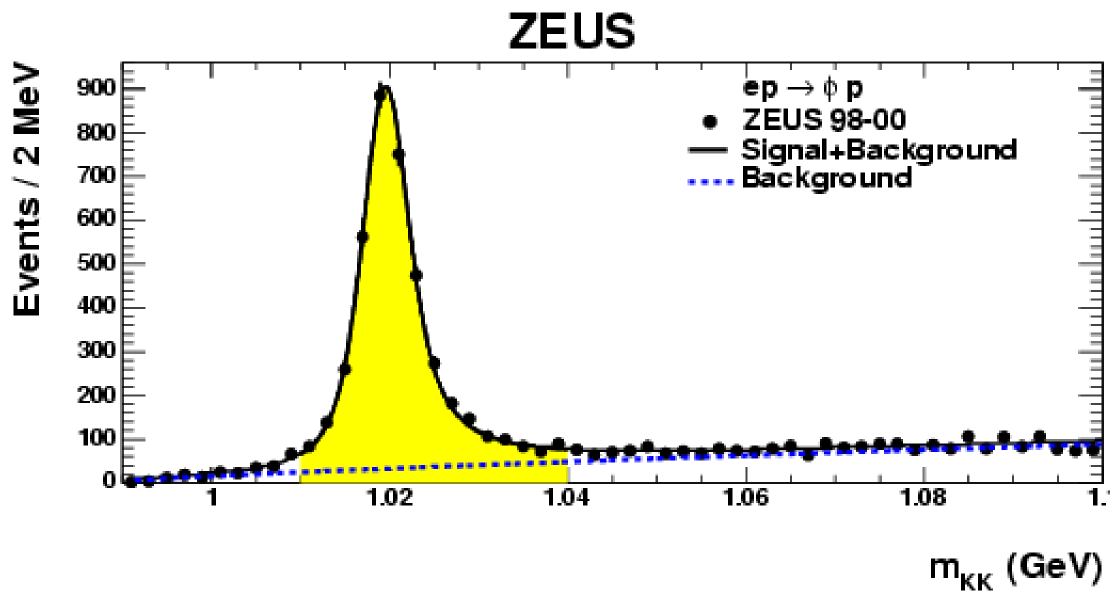
Kinematic range:

- $2 < Q^2 < 70$ GeV^2
- $|t| < 0.6$ GeV^2
- $35 < W < 145$ GeV
- $33.75\,\text{GeV} + 1.25\,\text{GeV}^{-1} \cdot Q^2 < W < 100\,\text{GeV} + 3.7\,\text{GeV}^{-1} \cdot Q^2$
- $x - Q^2$ plane for $1.01 < m_{KK} < 1.04$ GeV

Extraction of ϕ signal

- $\mathcal{L} = 65.1\,\mathrm{pb}^{-1}$, 3642 events in mass range of $1.01 < m_{KK} < 1.04$ GeV

- non-resonant background is typically 18% at $Q^2 = 2.4\,\mathrm{GeV}^2$ decreasing to 5% at $Q^2 = 13\,\mathrm{GeV}^2$

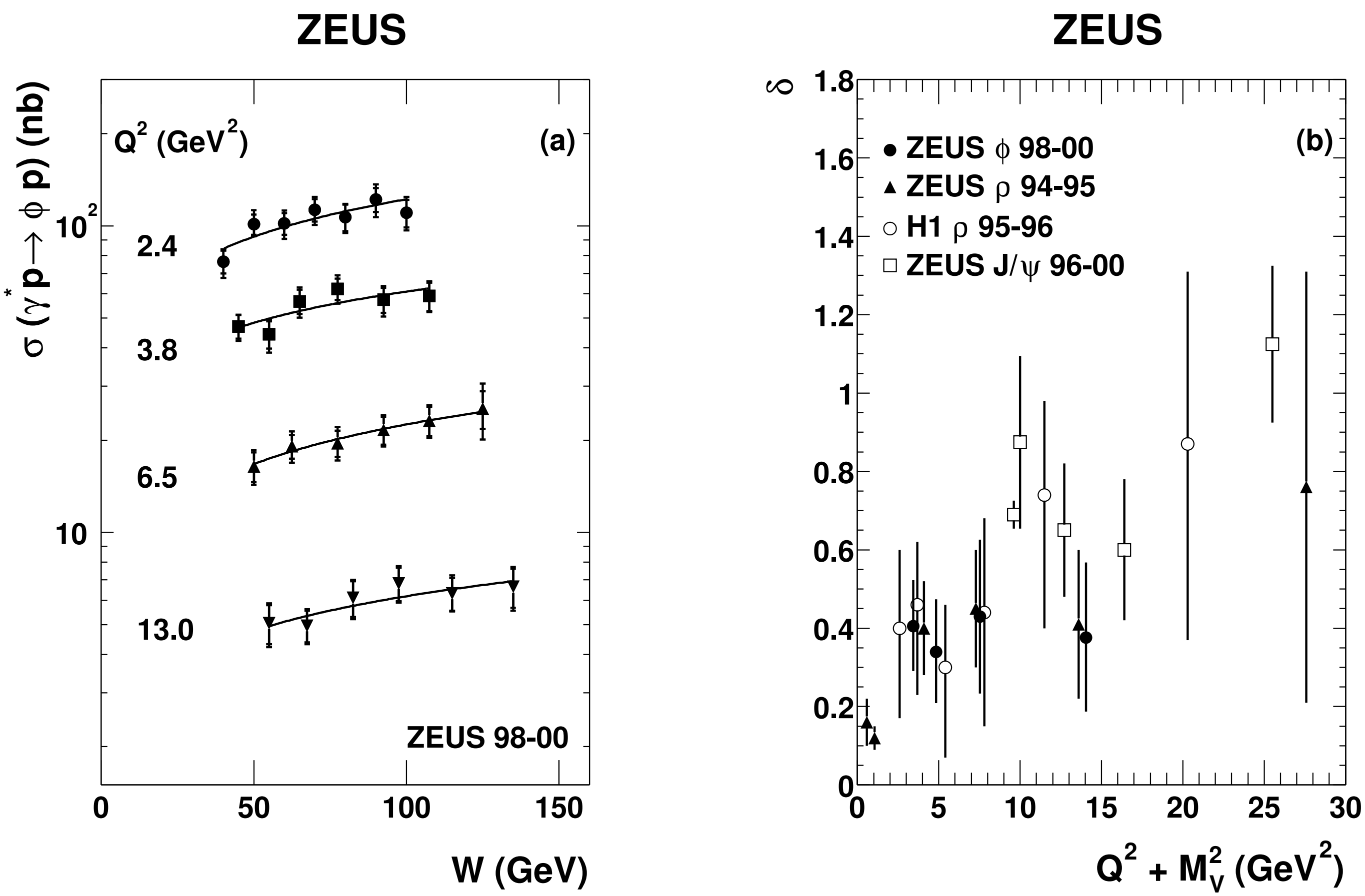


- background from proton dissociative events: $ep \rightarrow e\phi Y$
  $\frac{d^2\sigma(\gamma p \rightarrow \phi Y)}{dt dM_Y^2} = f(Q^2, W) e^{bt} M_Y^{-\beta}$, with $b = (5.1 \pm 1.3)/(1 + R(Q^2))\,\mathrm{GeV}^{-2}$, $\beta = 2.5 \pm 0.5$ and $f(Q^2, W)$ the same as in exclusive sample

- contribution from proton dissociative events independent from W, Q^2 and θ_h $(7 \pm 0.4(stat.)^{+4.2}_{-2.8}(syst.))\%$ was subtracted

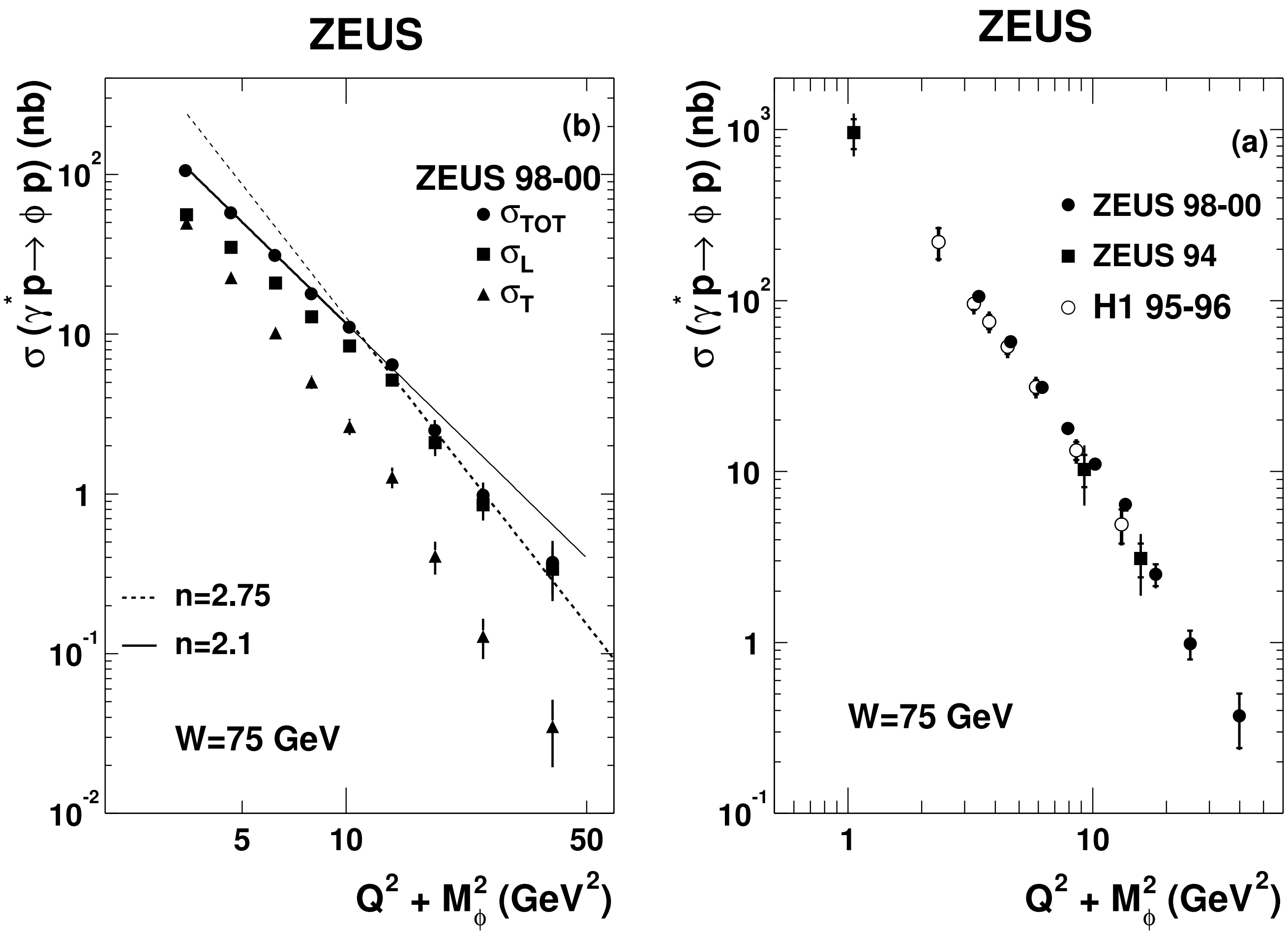
W dependence as function of Q^2

- $\sigma \propto W^{\delta}$, $\delta \approx 0.4$
- no Q^2 dependence of σ
- rise of δ as a function of $Q^2 + M_{VM}^2$ observed in global VM picture
- ρ, ϕ transition from soft to hard regime, while J/ψ hard already in photoproduction



Q^2 dependence

- Q^2 dependence different for σ_L and σ_T
- Q^2 dependence for $W = 75$ GeV
- $\sigma \propto (Q^2 + M_\phi^2)^{-n}$

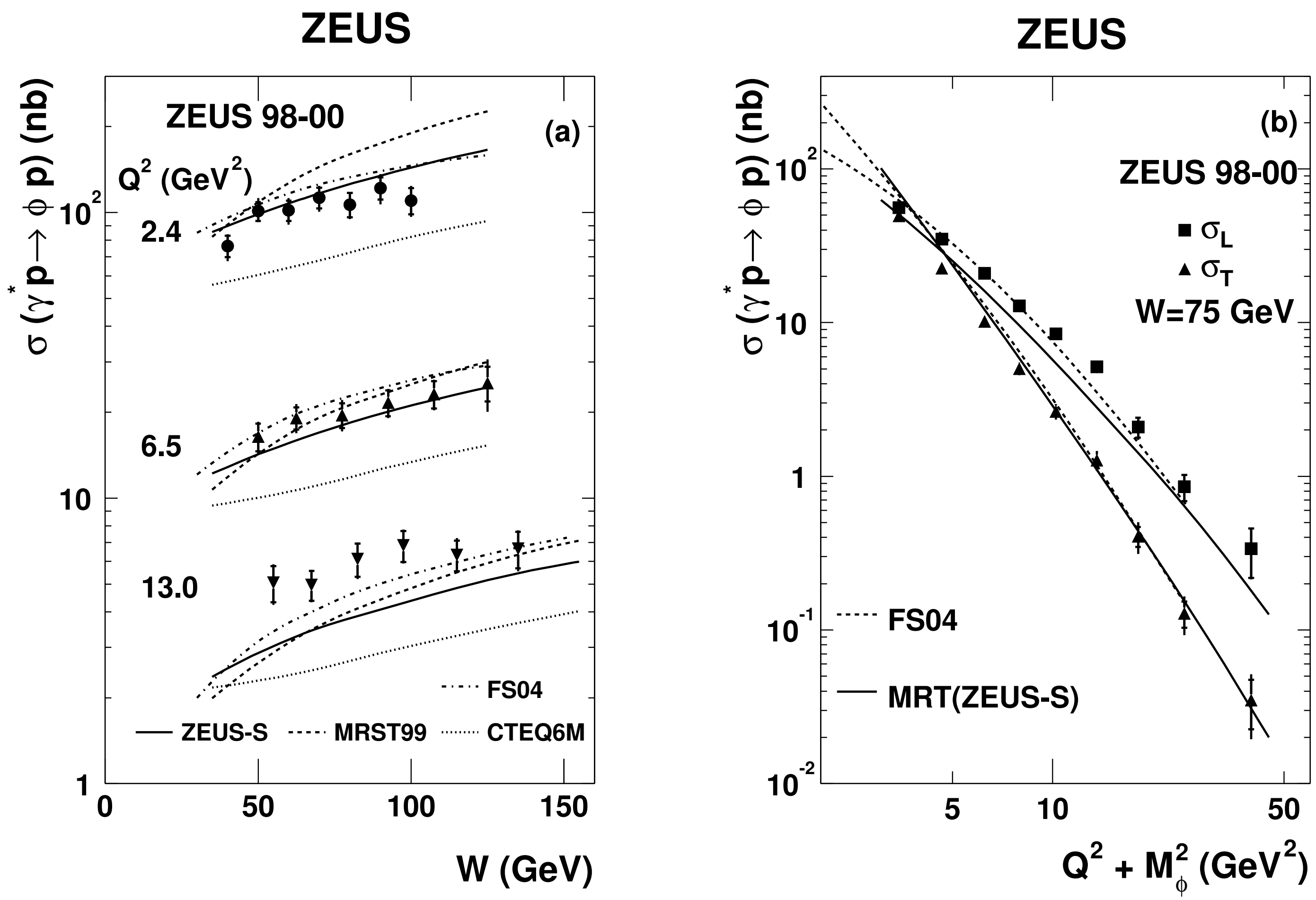


$n = 2.087 \pm 0.055_{stat} \pm 0.050_{syst}$ for $2.4 \leq Q^2 \leq 9.2$ GeV^2

$n = 2.75 \pm 0.13_{stat} \pm 0.07_{syst}$ for $9.2 \leq Q^2 \leq 70$ GeV^2

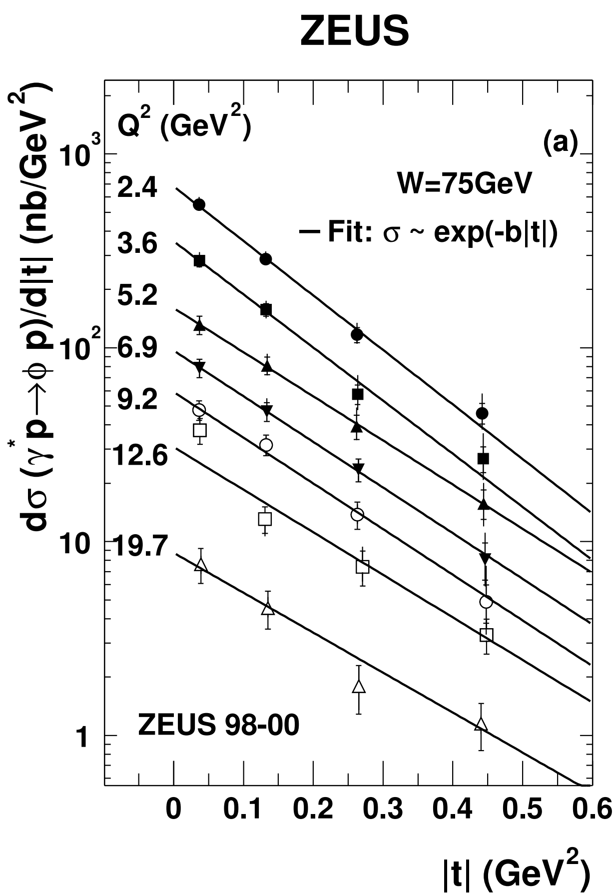
Q^2 dependence - comparison with theory

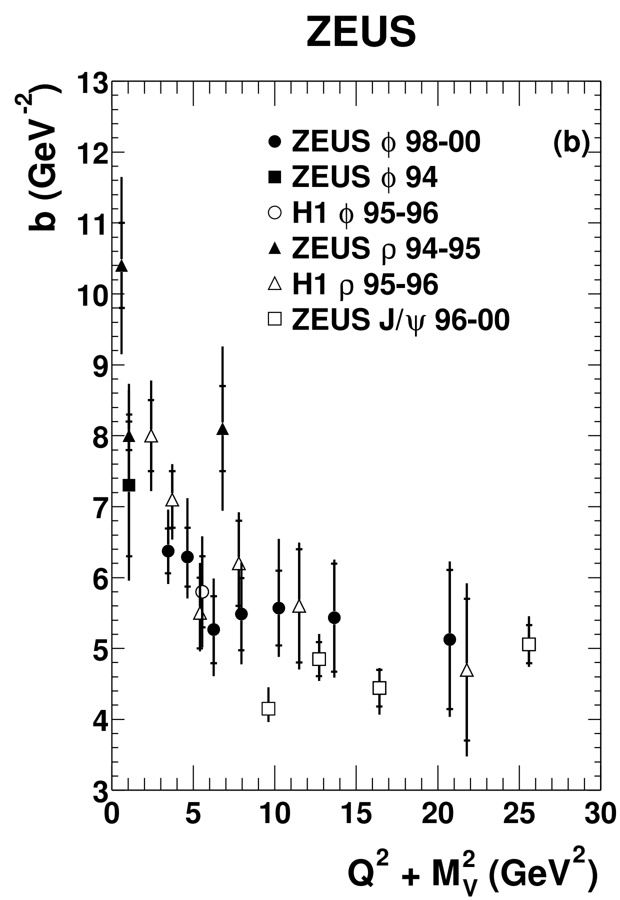
- comparison with MRT and FS04 QCD models
  - different assumptions on gluon densities
- models describe qualitatively data; better description FS04 model



t dependence

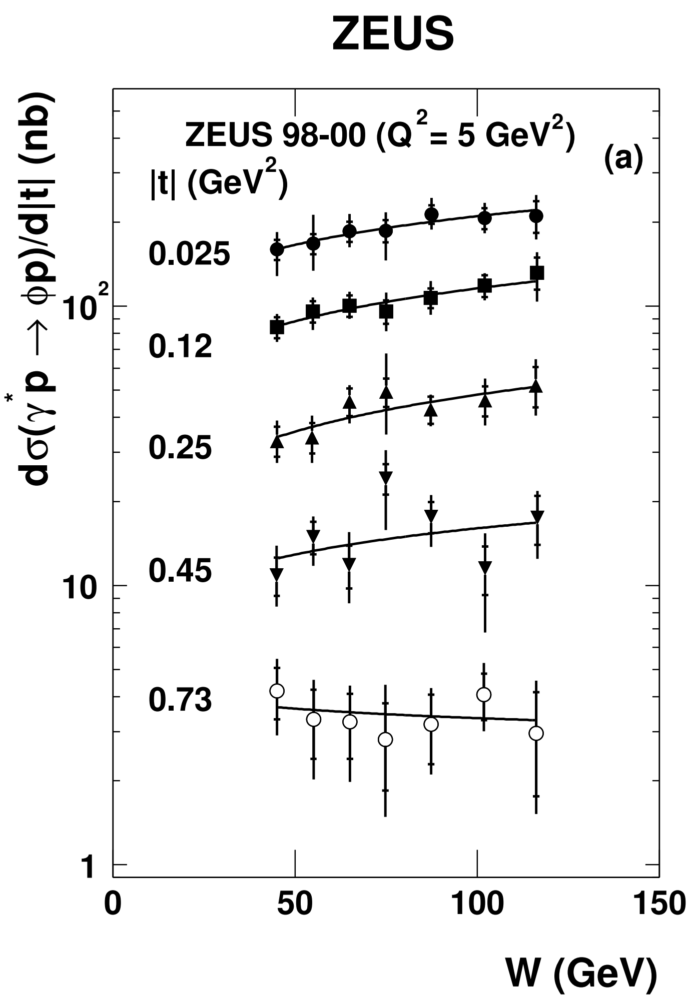
- $d\sigma/dt \propto exp(-b|t|)$ for $W = 75$ GeV
- b shows no Q^2 dependence within the uncertainties
- data suggest scaling with $Q^2 + M_{VM}^2$

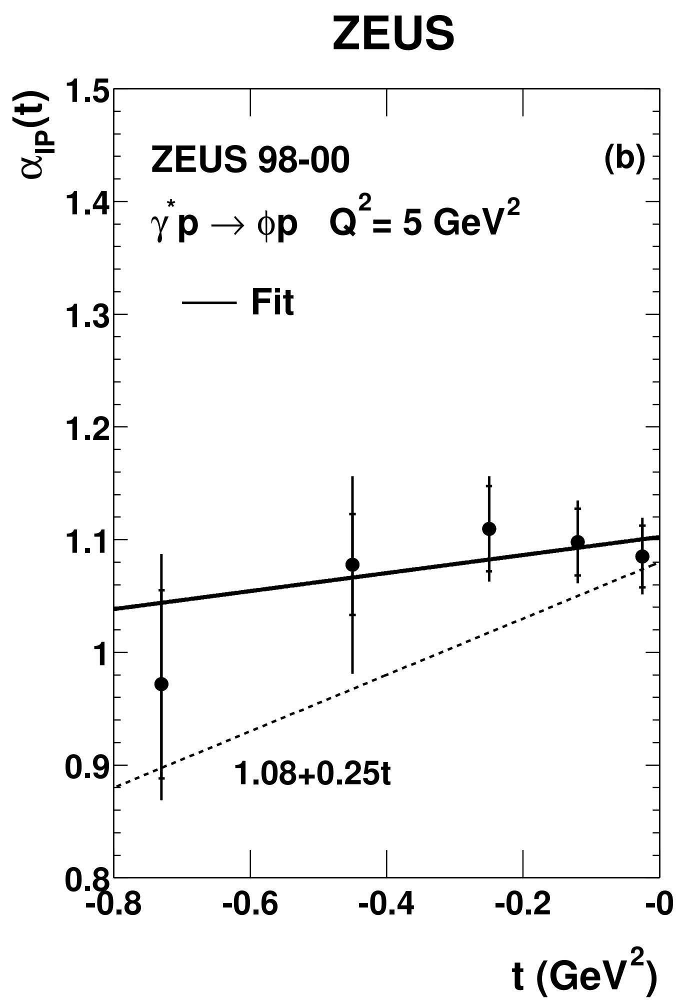




W dependence as fuction of t

- fit to $\sigma \propto W^{\delta}$ for $Q^2 = 5\,\mathrm{GeV}^2$
- δ related to pomeron trajectory
$\delta = 4(\alpha_{IP}(t) - 1)$ with $\alpha_{IP}(t) = \alpha_0 + \alpha' \cdot t$
- data are consistent with
no t-dependence of δ

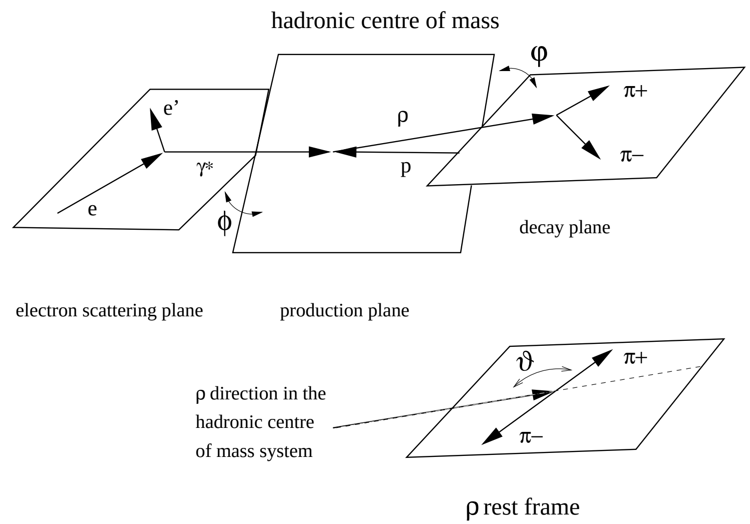


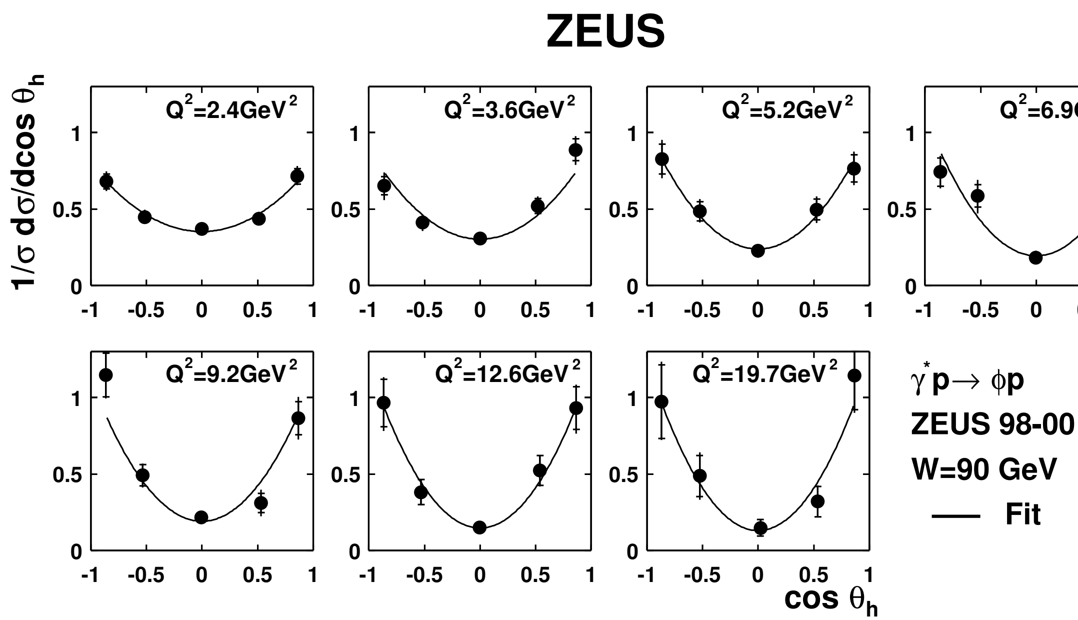


$\alpha_{IP}(0) = 1.10 \pm 0.2(stat.) \pm 0.2(syst.)$
$\alpha'_{IP} = 0.08 \pm 0.09(stat.) \pm 0.08(syst.)\ \mathrm{GeV}^{-2}$

Helicity analysis

- $\sigma = \sigma_T + \epsilon \sigma_L$
- angular distributions allow to extract σ_L/σ_T
- $\frac{1}{N}\frac{dN}{d\cos(\theta_h)} = \frac{3}{8}(1 + r^{04}_{00} + (1 - 3r^{04}_{00}\cos^2\theta_h))$
- $R = \frac{\sigma_L}{\sigma_T} = \frac{1}{\epsilon}\frac{r^{04}_{00}}{1-r^{04}_{00}}$, $\epsilon \approx 0.99$
- Expected rise of $R = \sigma_L/\sigma_T$ with Q^2



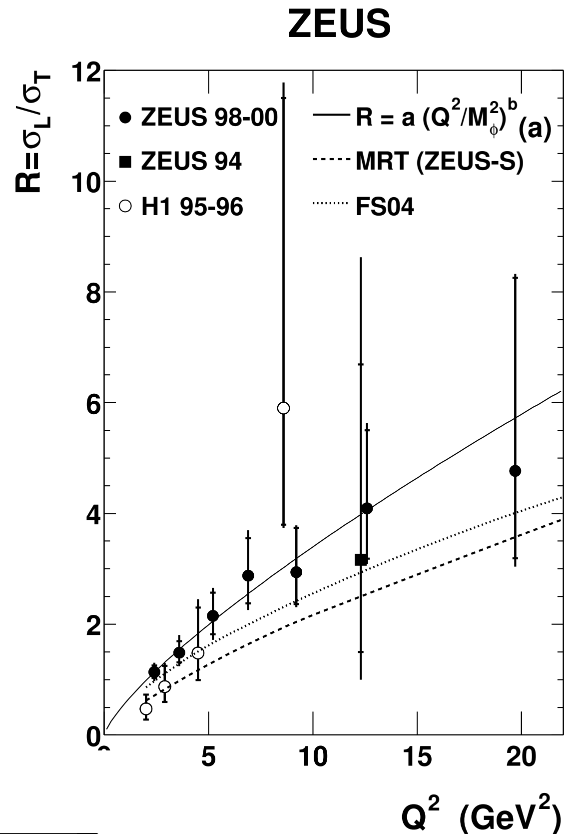


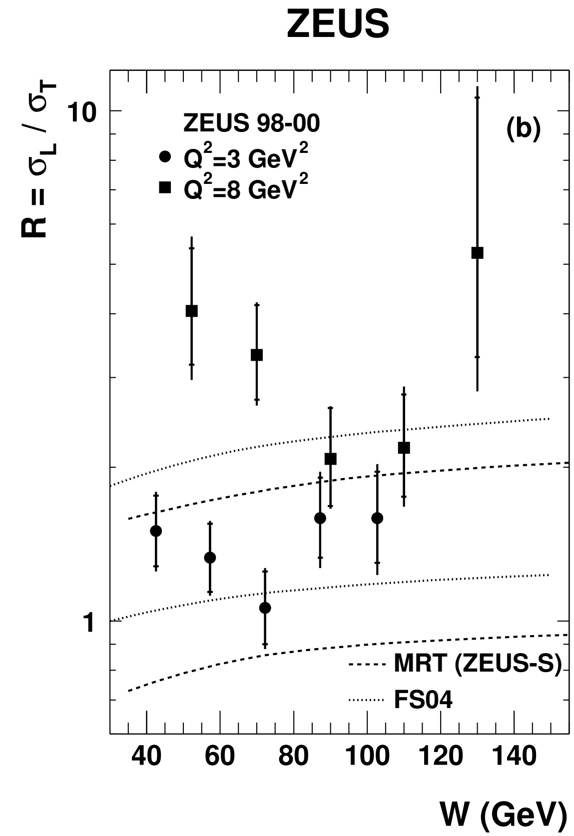
Helicity analysis - ratio σ_L/σ_T

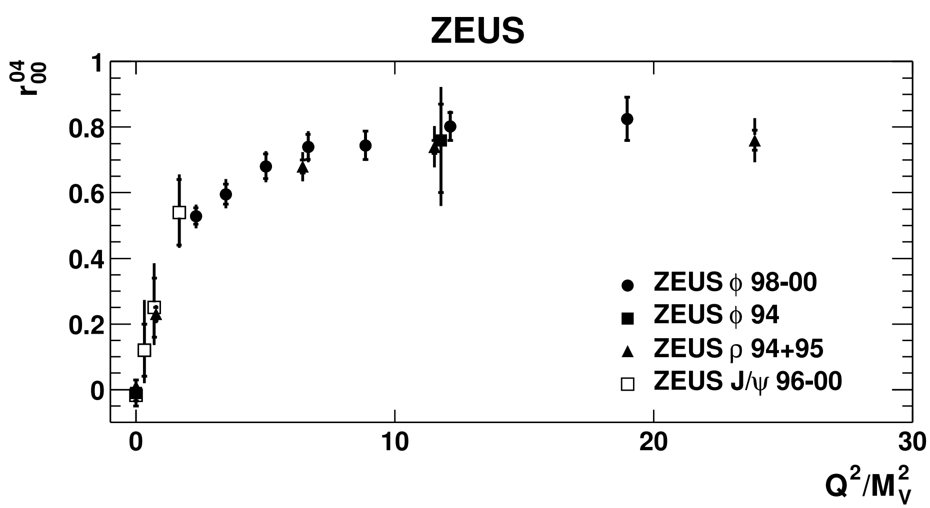
- fit to $R = a(Q^2/M_\phi^2)^b$

  $a = 0.51 \pm 0.07_{stat} \pm 0.95_{syst}$

  $b = 0.86 \pm 0.11_{stat} \pm 0.05_{syst}$







- scaling with Q^2/M_{VM}^2 observed
- weak W dependence of R
- MRT and FS04 underestimate data

J/ψ photoproduction at high $|t|$

- test pQCD based models: BFKL and DGLAP

BFKL:

Bartels, Forshaw, Lotter, Wüsthoff; Phys. Lett. B375 (1996) 301

Forshaw, Ryskin; Z.Phys. C68 (1995) 137

Enberg, Motyka, Poludniowski; Eur. Phys. J. C26 (2002) 219

– non-forward NLO BFKL kernel evaluated recently for $t \neq 0$

hep-ph/0502045

DGLAP: Gotsman, Levin, Maor, Naftali; Phys. Lett. B352 (2002) 37

- high $|t|$ domain little explored so far:

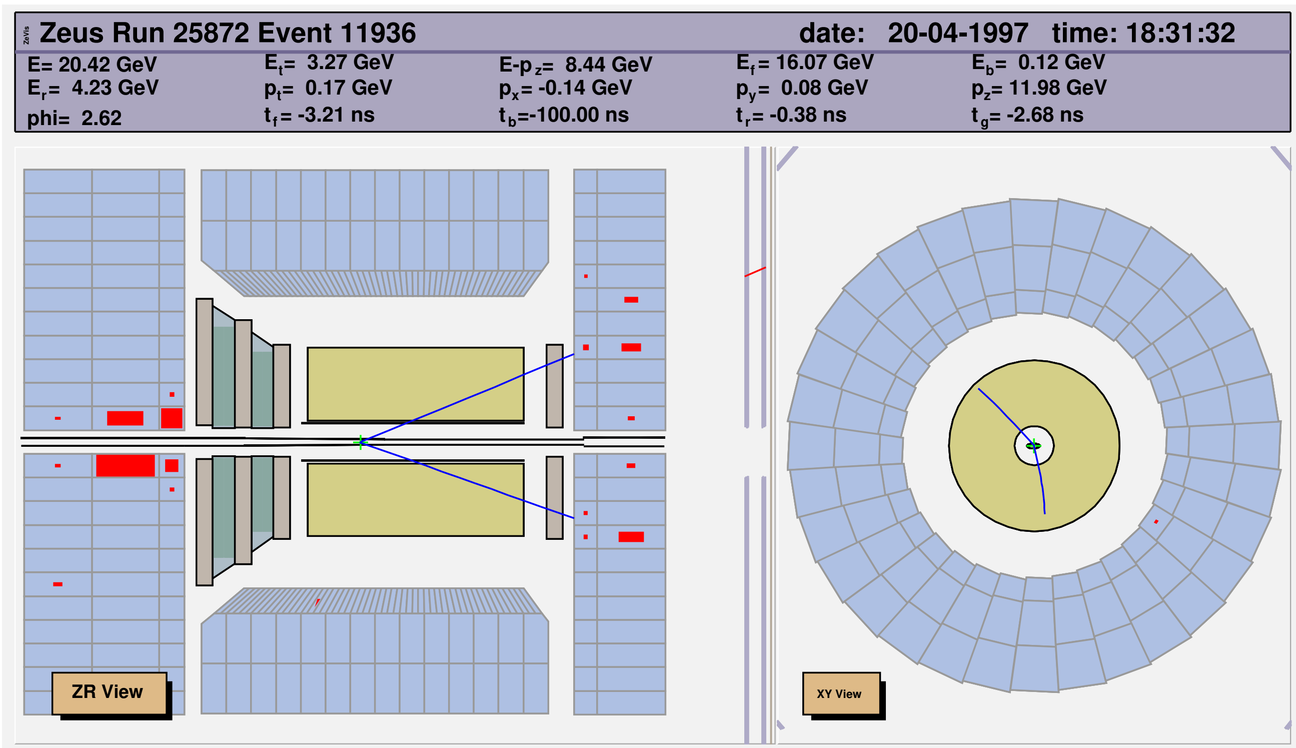
– H1 measurement for $|t| < 30\,\mathrm{GeV}^2$ Phys. Lett. B483, 23 (2000)

– ZEUS measurement with low statistics (~ 100 events) for $|t| < 6.5\,\mathrm{GeV}^2$ Eur. Phys. J. C26, 389 (2003)

- First ZEUS measurement now at large $|t|$ up to $20\,\mathrm{GeV}^2$

$\gamma p \to J/\psi Y$ - experimental signature

- scattered e undetected in CAL
- proton debris detected by FCAL and forward detectors
- two tracks reconstructed in CTD associated to muons
- nothing else in detector above 300 MeV

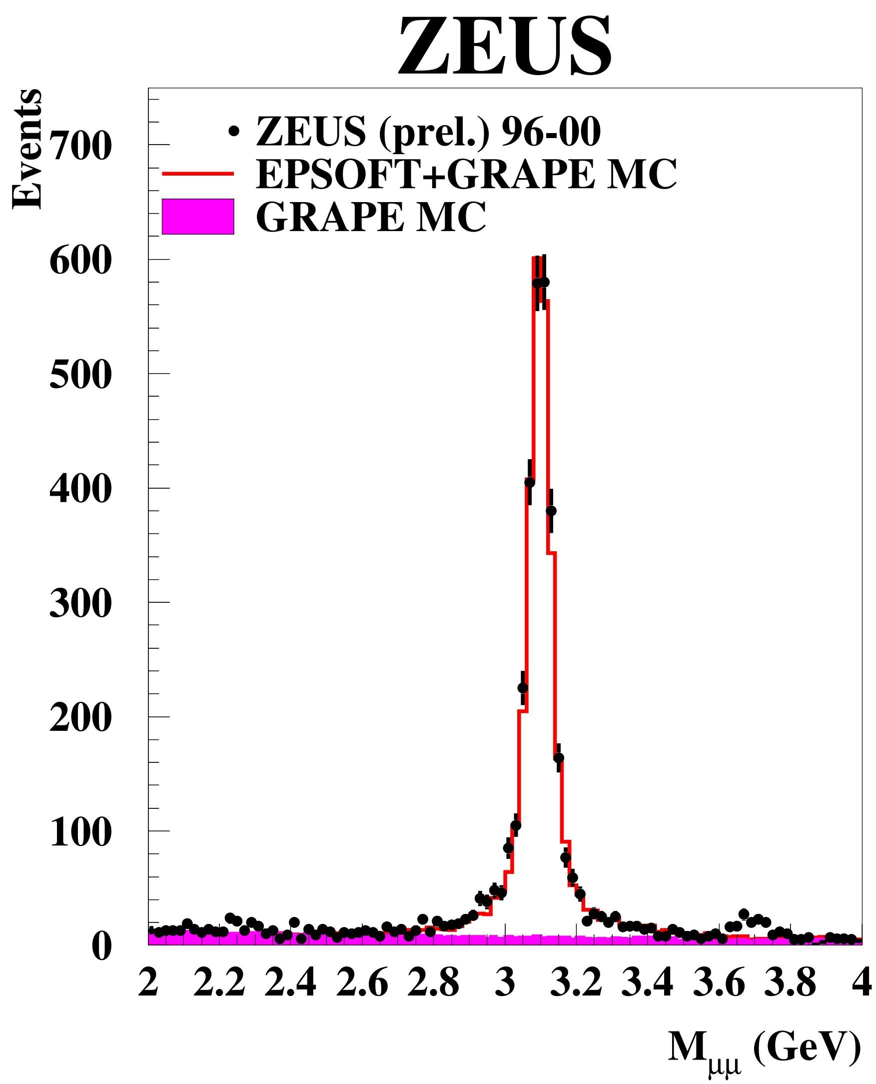


Extraction of J/ψ signal

- $J/\psi \to \mu^+\mu^-$ (BR=6%)
- data 1996 - 2000
- $\mathcal{L} = 112\,\mathrm{pb}^{-1}$
- ~ 3000 events
- $|t| > 1\,\mathrm{GeV}^2$
- $50 < W < 150\,\mathrm{GeV}$
- $z > 0.95$, where $z = \frac{p \cdot p_{J/\psi}}{p \cdot q}$
- $M_Y < 30\,\mathrm{GeV}$

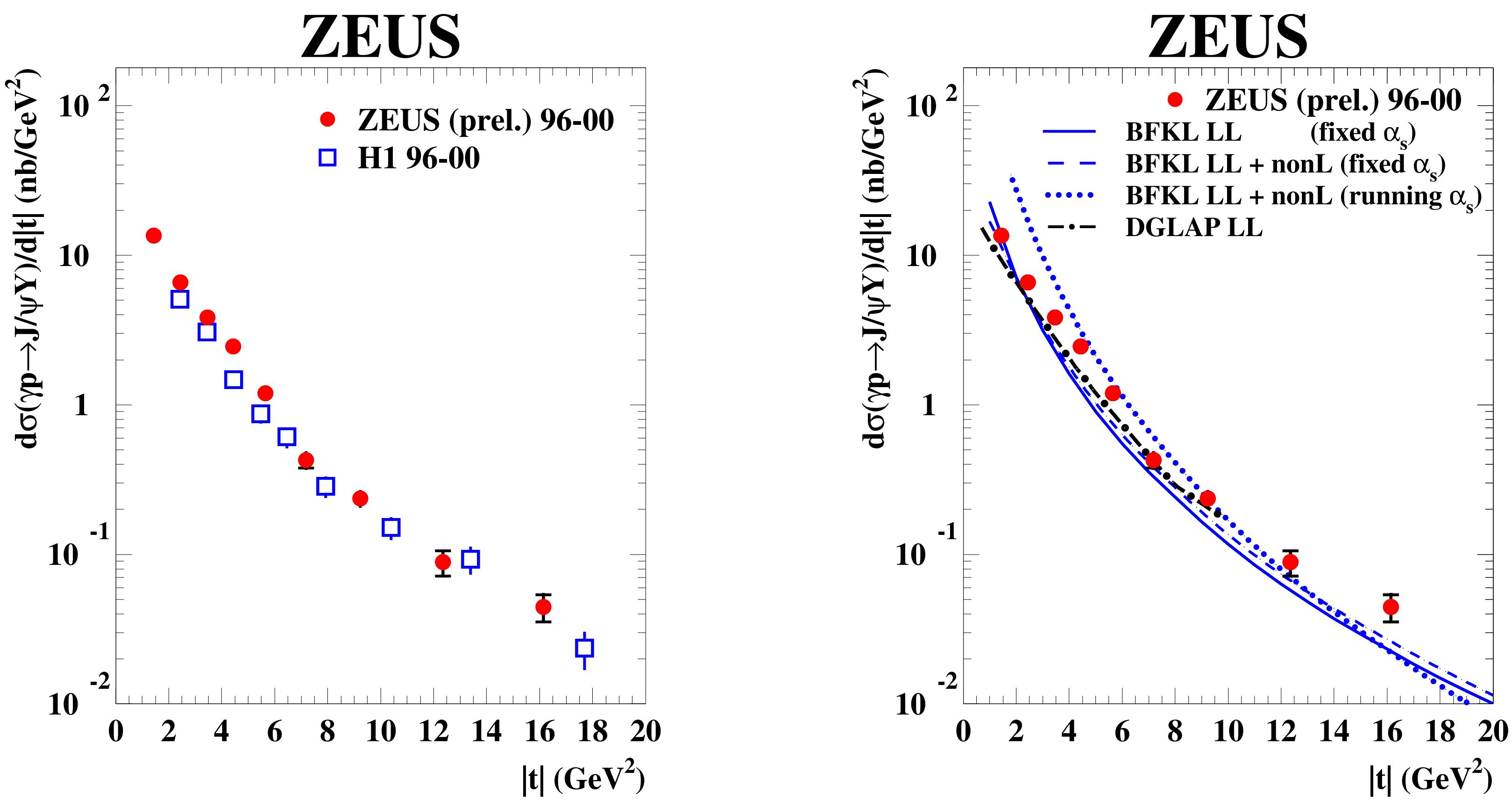
- background: $ep \to e\mu^+\mu^- Y$

subtracted bin by bin
for $|t| = 1\,\mathrm{GeV}^2$ 6% up to
$\sim 20\%$ for $|t| > 10\,\mathrm{GeV}^2$

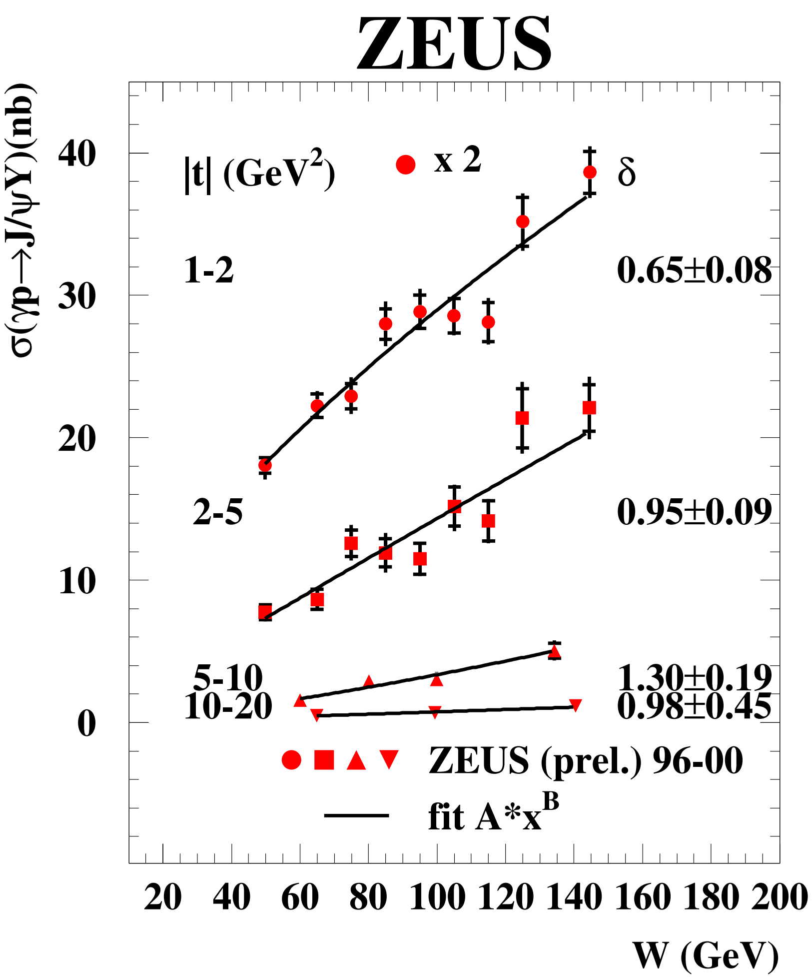


t dependence

- for lower $|t|$ ZEUS data higher than H1
- DGLAP and BFKL LL with fixed α_S describe general behaviour of data
- BFKL LL with running α_S is too steep



W dependence



- fit form: $\sigma \propto (W/90\,\text{GeV})^{\delta}$
- δ rising with $|t|$
- effective pomeron trajectory

$\delta = 4\alpha_{IP}(t) - 4$

$\alpha_{IP} = \alpha(0) + \alpha'(t)$

$\alpha(0) = 1.153 \pm 0.048_{stat} \pm 0.039_{syst}$

$\alpha' = -0.020 \pm 0.014_{stat} \pm 0.010\,\text{GeV}^{-2}_{syst}$

H1:

$\alpha(0) = 1.167 \pm 0.048_{stat} \pm 0.027_{syst}$

$\alpha' = -0.0135 \pm 0.0074_{stat} \pm 0.0051_{syst}\,\text{GeV}^{-2}$

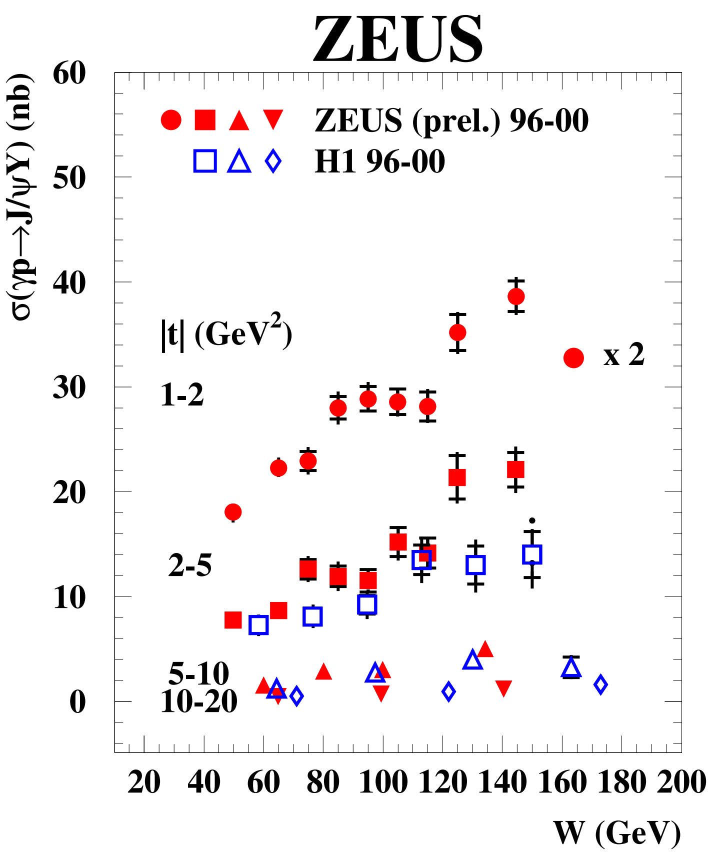
ZEUS: exclusive J/ψ

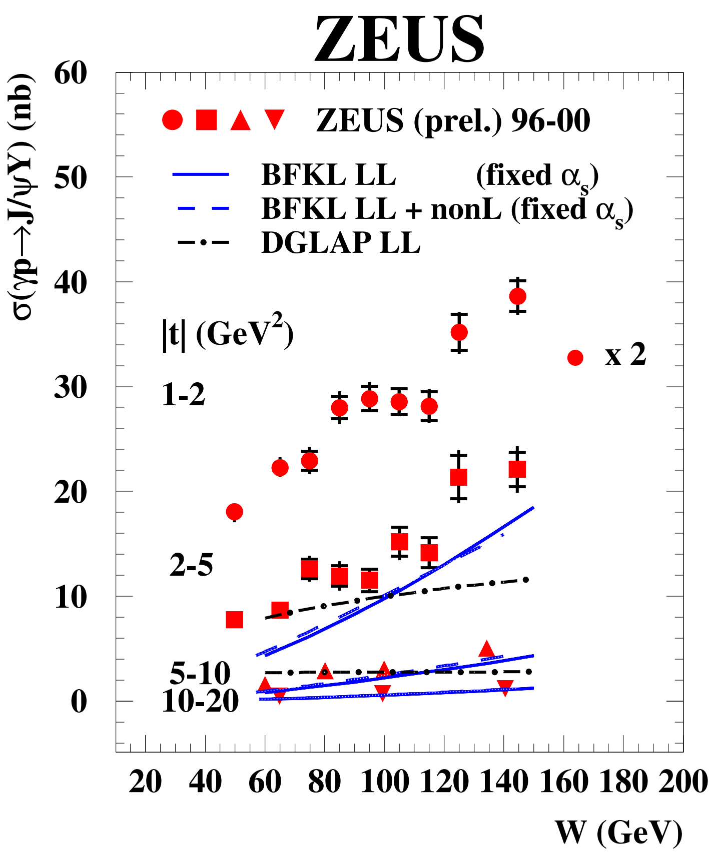
$\alpha(0) = 1.20 \pm 0.03_{stat}{}^{+0.01}_{-0.03}{}_{syst}$

$\alpha' = 0.07 \pm 0.05_{stat}{}^{+0.03}_{-0.04}{}_{syst}\,\text{GeV}^{-2}$

W dependence

- ZEUS data higher than H1 measurement
- DGLAP does not describe rise with W
- BFKL reproduces general behaviour of data





Summary

$ep \longrightarrow e\phi p$

- measured as a function of Q^2, W and t
- $\sigma_{\gamma p} \propto W^{\delta}$: $\delta \approx 0.4 \rightarrow$ between a soft and hard regime
- t distribution is well described by $exp(-bt)$
- δ and b are scaling as a function of $Q^2 + M_{VM}^2$
- cross section as a function of Q^2 cannot be fitted with a single power over whole Q^2 range
- σ_L and σ_T: extracted separately using measured value of R
  – for both a different Q^2 dependence is observed
- MRT model does not reproduce the Q^2 dependence, while the FS04 does

$ep \longrightarrow e\phi J/\psi Y$:

- measured by ZEUS for $|t|$ up to 20 GeV^2 for the first time
- $\sigma_{\gamma p} \propto W^{\delta}$: $\delta \approx 1.0$
- no significant t dependence of δ is observed
- pQCD models (BFKL and DGLAP) quantitatively describe the data