Measurements of DVCS and High $|t|$ Vector Meson Production at HERA

Duncan Brown

DESY, Hamburg

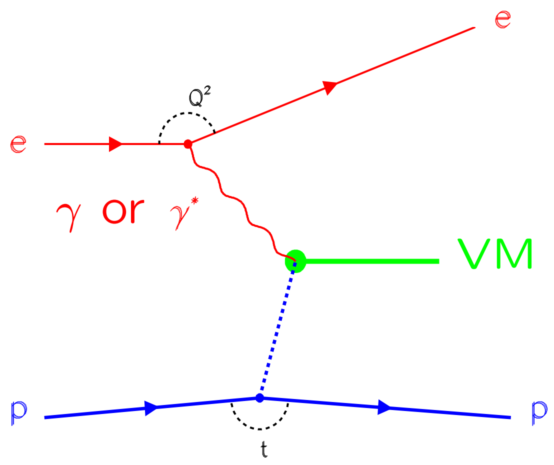
On Behalf of the H1 and ZEUS Collaborations

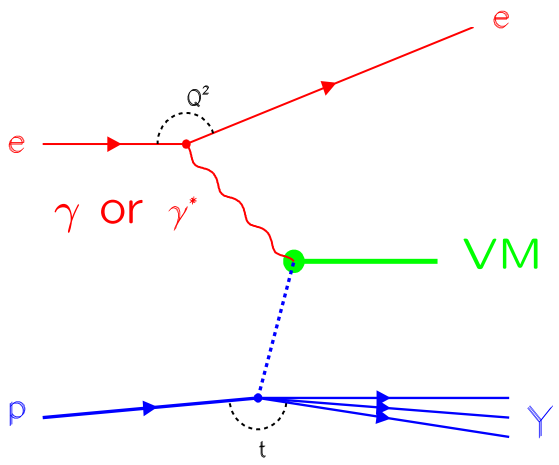
Moriond Conference on QCD and High Energy Hadronic Interactions

March 27 2003

Diffractive Vector Meson Production at HERA

proton elastic	proton dissociative





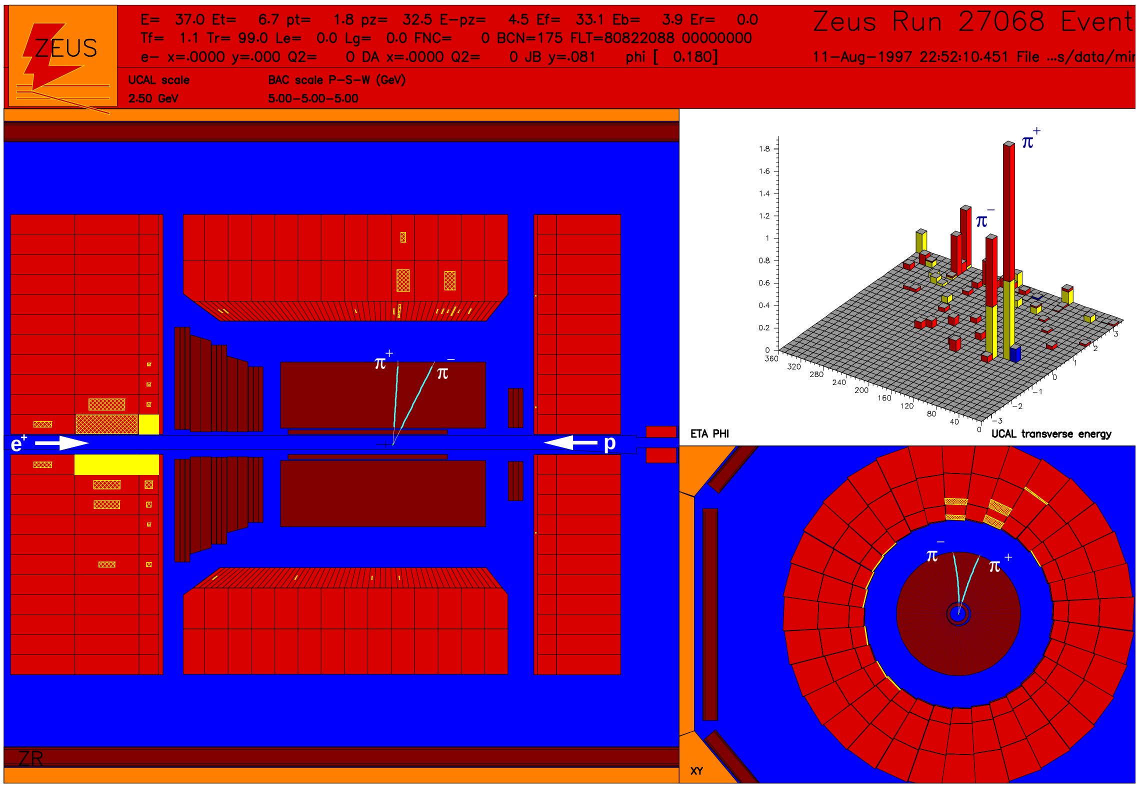
Low $|t|$ — Dominates at Large $|t|$.

Q^2	γ^* Virtuality	$\sim 0 < Q^2 < 100\ \mathrm{GeV}^2$
$W_{\gamma p}$	CM Energy of $\gamma^* p$ system	$20 < W_{\gamma p} < 290\ \mathrm{GeV}$
t	(4-mom. transfer at p vertex)^2	$\sim 0 < \|t\| < 30\ \mathrm{GeV}^2$
VM	Vector Meson	$\rho^0,\ \omega,\ \phi,\ J/\psi,\ \psi',\ \Upsilon$

$\Rightarrow$ Simultaneous Probe of Different Kinematical Quantities.

Large $|t|$ Experimental Signature

Large $|t|$ Photoproduction Events



- Incoming Lepton scatters through small angle

⇒ No Scattered Lepton in Main Detectors

- High Energy Proton dissociates.

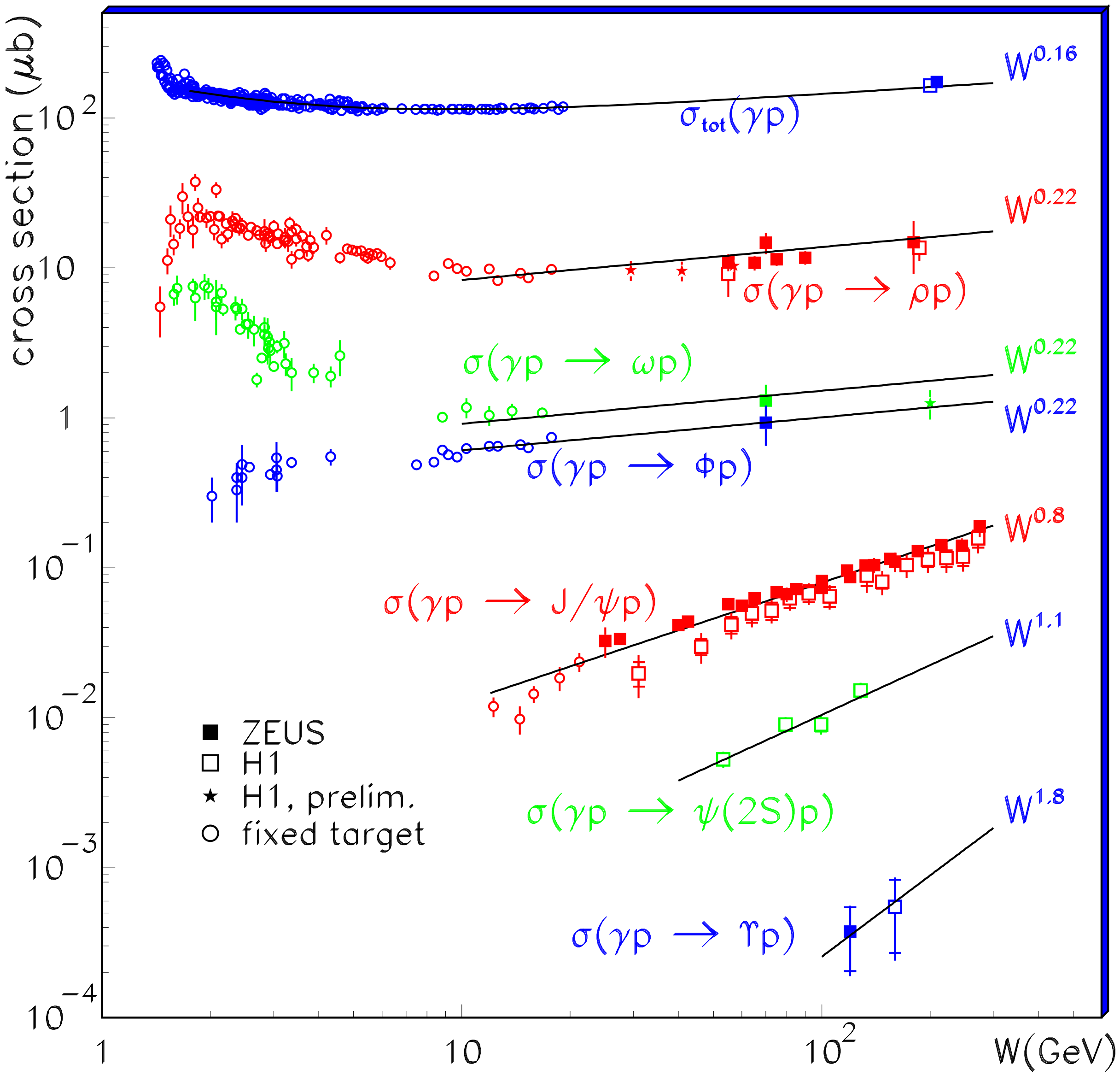
⇒ Energy deposits in forward detectors.

- Can reconstruct $|t|$ from two large p_T tracks

⇒ ρ^0 candidate at large |t|
in photoproduction.

Elastic Photoproduction $\gamma p \to V p$

$Q^2 \approx 0$, $|t| \approx 0$ $\Rightarrow M_V$ provides hard scale



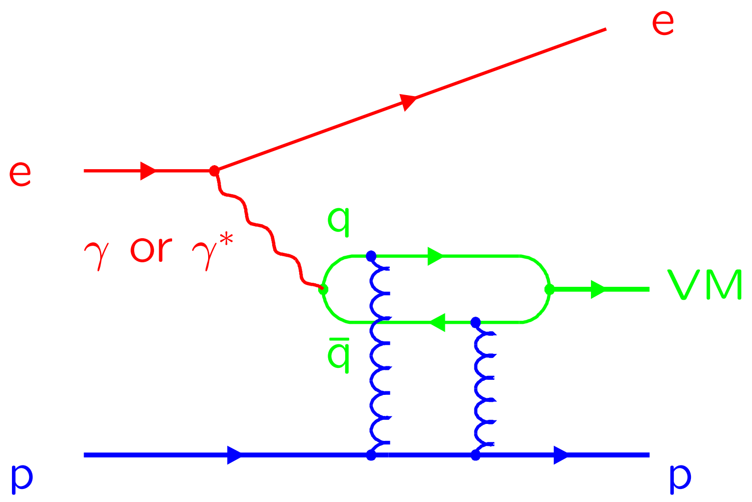
- Light Vector Mesons $\sigma \sim W^{\delta}$, $\delta = 0.22$

  $\Rightarrow$ Predicted by soft pomeron model

- Steeper rise in the J/ψ cross section

Diffractive VM Production in pQCD

- Two Gluon Exchange



Meson WF?

$\Rightarrow$ Calculations require hard-scale M_V^2,Q^2: what about $|t|$?

- Large $|t|$ Predictions using BFKL ($W_{\gamma p}^2 \gg |t|$)

$\Rightarrow$ Perturbative series in α_s

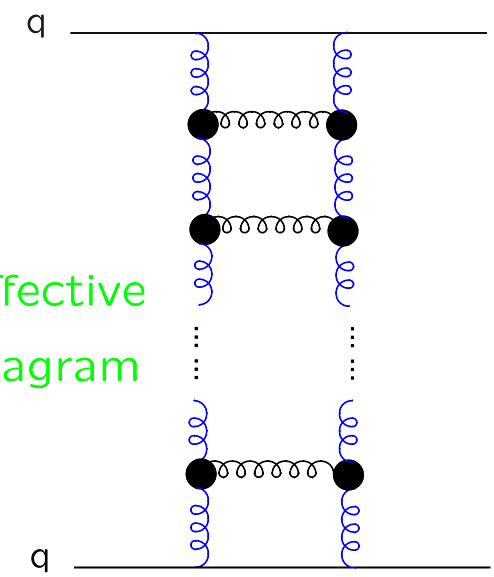
$\Rightarrow$ Reggeized Gluon Ladder

$\Rightarrow$ BFKL iteration adds

a rung to the ladder.

Effective

Diagram



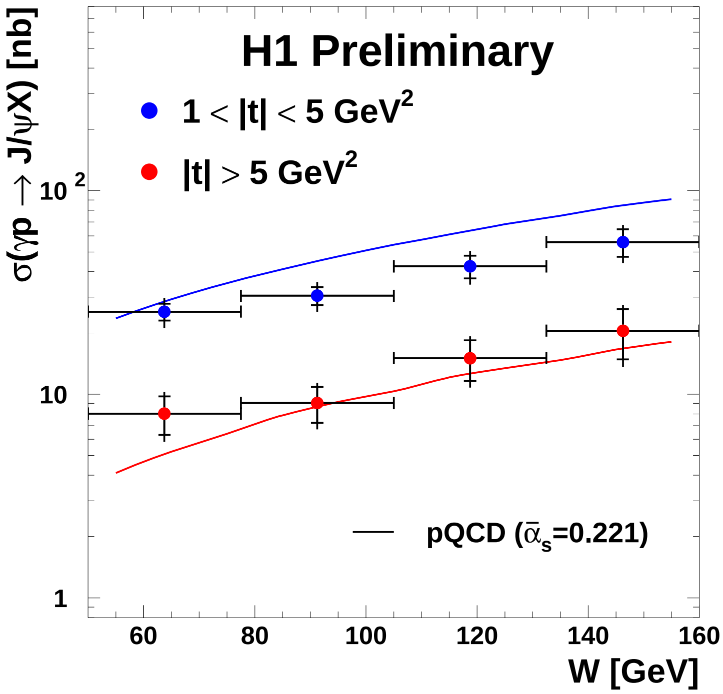
- DGLAP Predictions

$\Rightarrow$ Ordered momenta along gluonic ladder

$\Rightarrow$ Could play a role for $|t| < M_V^2$ (heavy VMs?)

Heavy vector mesons: J/ψ production at Large $|t|$

- Similar rise ($\delta \sim 1$) as for J/ψ at low $|t|$



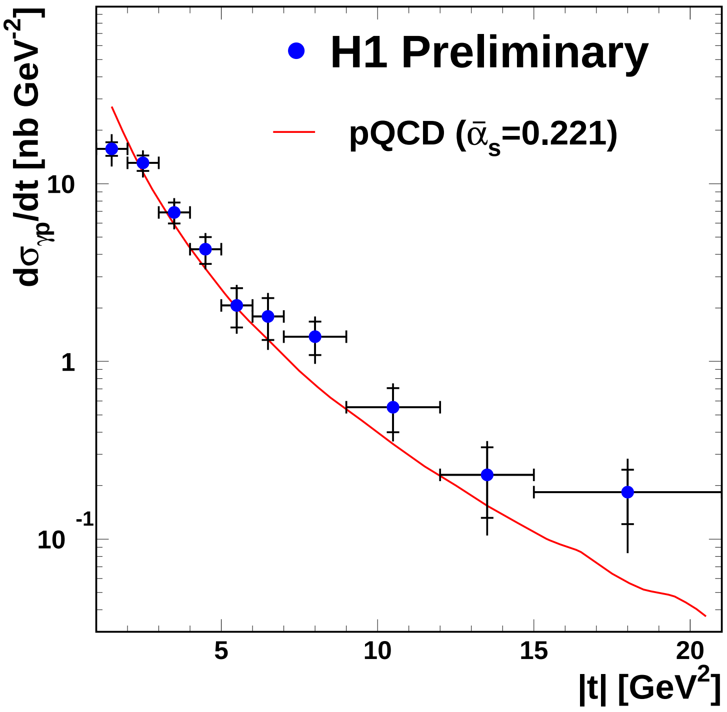
H1 Collaboration

$Q^2 < 1\,\mathrm{GeV}^2$

$50 < W < 160\,\mathrm{GeV}$

$19\,\mathrm{pb}^{-1}$

$1.0 < |t| < 21.0\,\mathrm{GeV}^2$

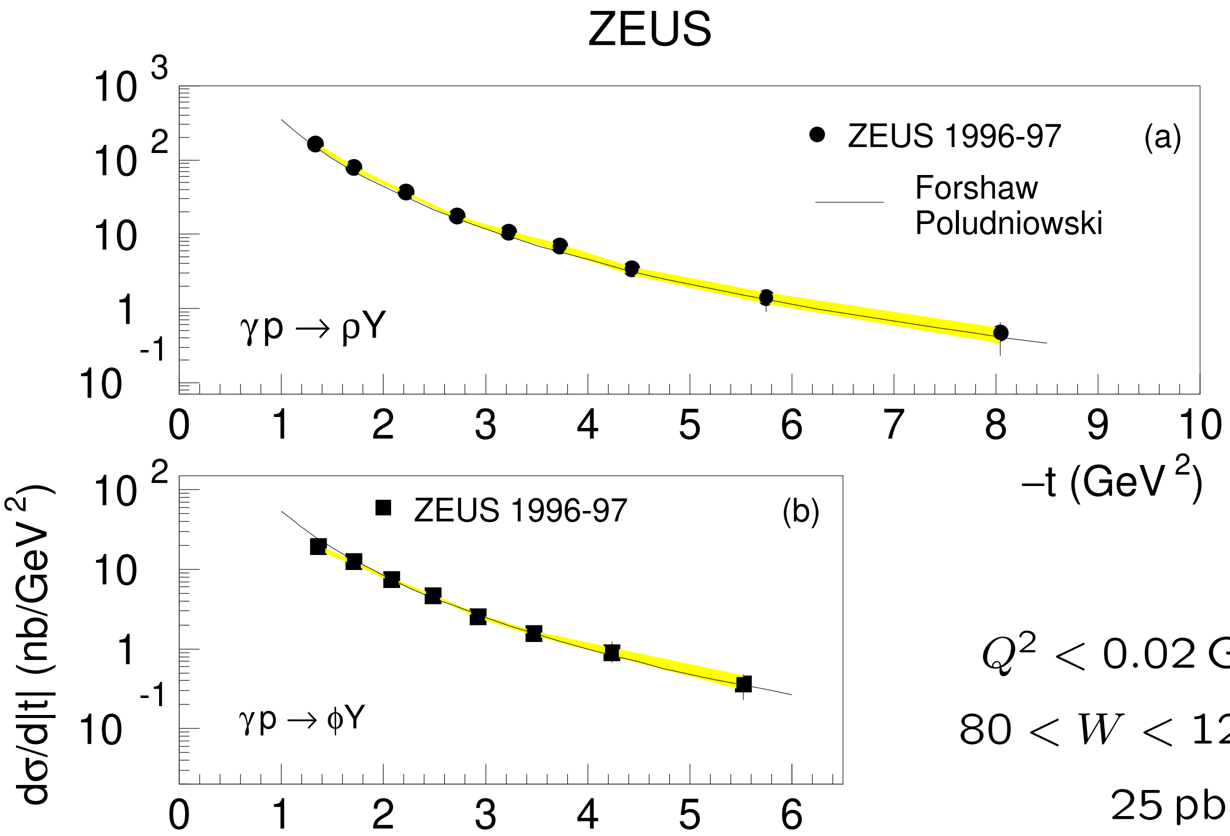


BFKL Model ($\bar{\alpha}_s \sim 0.2$) describes behaviour

($\bar{\alpha}_s$ treated as a free parameter in model)

Light Vector Meson Production at High $|t|$

- Proton dissociative photoproduction of ρ, ϕ



$Q^2 < 0.02\,\mathrm{GeV}^2$

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

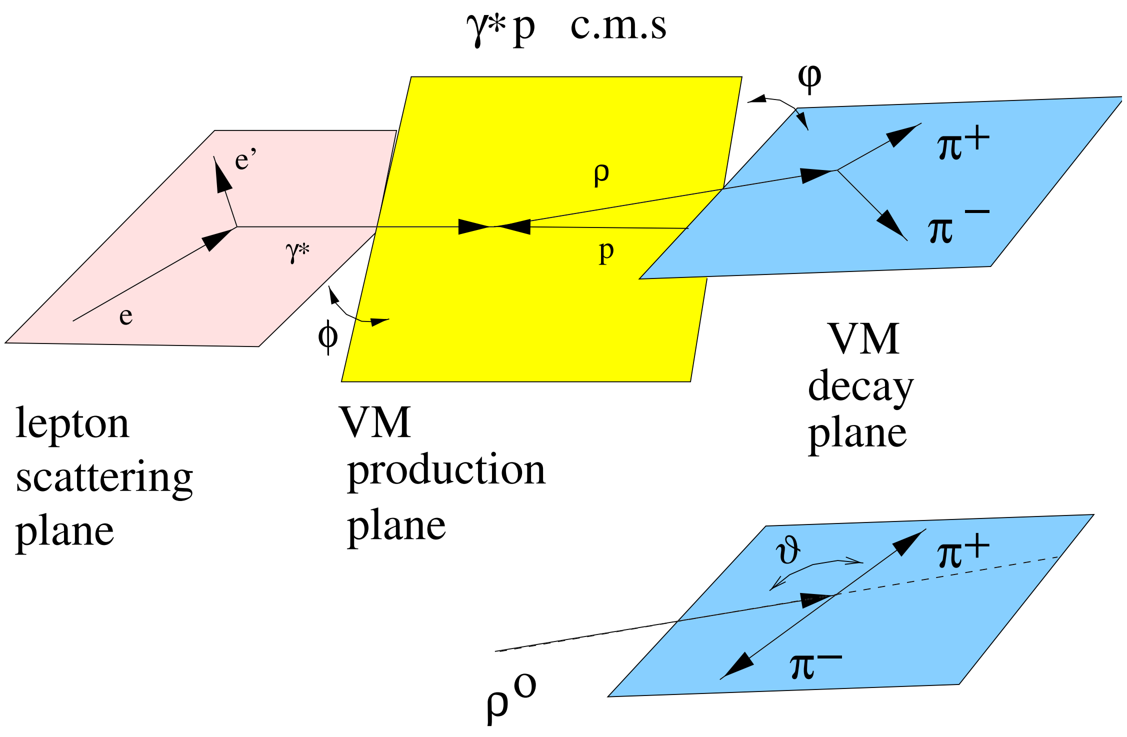
$25\,\mathrm{pb}^{-1}$

- Large |t| Dependence $\propto |\mathrm{t}|^{\mathrm{n}}$ with $n \sim -3$ for both ρ and ϕ
- BFKL Model gives good description

$\Rightarrow$ Simple Non-Relativistic Meson WF might already be sufficient at large $|t|$

Helicity Studies

Define three angles in the Helicity system



Normalised decay angular distribution (W) is a function of $\cos(\vartheta), \varphi, \Phi$

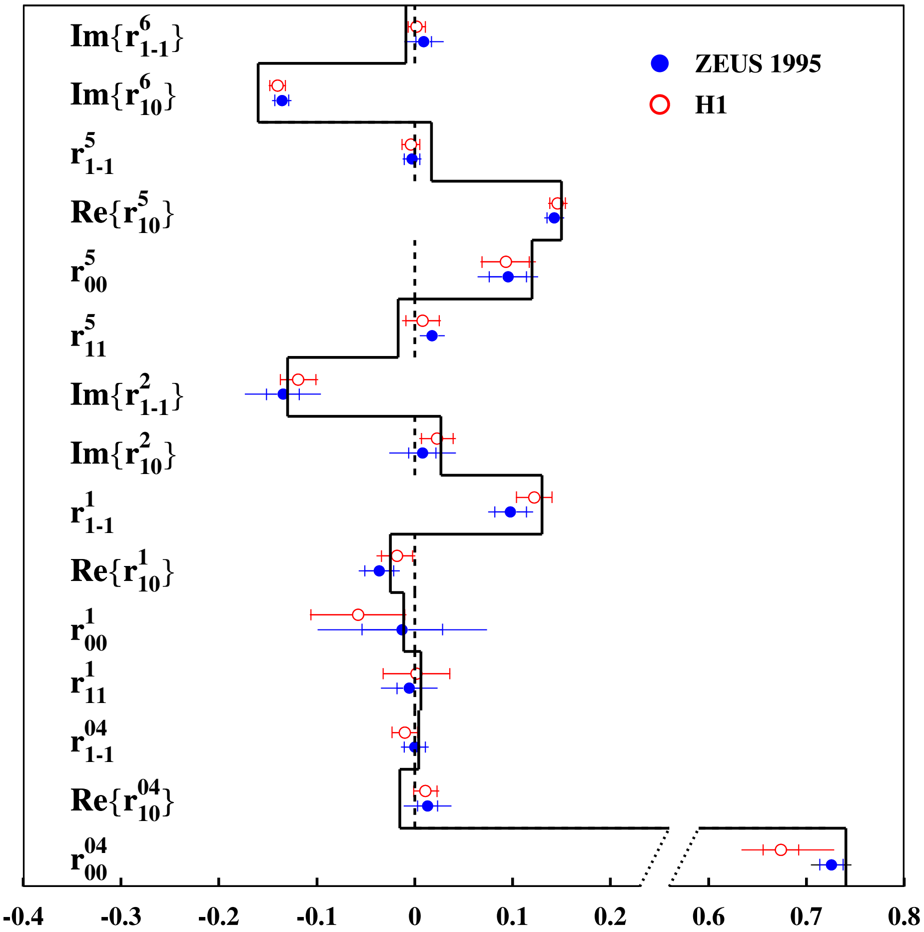
Written as a function of 15 independent linear combinations (r) of spin density matrix elements

For: SCHC, NPE:

expect 5 combinations to be non-zero.

Elastic Electroproduction $\gamma^* p \longrightarrow \rho p$

Combinations of spin density matrix elements



r^5_{00}: $\rightarrow$ Production of Longit. Pol. Vector Meson

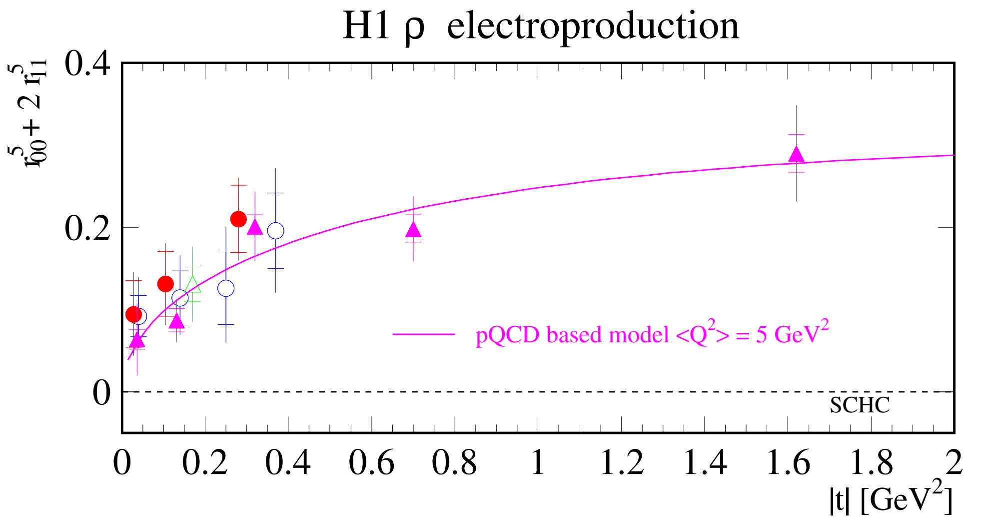
D.Yu.Ivanov,R.Kirschner Phys. Rev. D58 (1998) 114026

• pQCD model (solid line) predicts violation
• Wavefunction considers momentum distribution of quarks in meson.

Electroproduction of ρ at high $|t|$

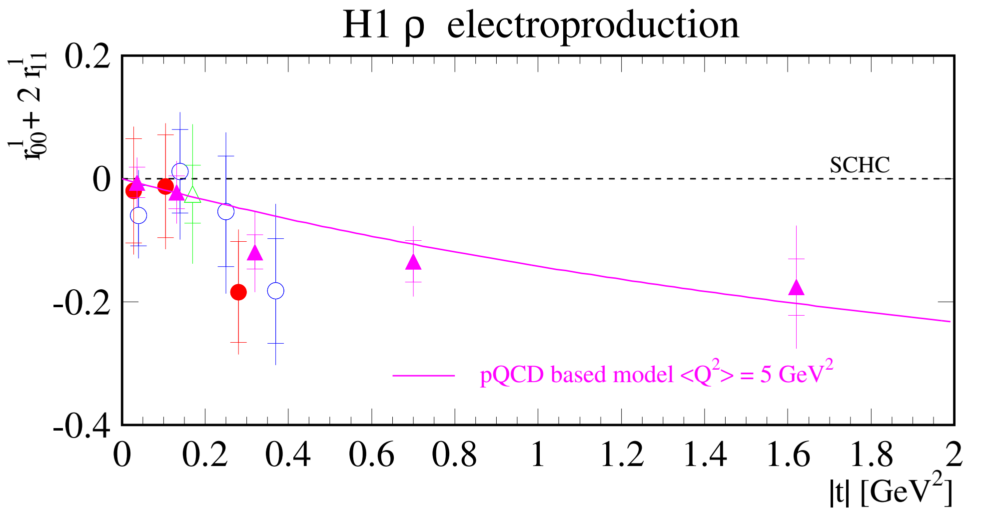
H1 Measurement:

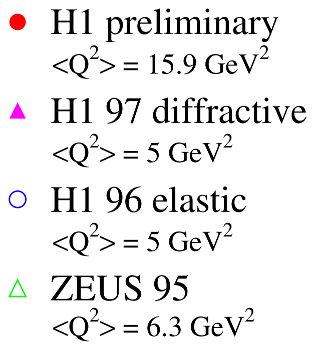
$2.5 < Q^2 < 60\,\mathrm{GeV}^2$, $40 < W < 120\,\mathrm{GeV}$, $6\,\mathrm{pb}^{-1}$



pQCD expects $r^5_{00} \propto \sqrt{t}$ and $r^5_{11} \propto \sqrt{t}$

Violation increases with t as expected





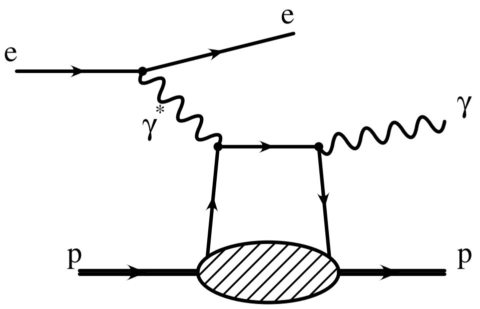
pQCD expects $r^1_{00} \propto -|t|$ and $r^1_{11} \propto |t|$

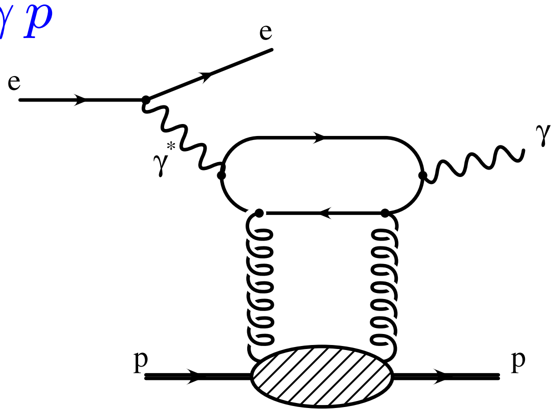
$\propto |t|$ as expected

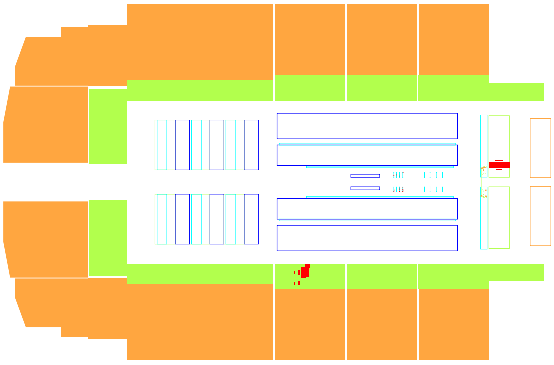
r^1_{00} dominates (depends on single flip T_{01})

Deeply Virtual Compton Scattering

$$e\,p \rightarrow e\,\gamma\,p$$







H1 Collaboration

$2 < Q^2 < 20$ GeV^2

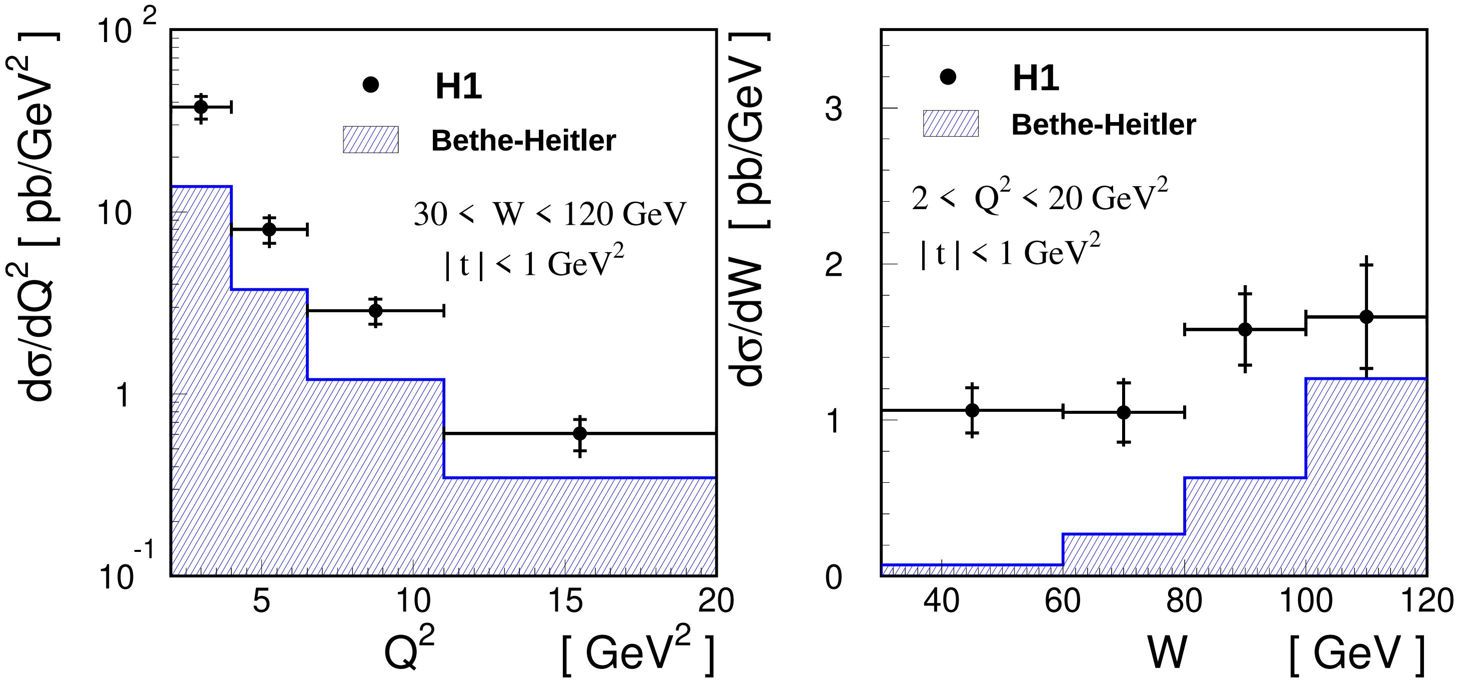
$30 < W_{\gamma p} < 120$ GeV

$|t| < 1.0$ GeV^2

$8\,\mathrm{pb}^{-1}$

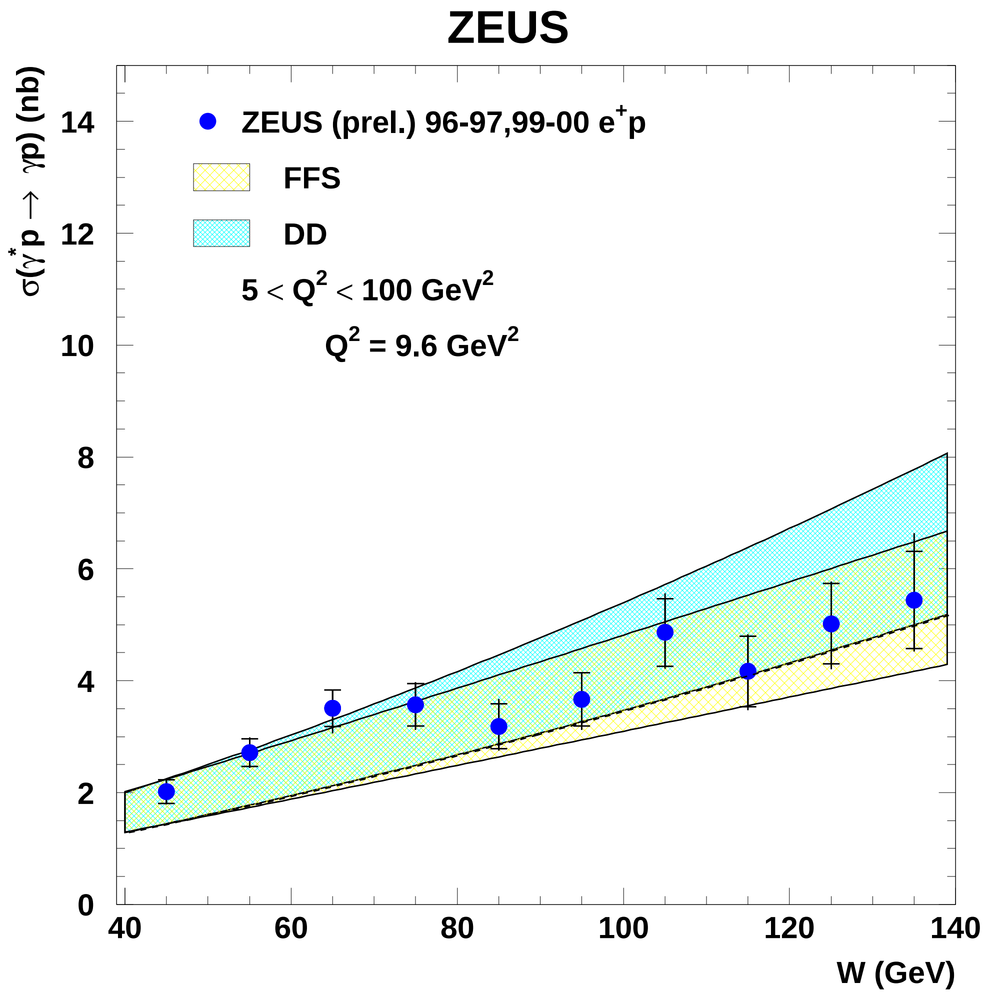
Ratio DVCS / Bethe-Heitler $\Rightarrow$ forward photons

Integration over ϕ $\Rightarrow$ Interference term ~ 0



Deeply Virtual Compton Scattering

e^+p Measurements:



ZEUS collaboration

$5 < Q^2 < 100\,\mathrm{GeV}^2$

$40 < W < 140\,\mathrm{GeV}$

$e^+p = 95\,\mathrm{pb}^{-1}$

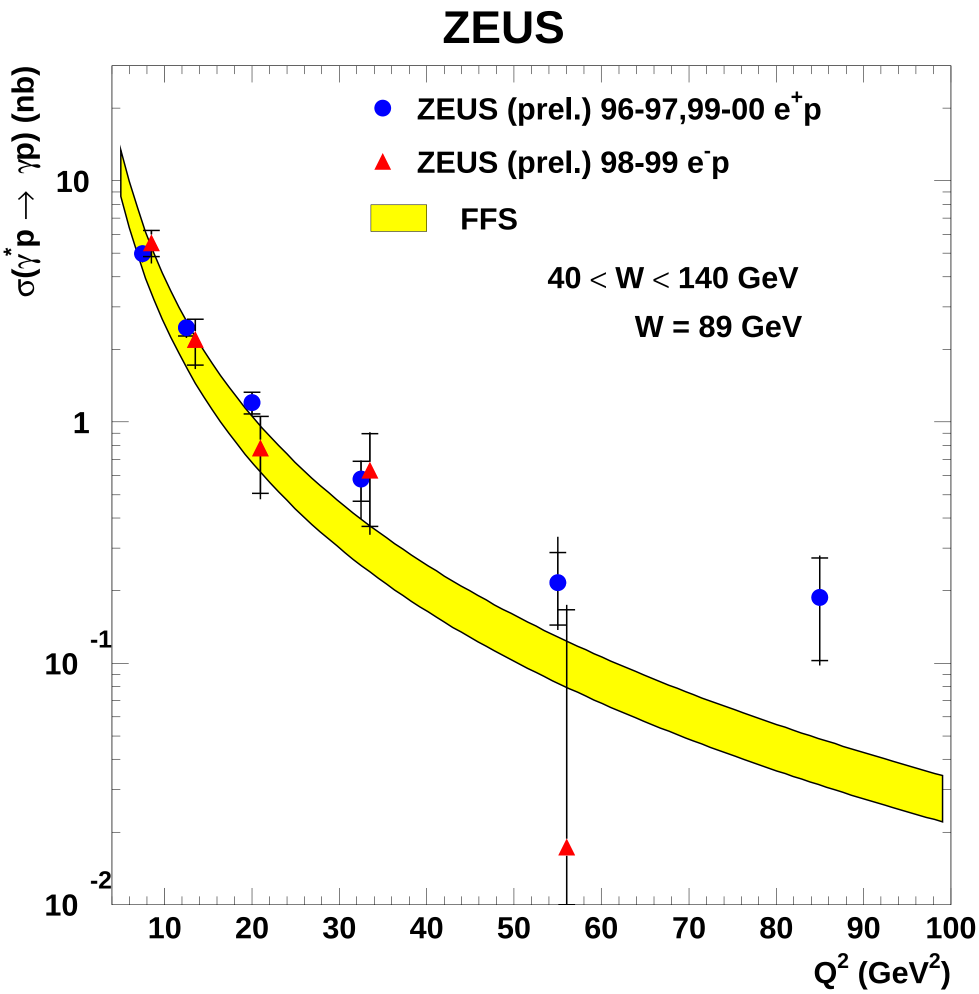
and $e^-p = 17\,\mathrm{pb}^{-1}$

- In both models: soft and hard contributions
- Bands vary assumed $|t|$ dependence

- ZEUS Fit $W^\delta \Rightarrow \delta = 0.78 \pm 0.10$

$\Rightarrow$ Similar rise as J/ψ in Photoproduction

DVCS and Vector Meson Production



- pQCD expects $\sigma \sim 1/Q^4$

  ZEUS Fit $\propto (Q^2)^{-n} \Rightarrow n = 1.47 \pm 0.07$

For Comparison: ρ Electroproduction

- pQCD expects $\sigma \propto \alpha_s^2(Q^2)/Q^6\ [xg(x,Q^2)]^2$

  H1 Fit $\propto (Q^2 + m_\rho^2)^{-n} \Rightarrow n = 2.60 \pm 0.04$

Conclusions

- pQCD Predictions already giving Good Agreements for Large M_V^2, Q^2 and/or $|t|$
- Measurements of Diffractive Vector Meson Production and DVCS are providing insight:
  - Meson Wavefunctions
  - Structure of Gluonic Exchange
- Diffractive Vector Meson Production Measurements at Large $|t|$
  - Described by (LO) BFKL models
- Future Increase in Statistics (e.g Large Q^2)

$\Rightarrow$ Higher Precision Tests over Larger Kinematic Region