Diffractive Vector Meson Production and DVCS at HERA

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Overview of this Presentation

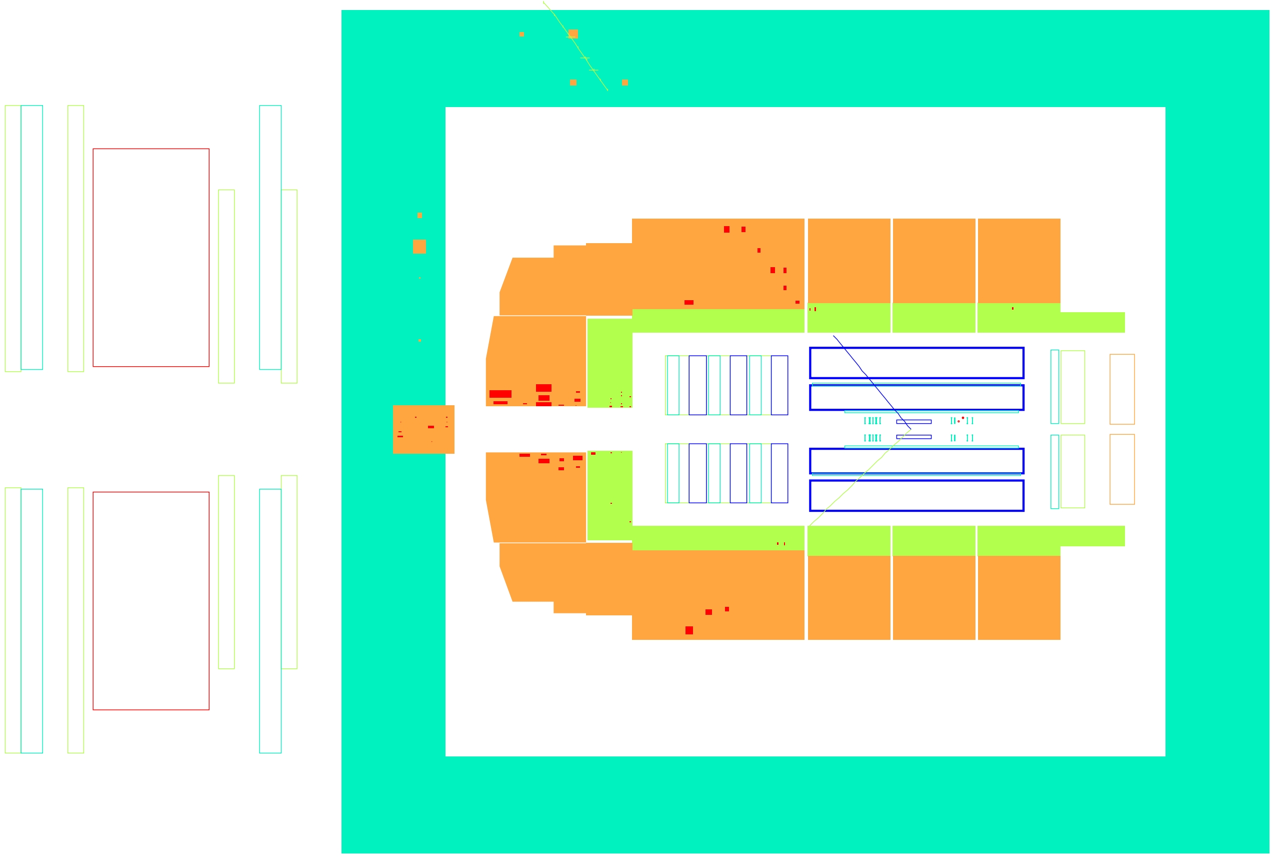
1. Introduction to HERA ep Collider.
2. Diffractive Vector Meson Production
   - At HERA.
   - Theoretical Models.
3. Cross Section Measurements.
   - Elastic Vector Meson Production
   - Proton Dissociative Vector Meson Production at Large |t|
   - Electroproduction of Vector Mesons
4. Helicity Studies
   - Electroproduction of ρ at Large |t|
5. Deeply Virtual Compton Scattering.
   - At HERA.
   - Theoretical Models.
6. Conclusions

The HERA ep Collider

$$e^{\pm} \quad \Rightarrow \quad \sqrt{s} = 300/320 \text{ GeV} \Leftarrow \quad p$$

27.5 GeV — 820/920 GeV

H1 and ZEUS Detectors:

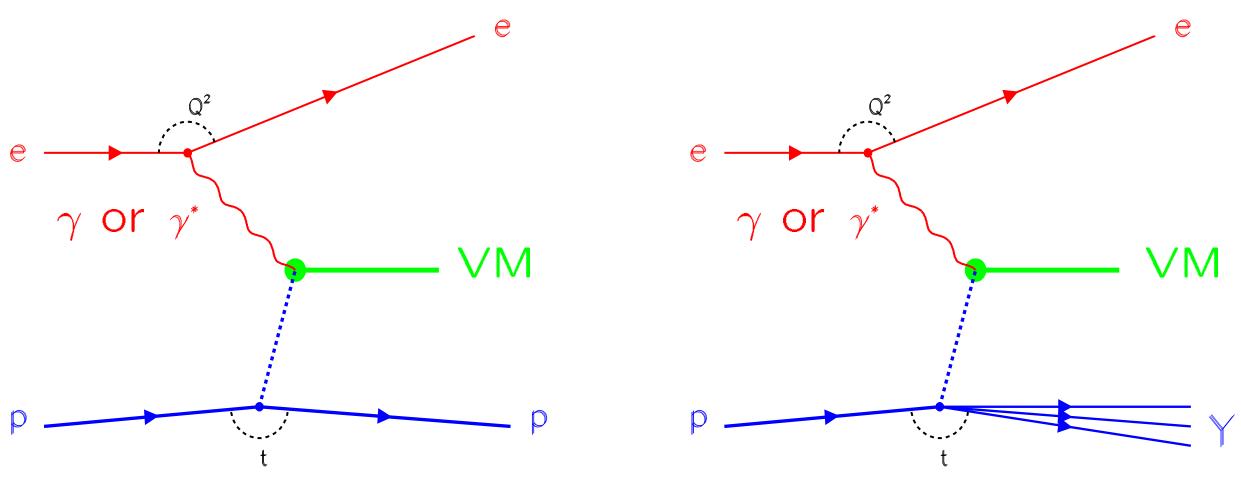


Two identified tracks with proton dissociation.

- HERA has provided $\sim 130\,\mathrm{pb}^{-1}$ since 1994
- About $68\,\mathrm{pb}^{-1}$ since mid-1999

Diffractive Vector Meson Production at HERA

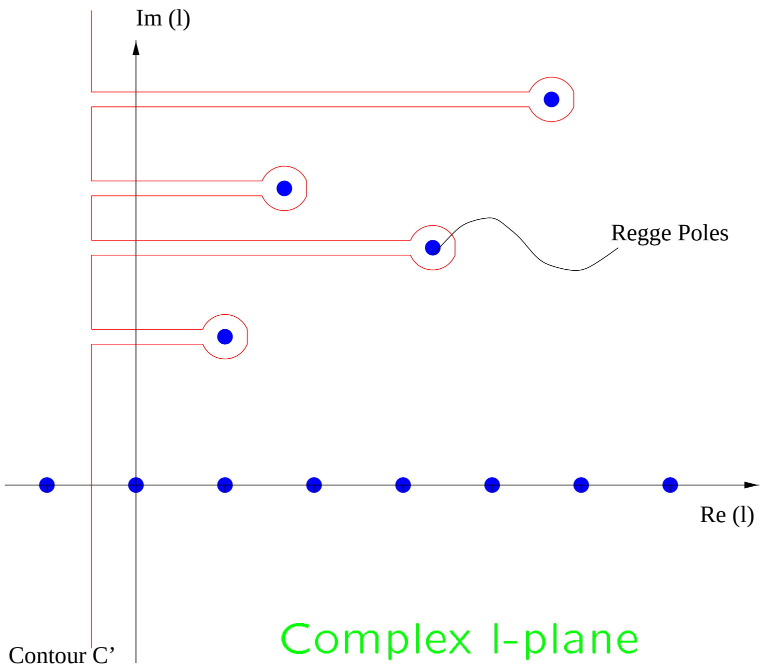
proton elastic | proton dissociative



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	$\sim 0 < \lvert t\rvert < 20\,\mathrm{GeV}^2$
VM	Vector Meson	$\rho^0,\ \omega,\ \phi,\ J/\psi,\ \psi',\ \Upsilon$

Theoretical Models

Regge Theory



Complex l-plane

Scattering Amplitude

$$A(s,t) \sim s^{\alpha(t)}$$

Hadron-Hadron scattering

$\Rightarrow \quad \alpha(t) = 1.08 + 0.25\ t$

HERA centre-of-mass range

$\sigma \sim W_{\gamma p}^{\delta}$ with $\delta \approx 0.22$

t-dependence

$d\sigma/d|t| \propto e^{-b|t|}$

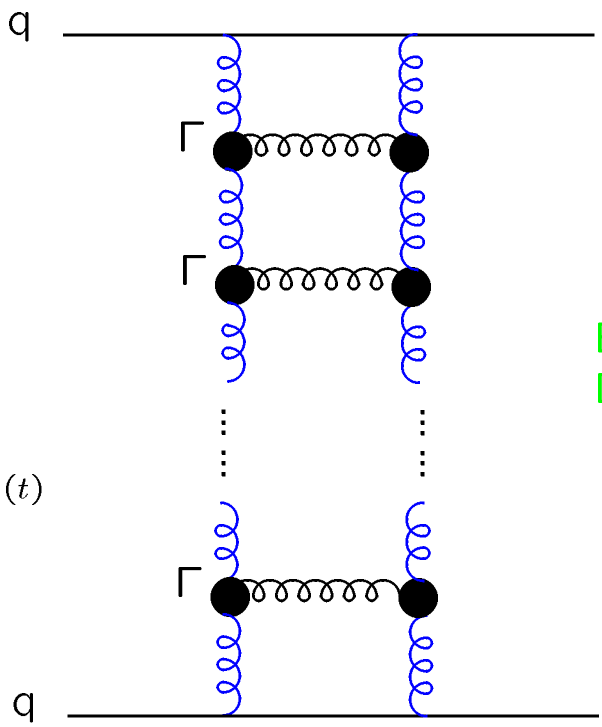
BFKL Formulism

Perturbative series in α_s

Reggeized Gluon Ladder

BFKL iteration adds a rung to the ladder

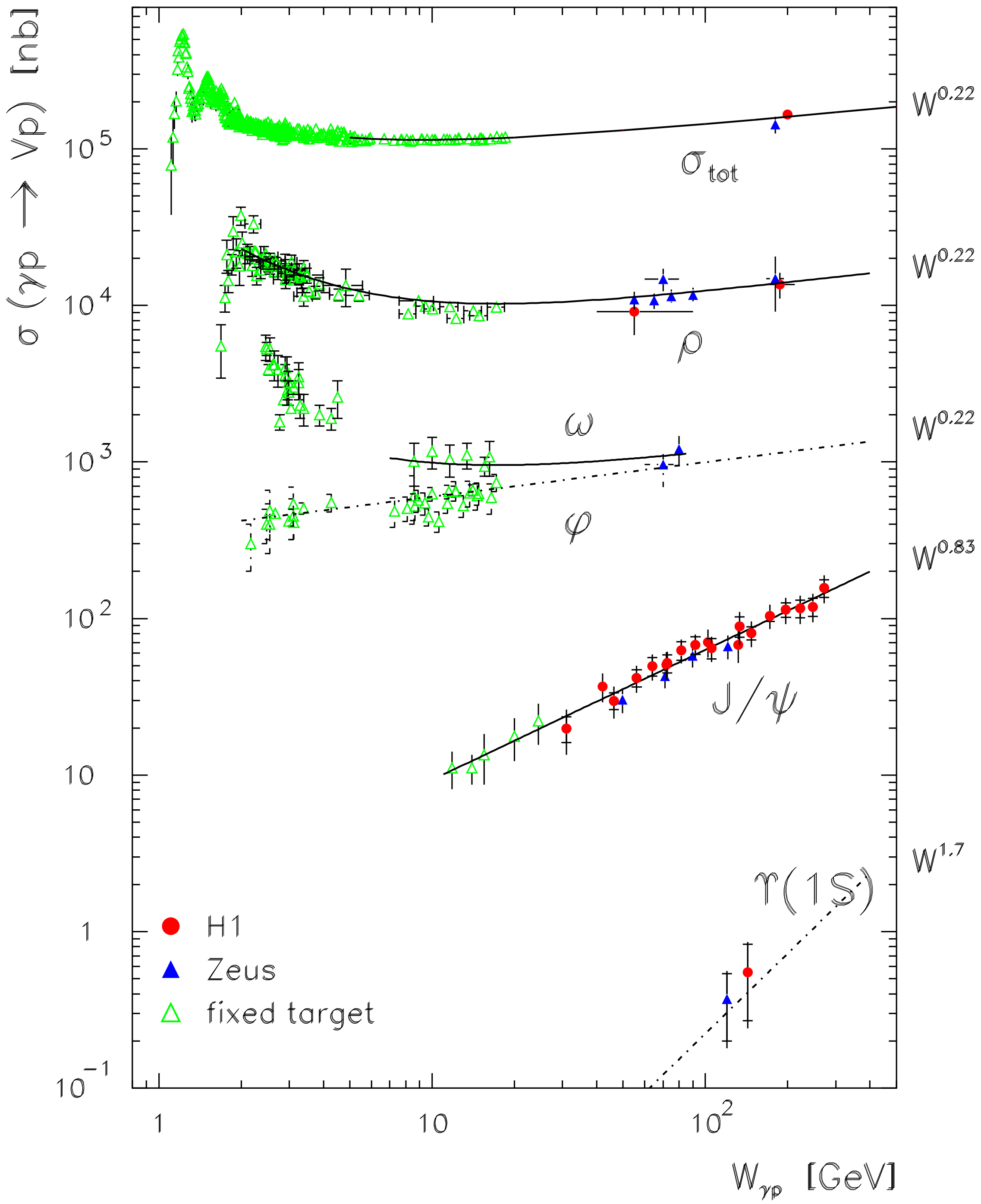
Scattering Amplitude $\sim s^{\alpha_P(t)}$ where $\alpha_P(t) = 1 + 4\bar{\alpha}_s\ ln2$



Effective Diagram

Elastic Photoproduction $\gamma p \to V p$

$Q^2 \approx 0$, $|t| \approx 0$



$\Rightarrow$ Steeper rise in the J/ψ cross section

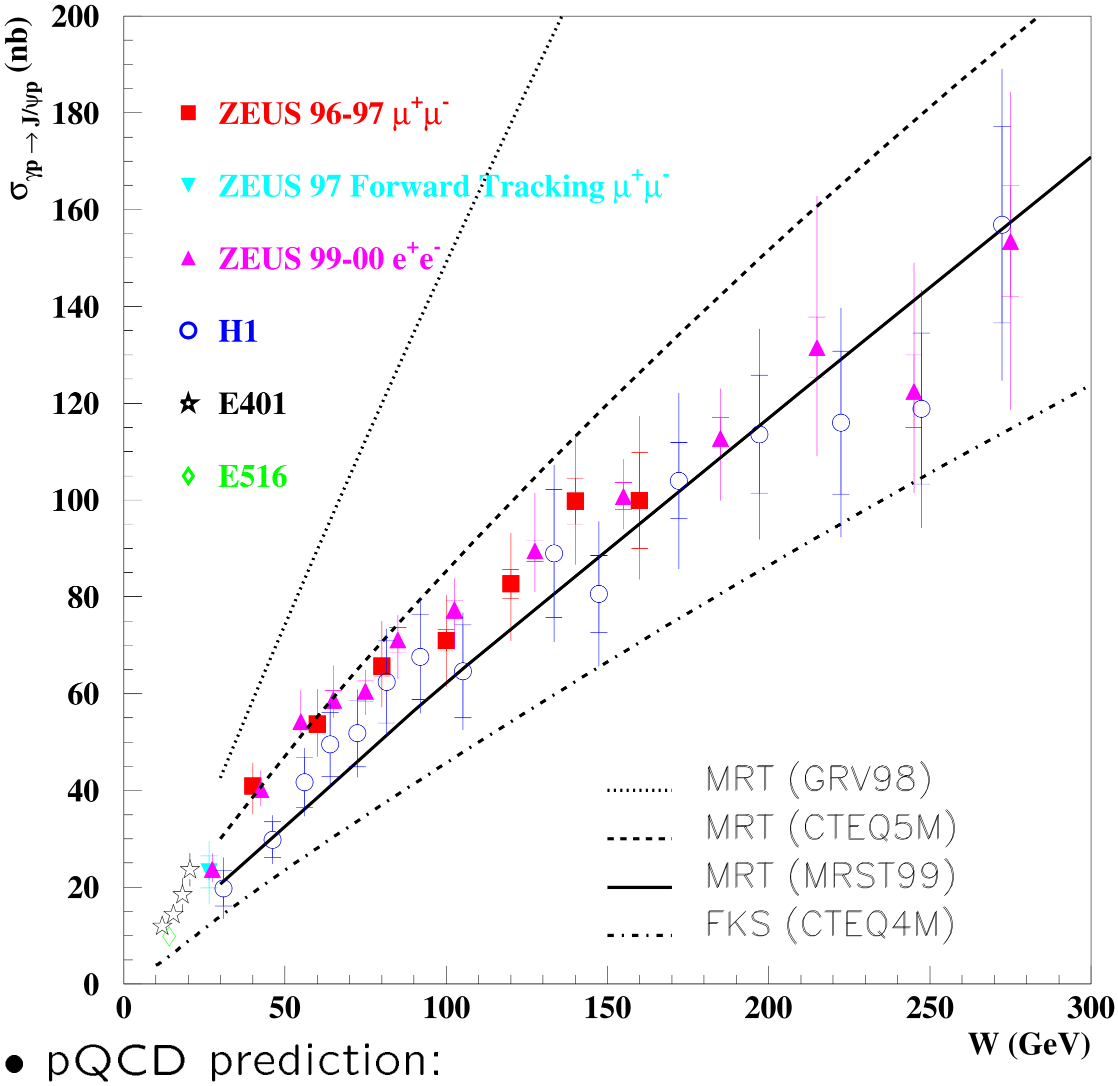
Elastic Photoproduction $\gamma p \to J/\psi\, p$

$Q^2 \approx 0$, $|t| \approx 0$ $\Rightarrow$ M_{VM} provides hard scale

Preliminary ZEUS data

$Q^2 < 1\,\mathrm{GeV}^2$ $\quad$ $38\,\mathrm{pb}^{-1}$ $(J/\psi \to \mu^+\mu^-)$

$20 < W_{\gamma p} < 290\,\mathrm{GeV}$ $\quad$ $48\,\mathrm{pb}^{-1}$ $(J/\psi \to e^+e^-)$



- pQCD prediction:

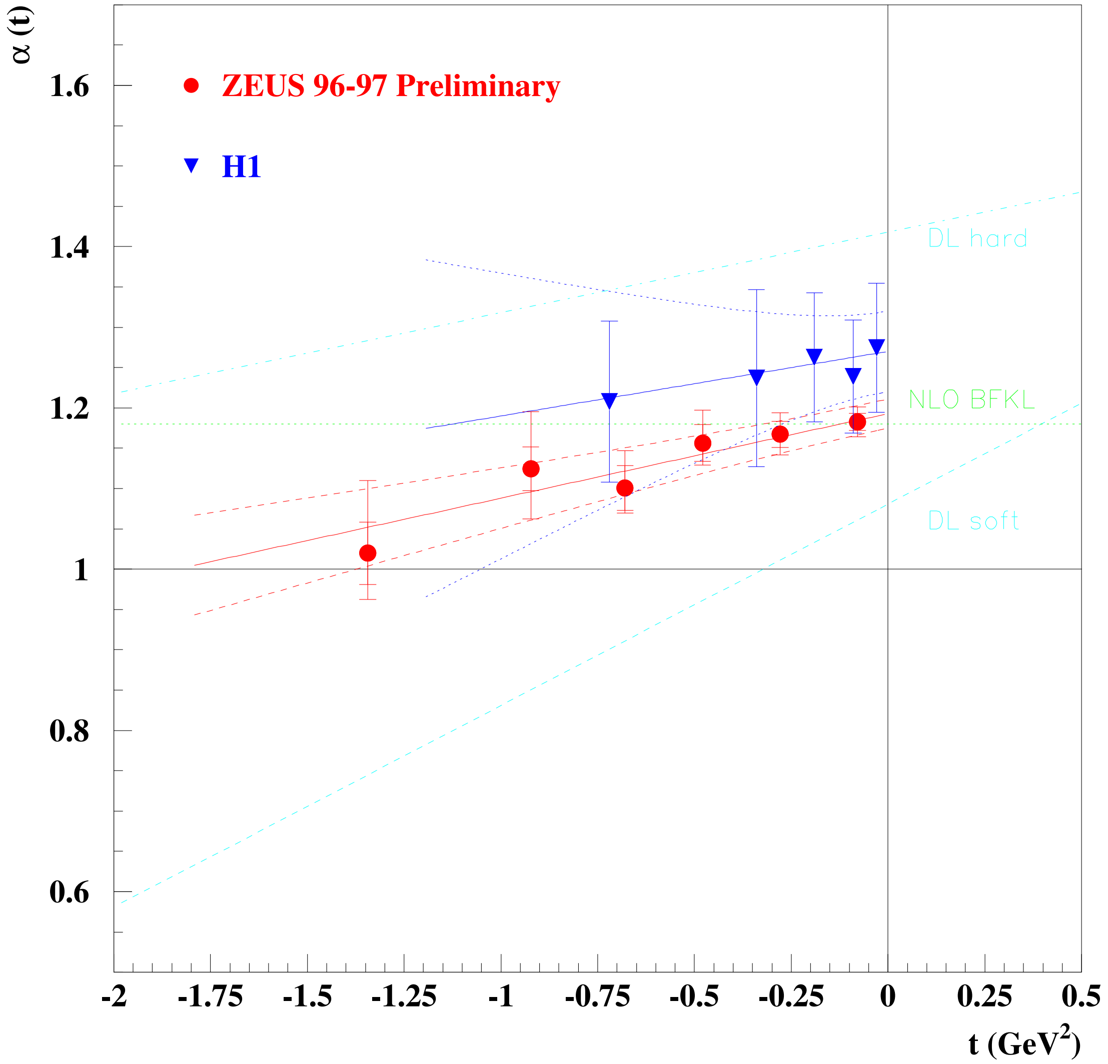
$$\sigma \propto [xg(x,Q^2)]^2$$

- Sensitive to the gluon density

Effective pomeron trajectory

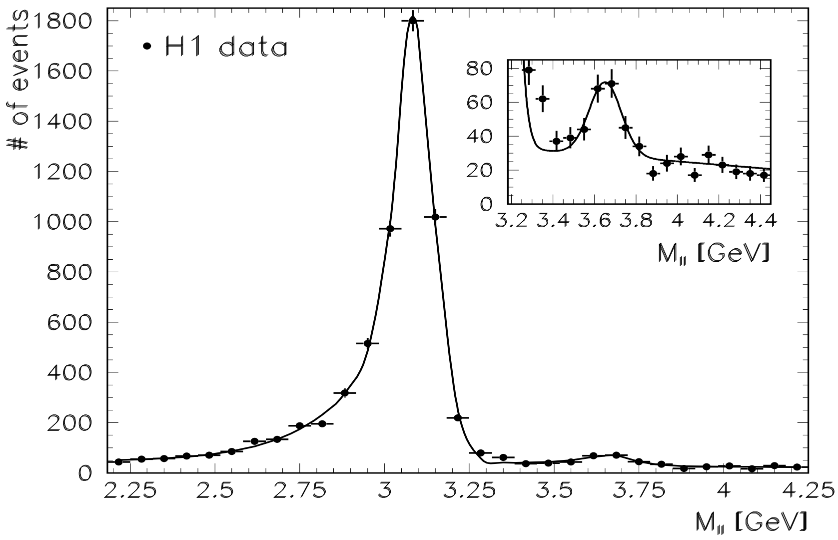
Elastic Photoproduction $\gamma\, p \rightarrow J/\psi\, p$

- fit $d\sigma(W_{\gamma p})/dt$ in t regions



- linear behaviour
- $\alpha(t = 0)$ in agreement with BFKL prediction

Elastic Photoproduction $\gamma\, p \rightarrow \psi'\, p$

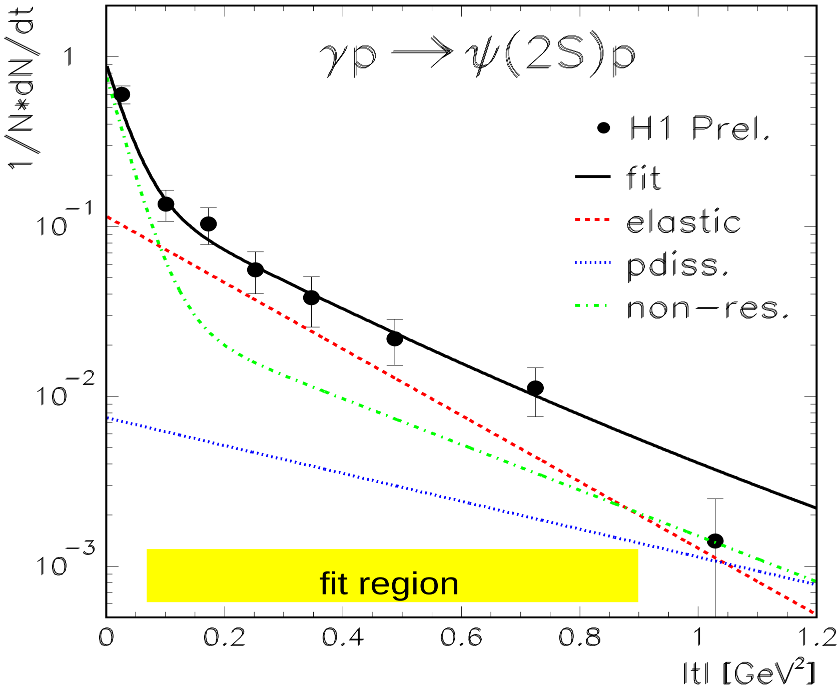


H1 preliminary

$Q^2 < 1$ GeV^2

$40 < W_{\gamma p} < 150$ GeV

38 pb^{-1}



$$b_{\psi'} = 4.5 \quad \pm 1.2 \ {}^{+1.4}_{-0.7} \quad \text{GeV}^{-2}$$

$$\Rightarrow b_{\psi'} \ \leq \ b_{J/\psi} = 4.73 \pm 0.25^{+0.30}_{-0.39} \ \text{GeV}^{-2}$$

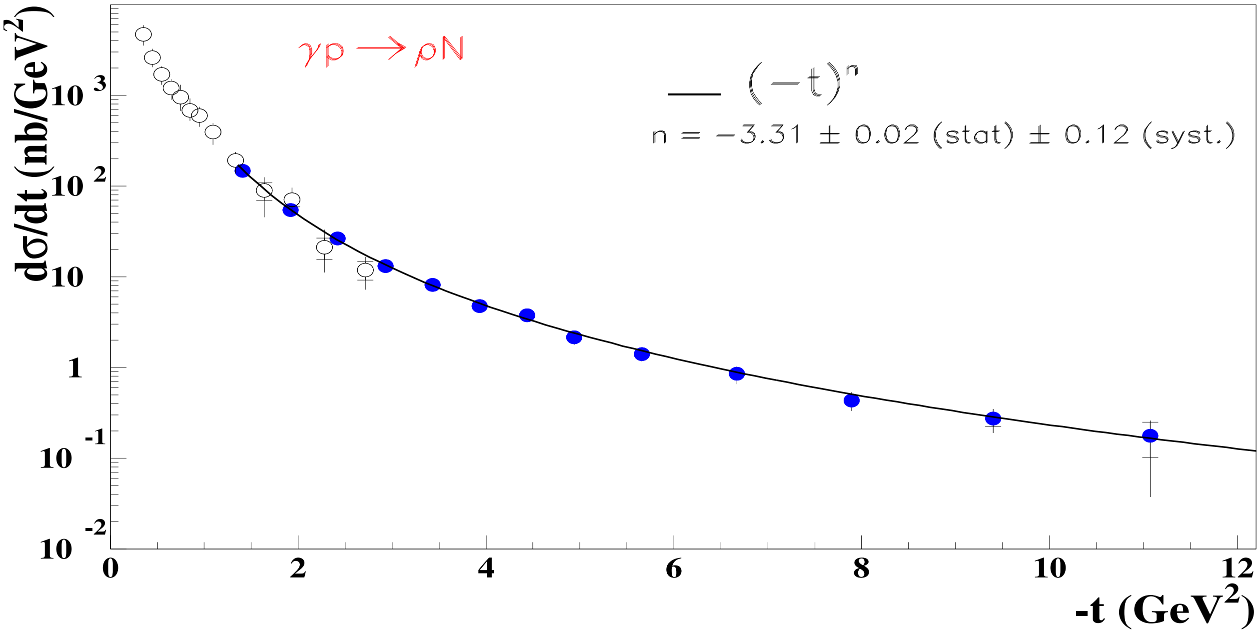
Nemchik et al.: Colour Dipole Model
ψ' wavefunction

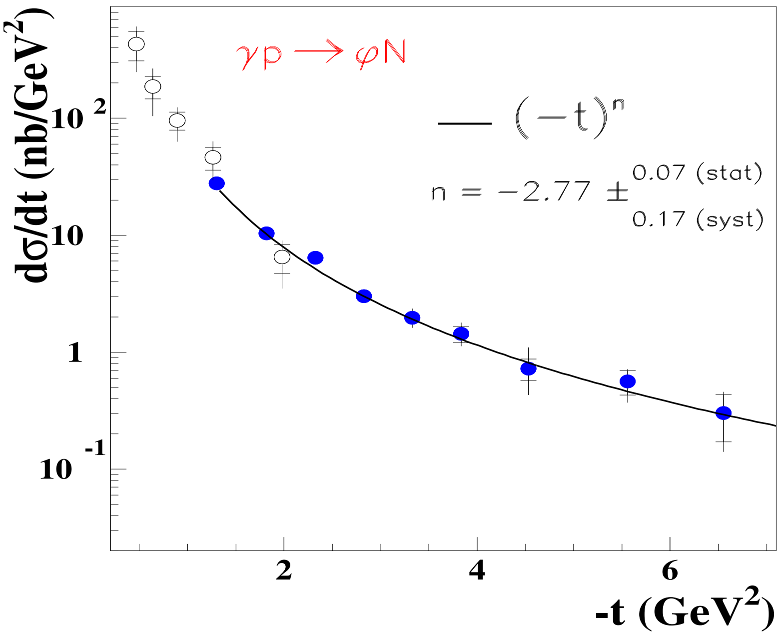
Light Vector Meson Production at High $|t|$

does $|t|$ provide a hard scale?

Proton dissociative photoproduction of ρ, ϕ

ZEUS 96 - 97 Preliminary





ZEUS 96-97

ZEUS 1995

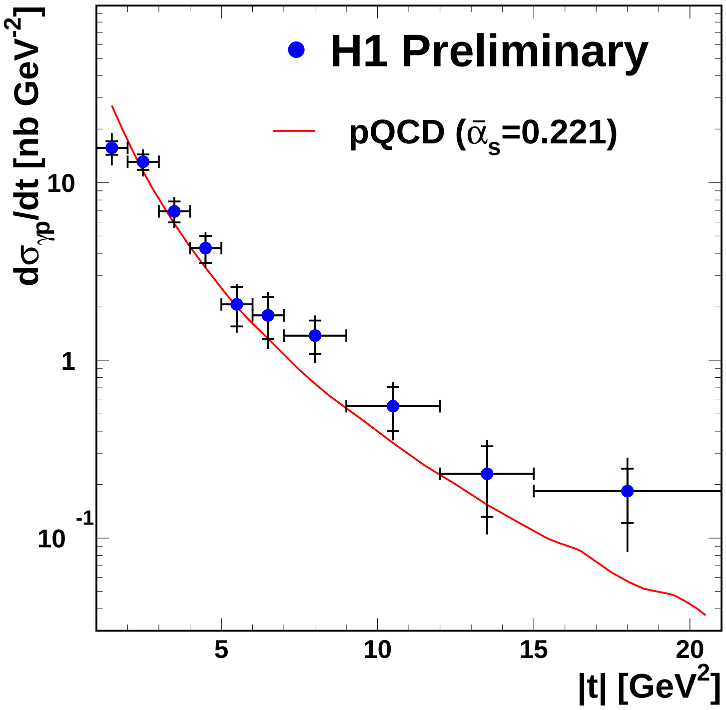
$Q^2 < 0.02$ GeV^2

$80 < W < 120$ GeV

24 pb^{-1}

- t dependence at high $|t| \propto (-t)^n$

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



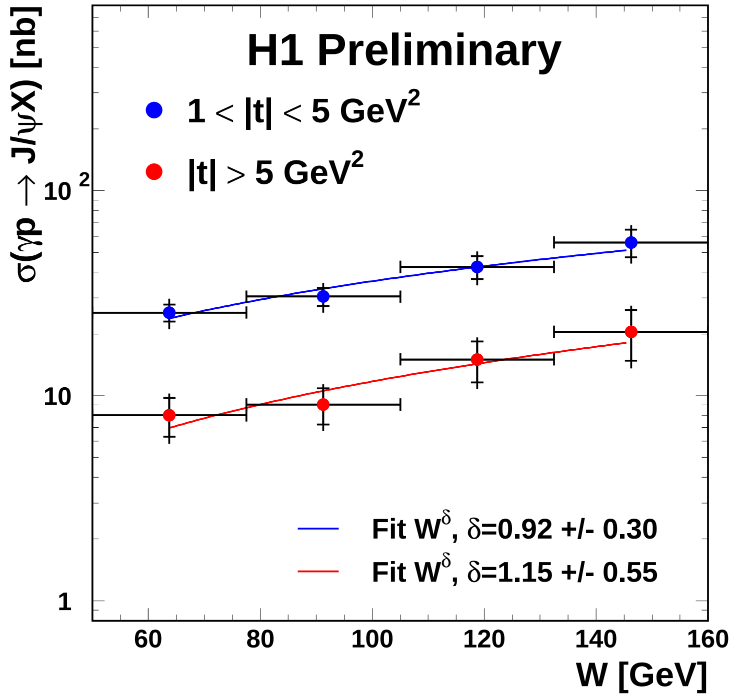
H1 Collaboration

$Q^2 < 1$ GeV^2

$50 < W < 160$ GeV

19 pb^{-1}

Forshaw, Bartels et.al., $\bar{\alpha}_s \sim 0.2$.
(Normalisation depends strongly on $\bar{\alpha}_s$)



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

Elastic Electroproduction $\gamma^* p \to \rho\, p$

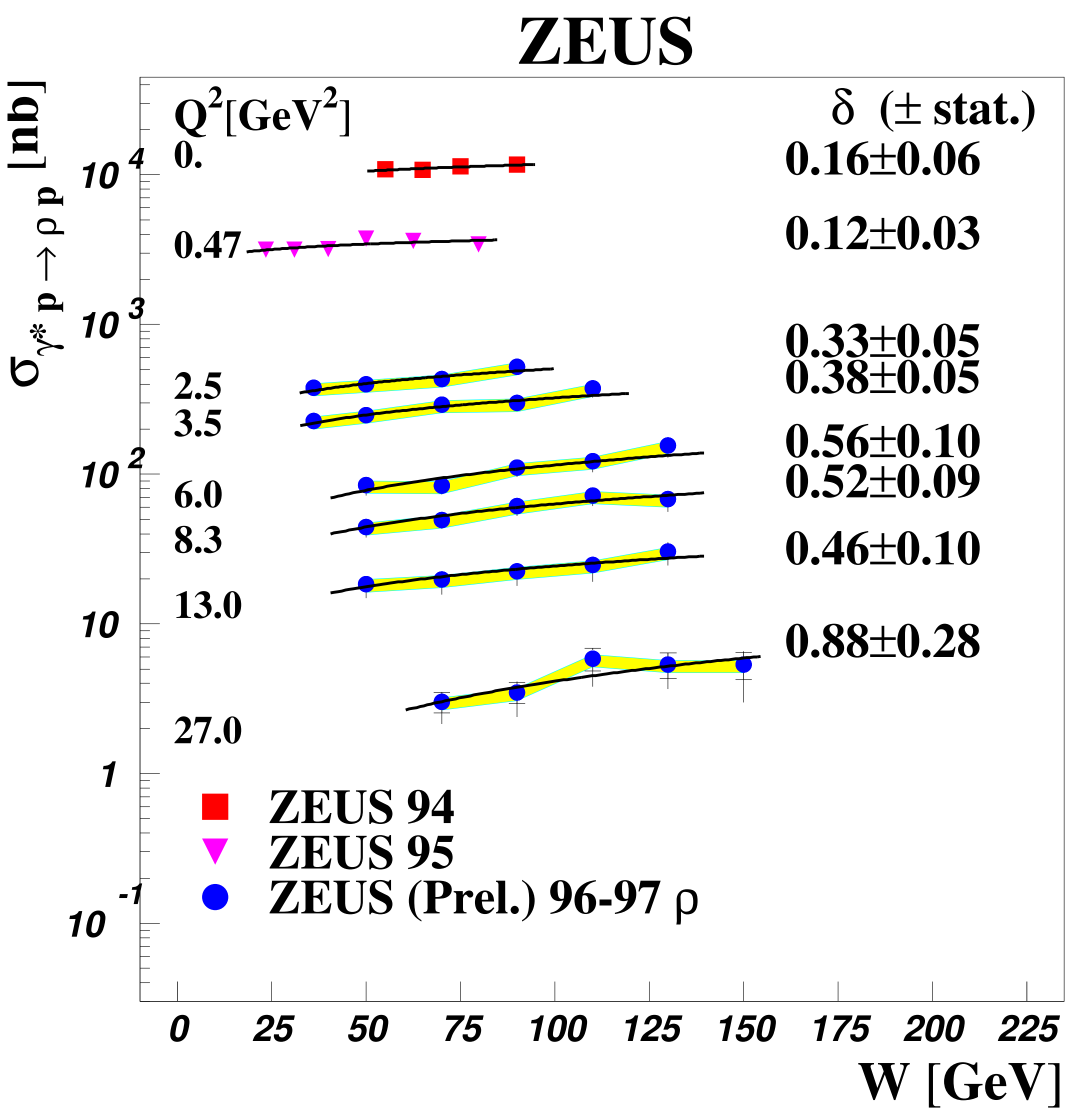
$|t| \approx 0$, $Q^2 \gg 0 \Rightarrow$ provides a hard scale

ZEUS preliminary

$5 < Q^2 < 80\,\mathrm{GeV}^2$

$32 < W < 160\,\mathrm{GeV}$

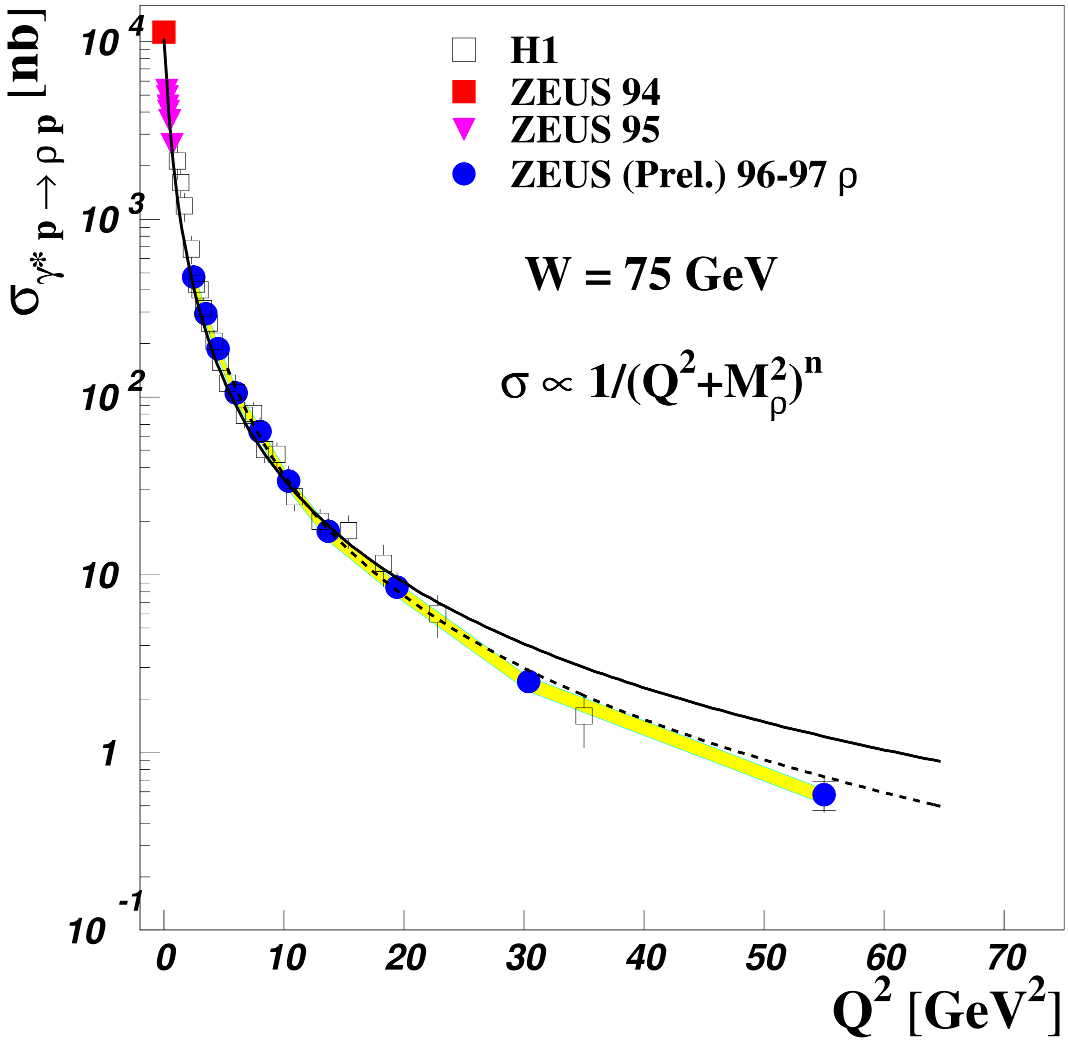
$38\,\mathrm{pb}^{-1}$



- Measured δ increases with increasing Q^2

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

Q^2 dependence:



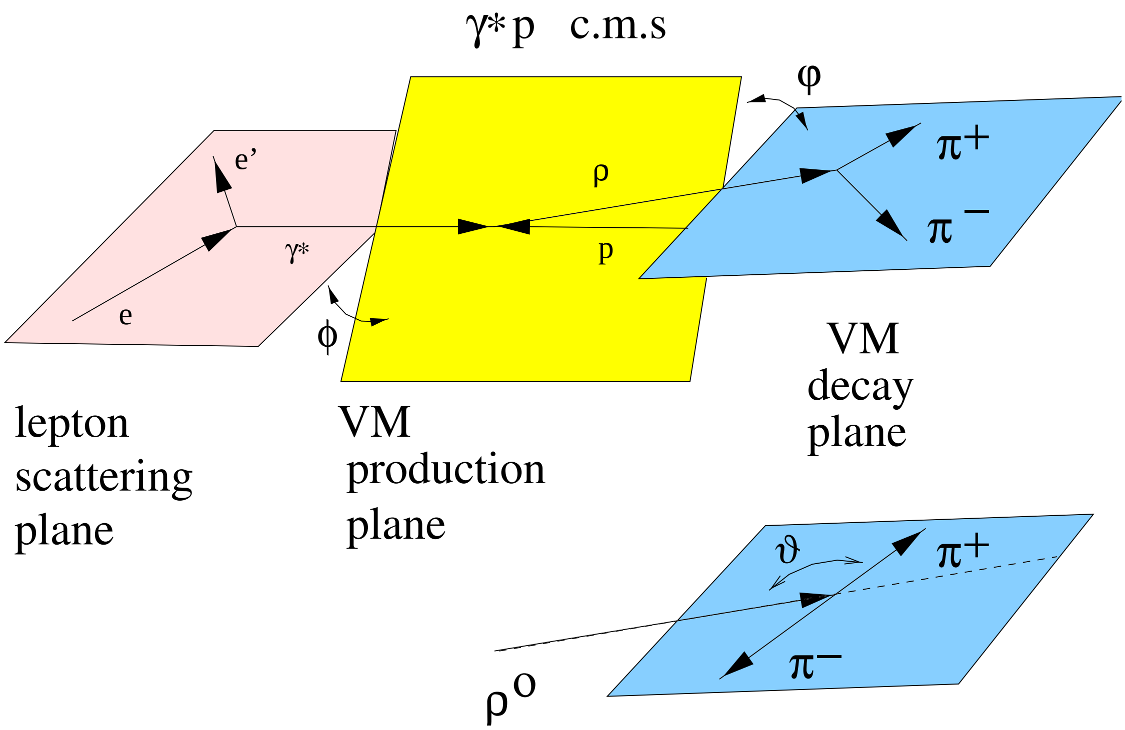
- fit $\propto (Q^2 + M_\rho^2)^{-n}$ describe $Q^2 > 5\,\mathrm{GeV}^2$ with

$$n = 2.36 \pm 0.04$$

- not if the low Q^2 region is included (solid line)

Helicity Studies

Define three angles in the Helicity system



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

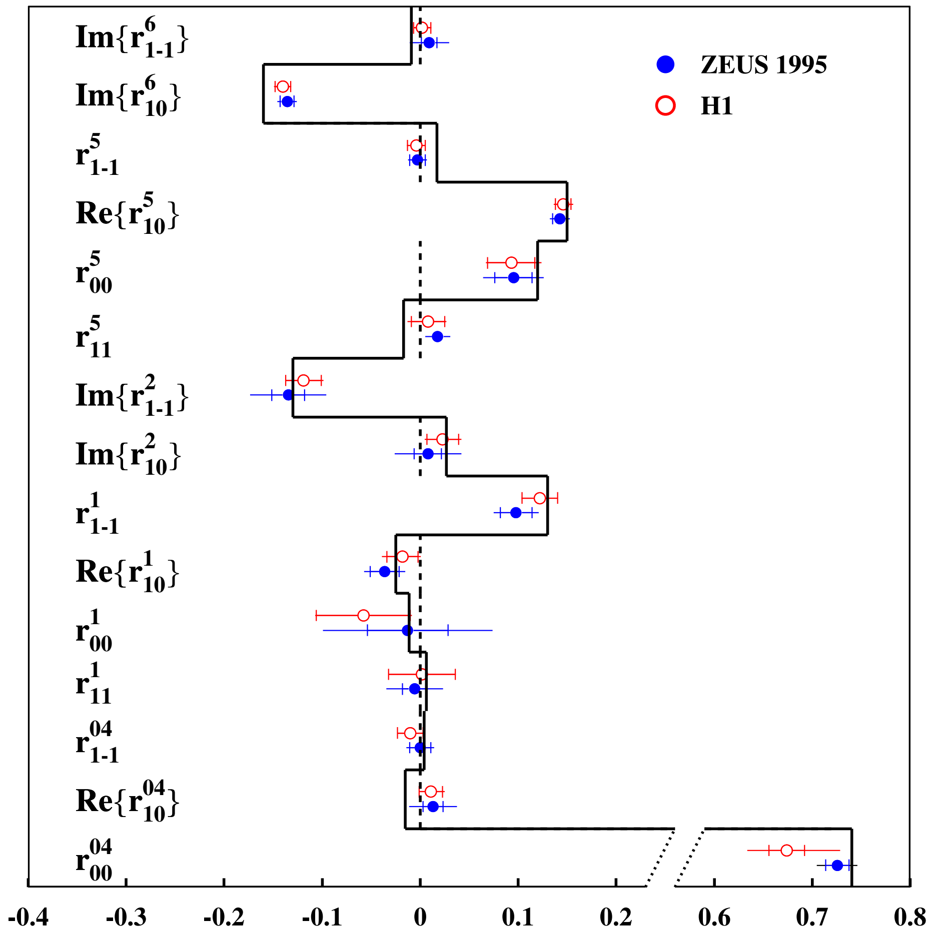
Written as a function of 15 independent linear combinations (r) of spin density matrix elements

For: **SCHC, NPE:**

expect 5 combinations to be non-zero.

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

Combinations of spin density matrix elements

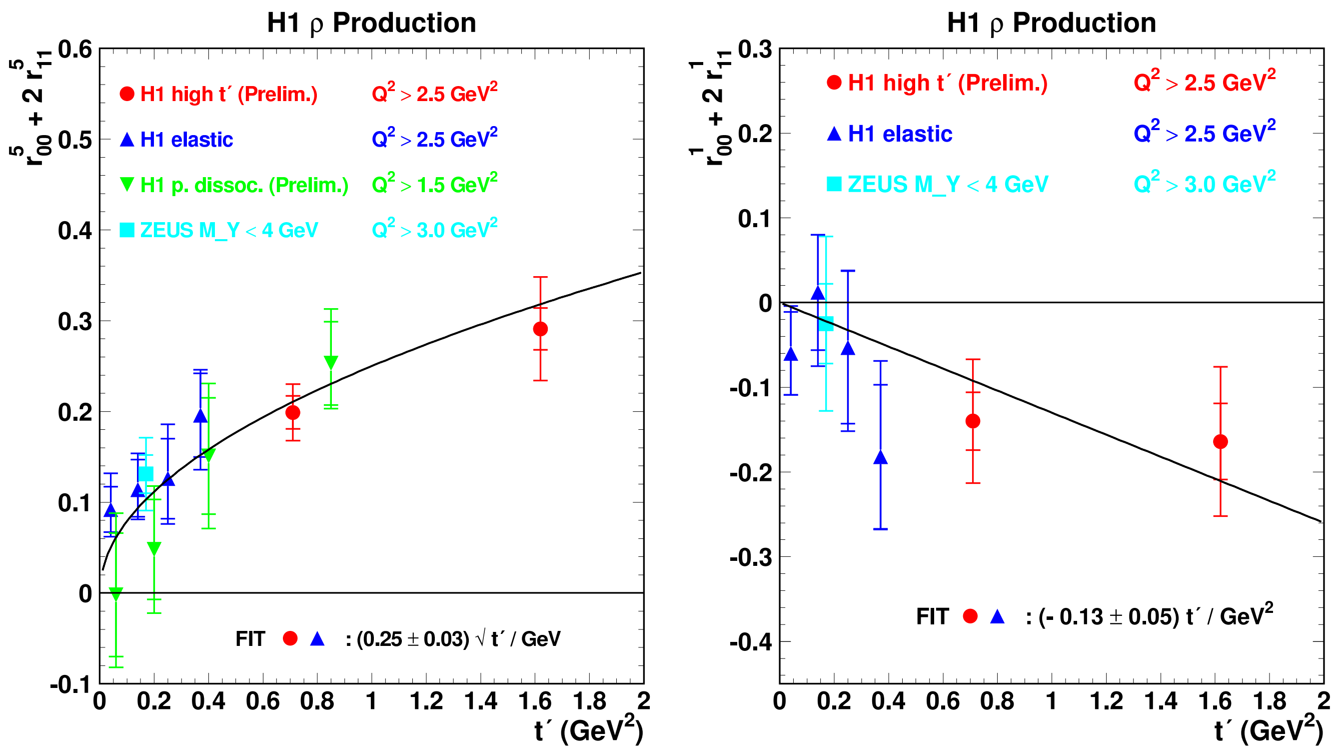


r^5_{00}: Transv. Photon $\to$ Longit. Vector Meson

QCD model (solid line) predicts violation
(Ivanov,Kirschner)

Electroproduction of ρ at high $|t|$

H1 Measurement:
$2.5 < Q^2 < 30\ \mathrm{GeV}^2$, $40 < W < 140\ \mathrm{GeV}$, $6\ \mathrm{pb}^{-1}$



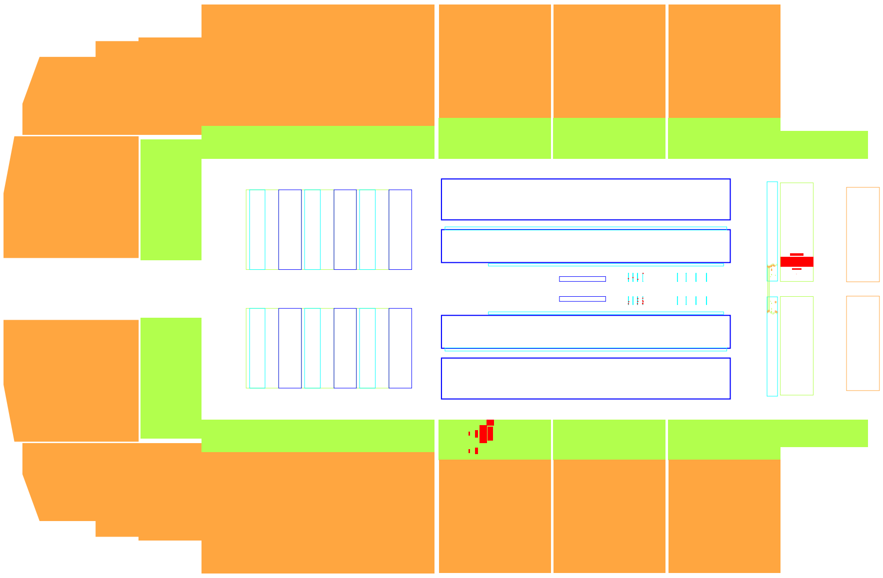
- $r^5_{00} + 2r^5_{11}$ implies violation increases with

$$t' = |t| - t_{min}$$

- indication of negative $r^1_{00} + 2r^1_{11}$

Deeply Virtual Compton Scattering

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



H1 Collaboration

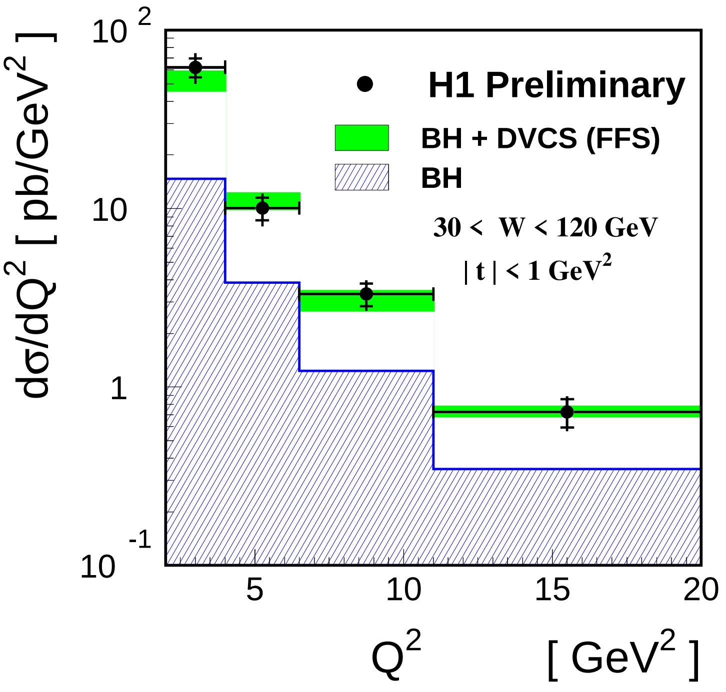
$2 < Q^2 < 20\ \mathrm{GeV}^2$

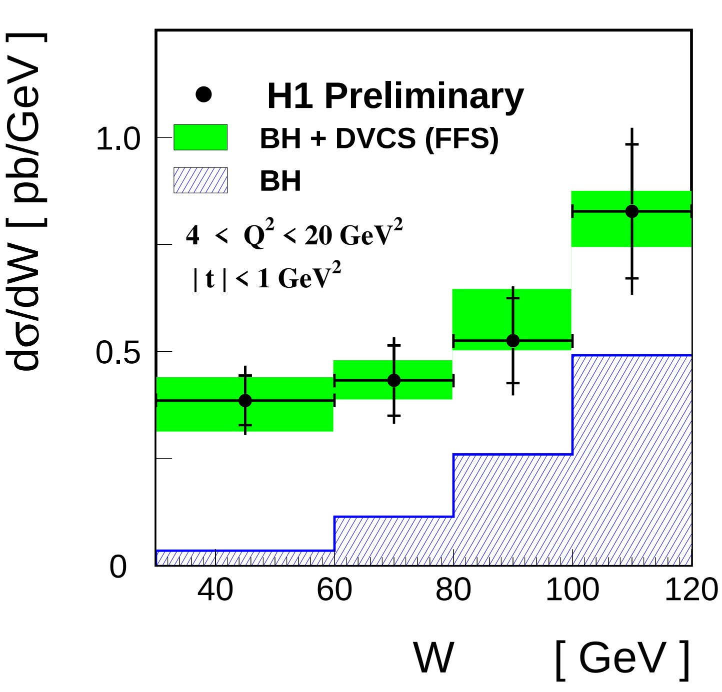
$30 < W_{\gamma p} < 120\ \mathrm{GeV}$

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

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

Ratio DVCS / Bethe-Heitler $\Rightarrow$ forward photons
Integration over ϕ $\Rightarrow$ Interference term ~ 0





Conclusions

- Presented Measurements of Diffractive Vector Meson Production
- Presented First Cross Section Measurement of DVCS
- More Detailed Analyses with Increased Luminosity
- HERA Access to Larger Kinematic Region
- HERA Data span the Transition Region from Soft to Hard Diffraction
- pQCD Predictions give Good Agreement for Large M_{VM}, Q^2 and/or $|t|$