Vector Mesons and Deeply Virtual Compton Scattering at HERA

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HSQCD 2005

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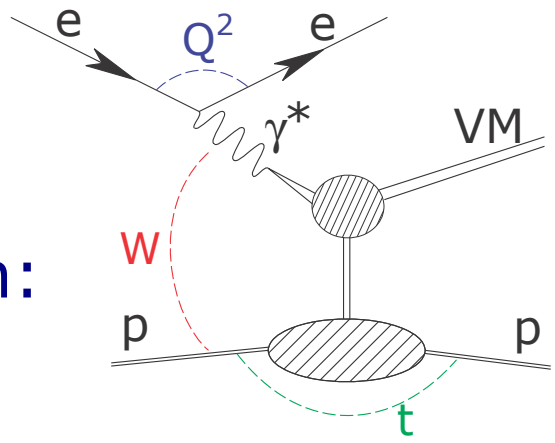
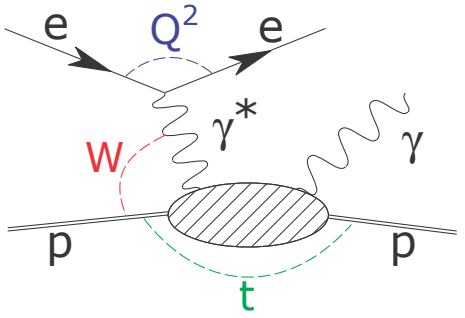
Overview



- Recent results on vector meson production:
  - J/Ψ in photo- and electroproduction
  - ϕ in electroproduction
  - high *t* ρ in photoproduction
- Results on Deeply Virtual Compton Scattering
- Conclusion and outlook



HERA, H1 and ZEUS

Diffractive Vector Meson Production

"Soft" processes well described by Regge Theory (Soft Pomeron)

vs.

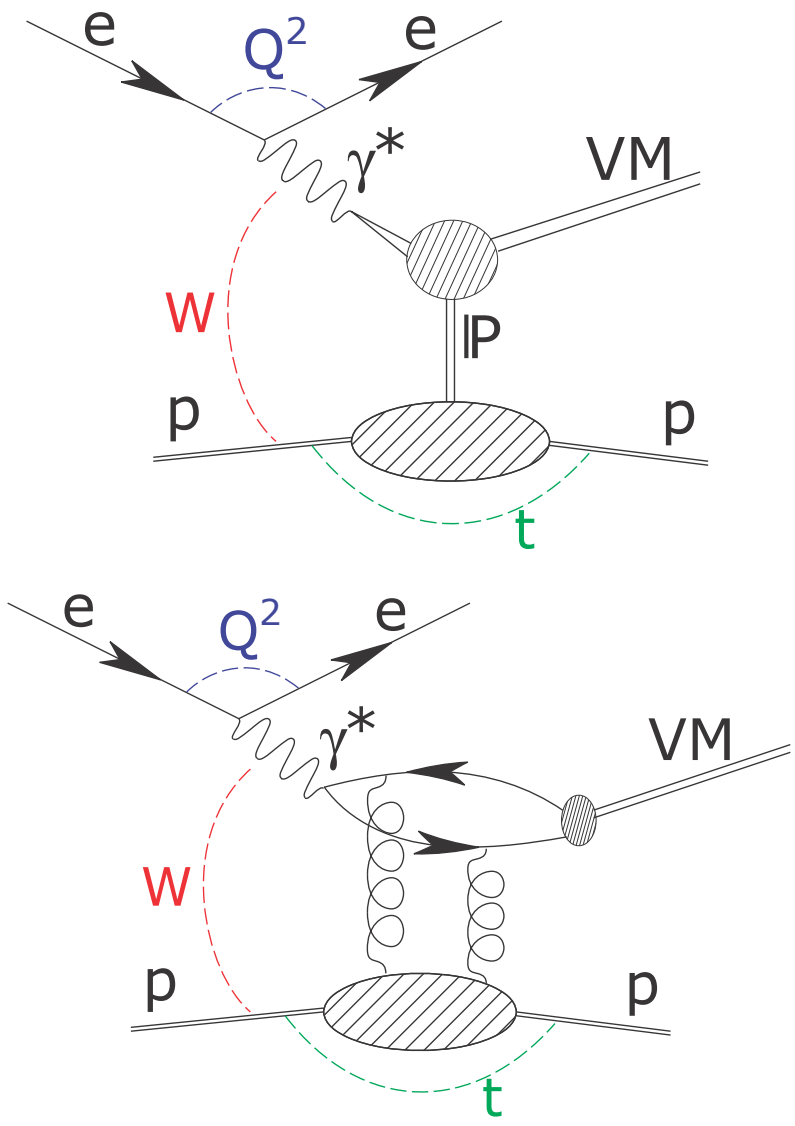
"Hard" processes calculable in pQCD

Hard scale can be set by:

- Q^2 (electroproduction)
- VM mass (J/Ψ, ϕ?)
- t (high t ρ)

Soft: Pomeron trajectory

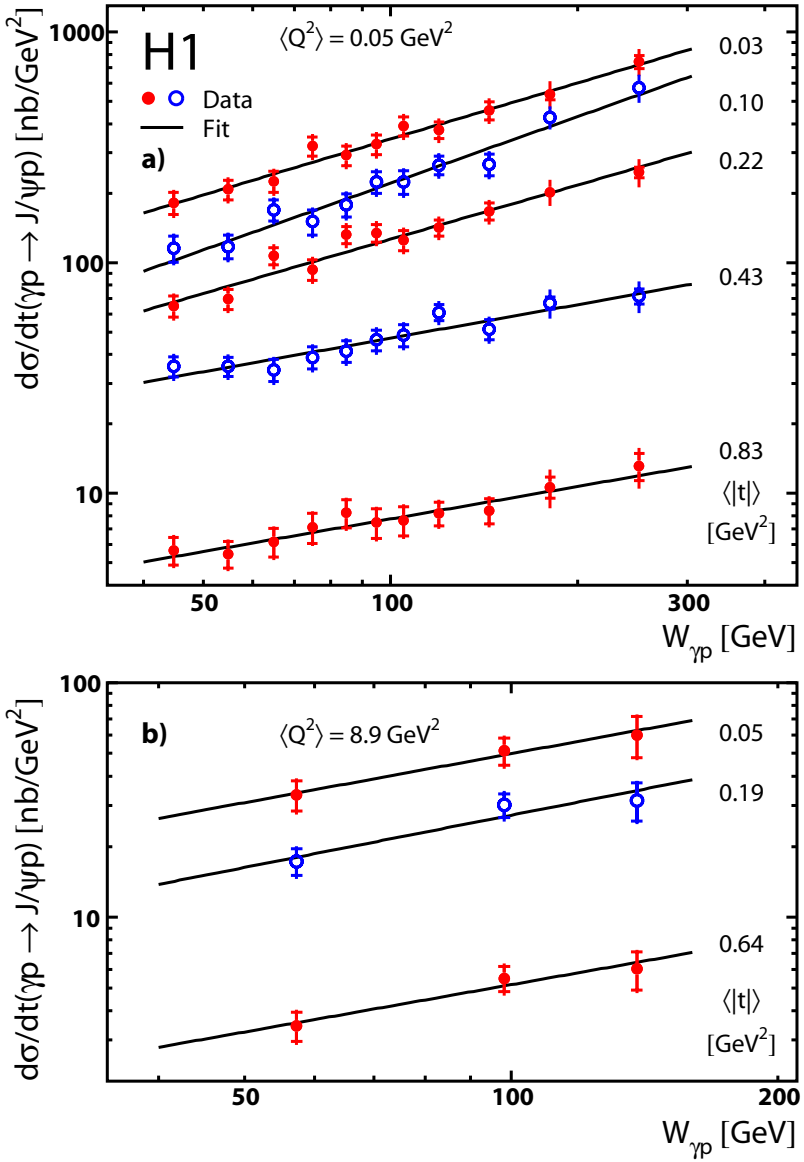
Hard: Gluon densities, evolution equations, s-channel helicity non-conservation



J/Ψ - extracting the pomeron trajectory

- Determine dependence of cross section on *W* in bins of *t*
- Fit $\sigma \propto W^{4(\alpha(t)-1)}$ in each *t* bin
- Photo- and electroproduction

H1: To be published in Eur.Phys.J. C
ZEUS: Nucl. Phys. B 695 (2004) 3 (DIS)
Eur.Phys.J. C 24 (2002) 345 (γp)



J/Ψ - pomeron trajectory

- Alternatively: do a 2-D fit
- J/Ψ harder than predicted by soft pomeron (γp):

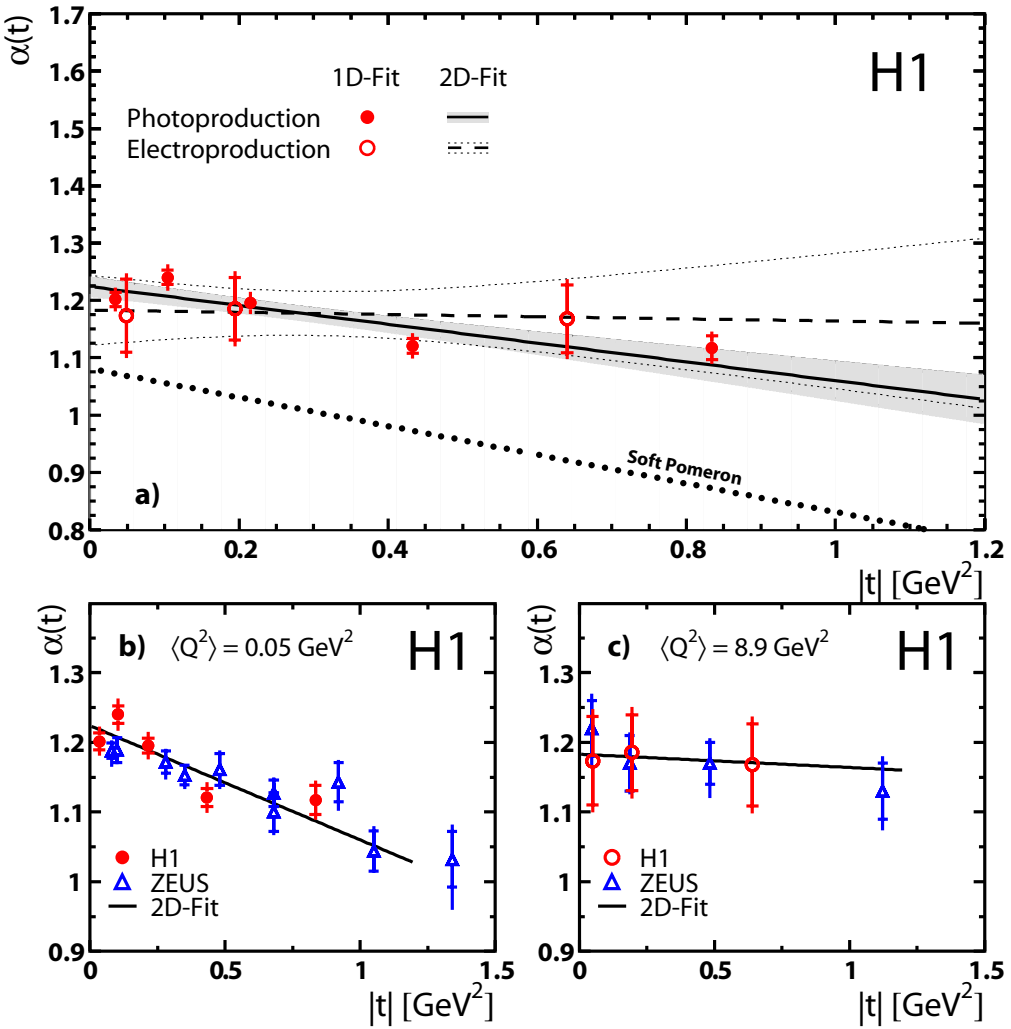
$\alpha_P(0) = 1.224 \pm 0.010 \pm 0.012$

$\alpha'_P = 0.164 \pm 0.028 \pm 0.030\,\mathrm{GeV}^{-2}$

- Significant *t* dependence in photoproduction:
  4σ evidence for shrinkage, but also 2σ below soft pomeron
- Electroproduction: even harder, compatible with no shrinkage

$\alpha_P(0) = 1.183 \pm 0.054 \pm 0.030$

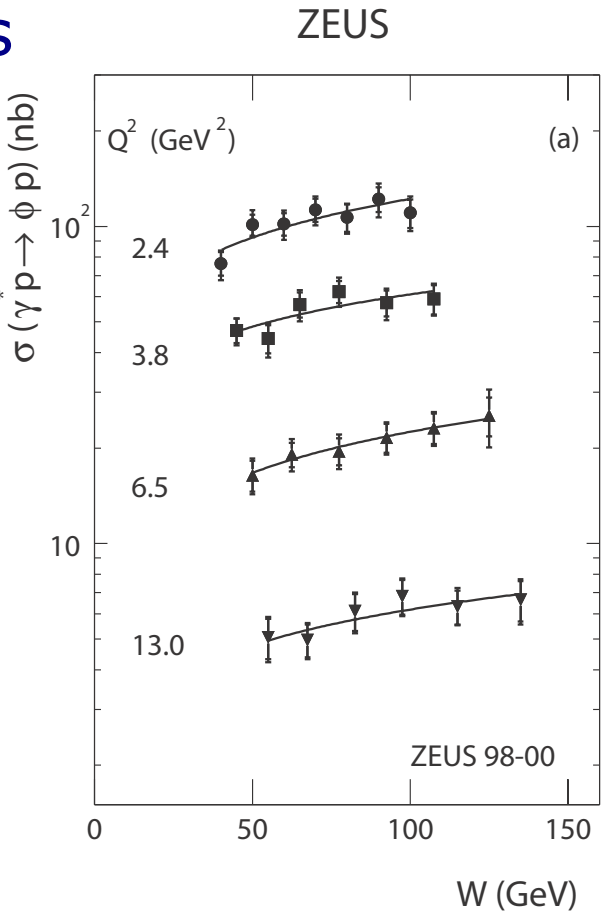
$\alpha'_P = 0.019 \pm 0.139 \pm 0.076\,\mathrm{GeV}^{-2}$

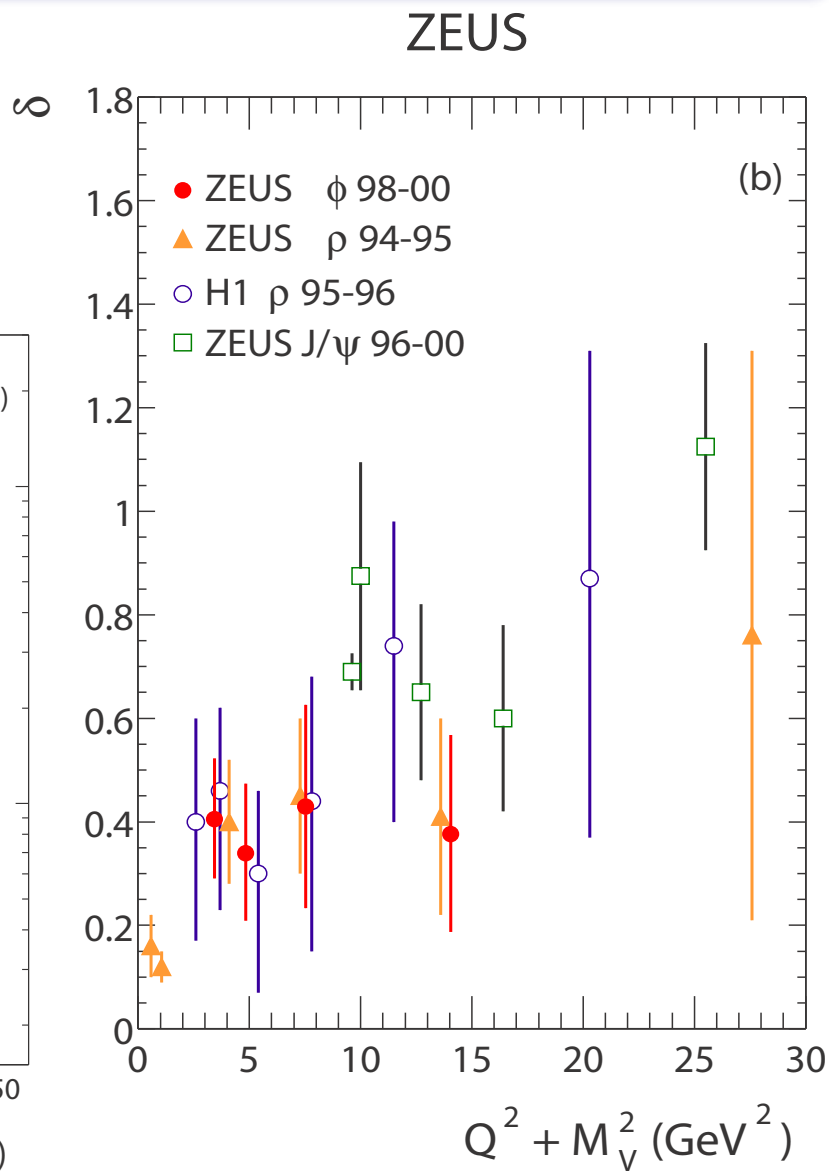


ϕ in electroproduction - W dependence

- Cross section dependence on W: fit $\sigma \propto W^{\delta}$
- δ consistent with other VM measurements

ZEUS: Nucl.Phys. B 718 (2005) 3



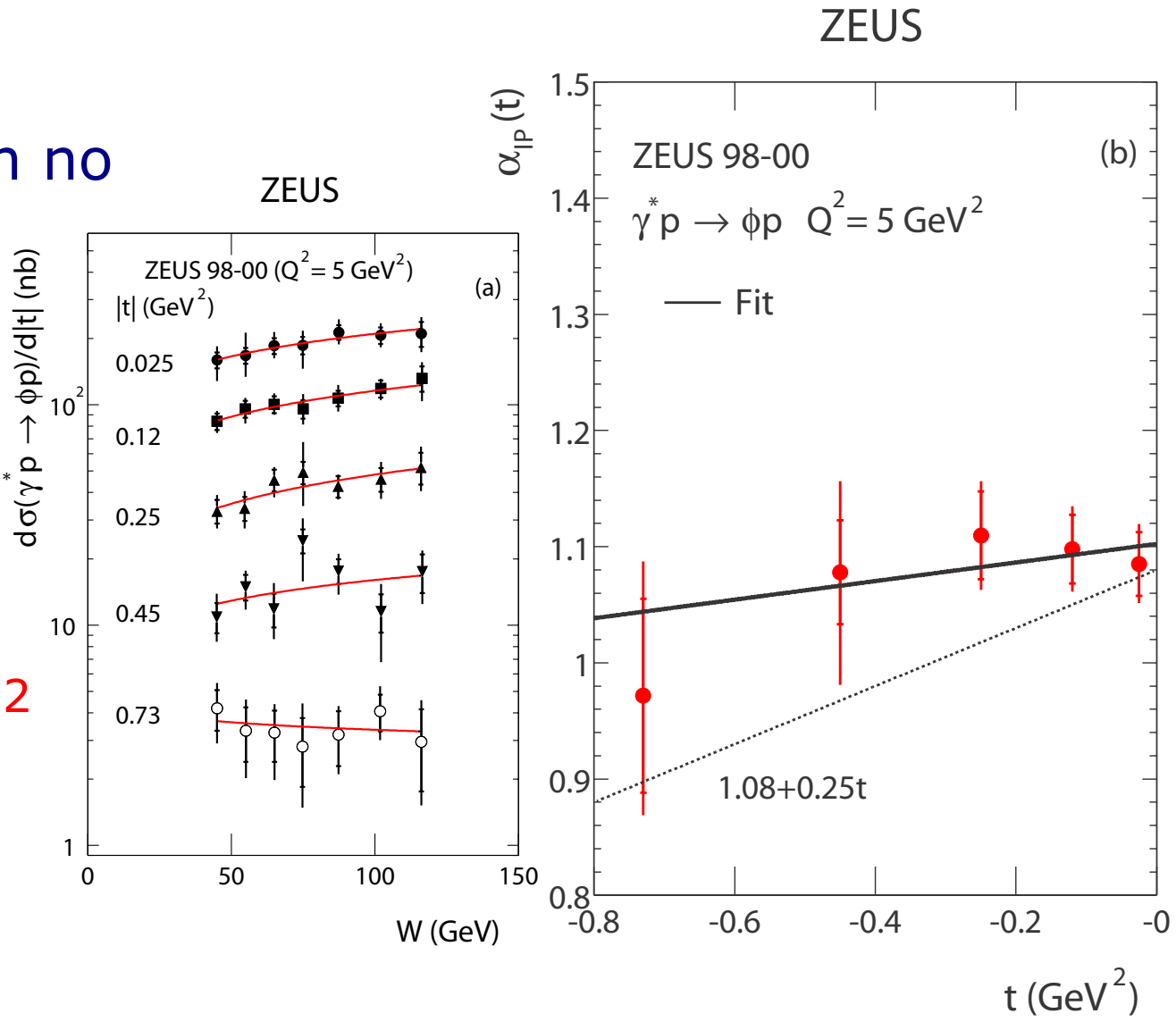


ϕ - Pomeron trajectory

- Departure from soft pomeron
- Data compatible with no shrinkage:

$\alpha_P(0) = 1.10 \pm 0.02 \pm 0.02$

$\alpha'_P = 0.08 \pm 0.09 \pm 0.08\,\mathrm{GeV}^{-2}$



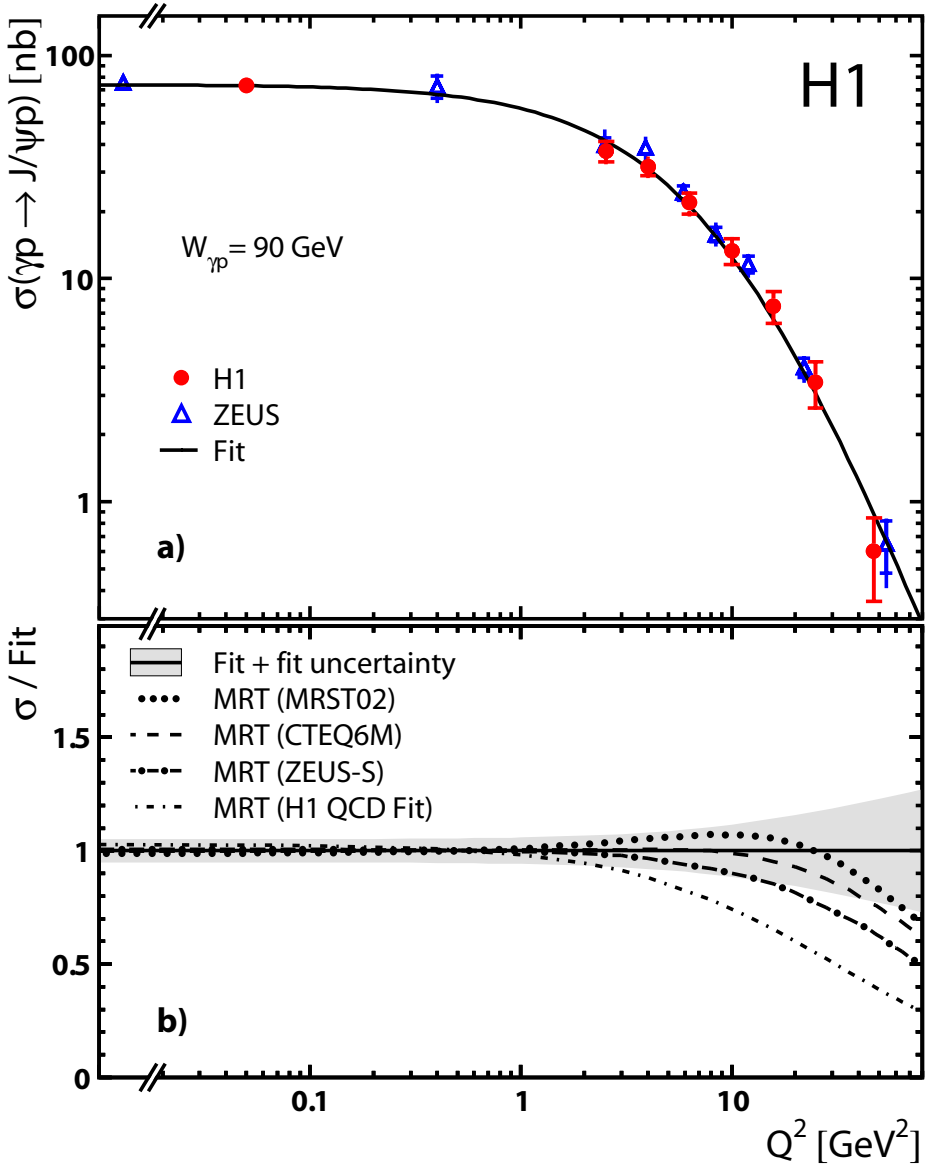
J/Ψ - testing gluon densities?

- High J/Ψ mass provides a hard scale - calculable in QCD
- Measure cross section as a function of Q^2, W, compare to models
- Phenomenological fit $(Q^2+M^2)^{-n}$

Martin, Ryskin and Teubner: pQCD model based on k_T factorisation and a parton-hadron duality ansatz

(Phys.Rev.D 62 (2000) 014022)

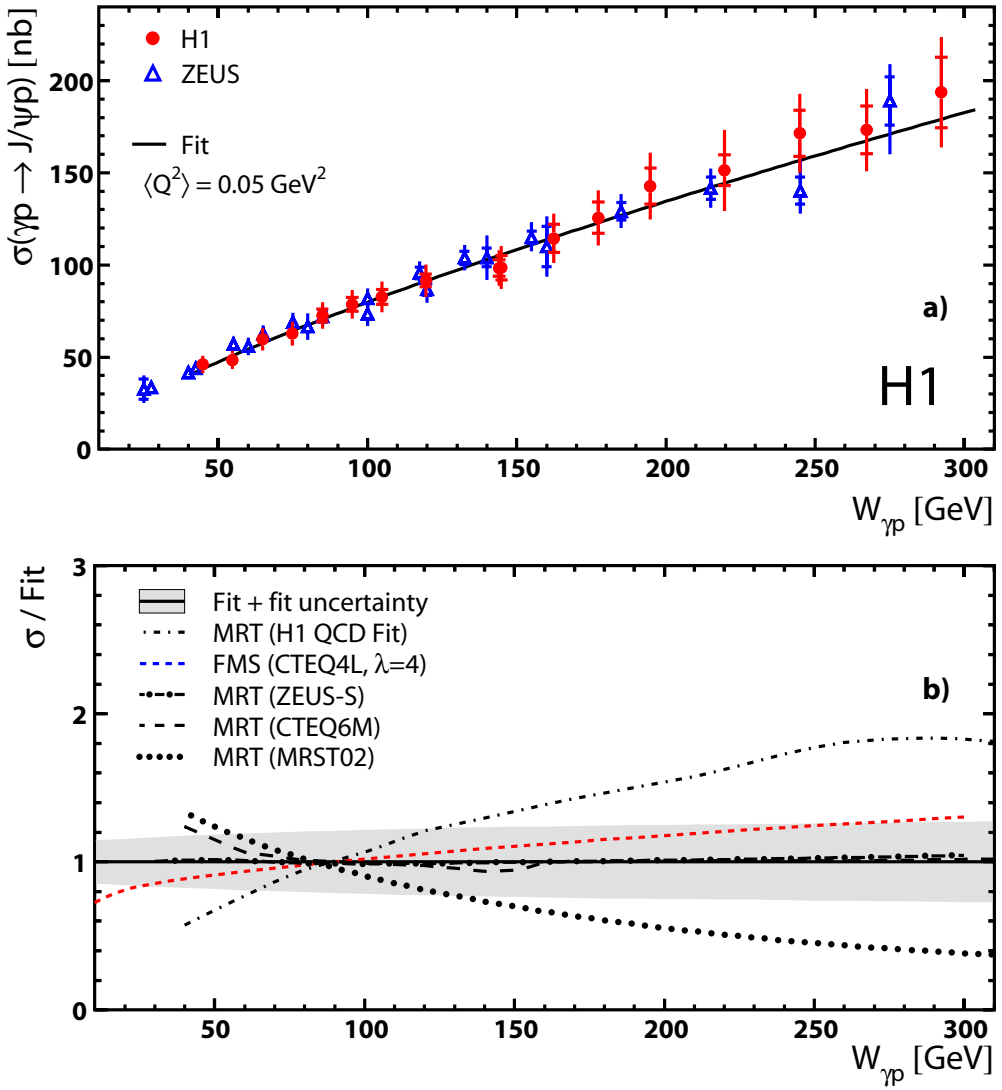
- Prediction normalised to data - shape comparison can constrain gluon density



J/Ψ - testing gluon densities!

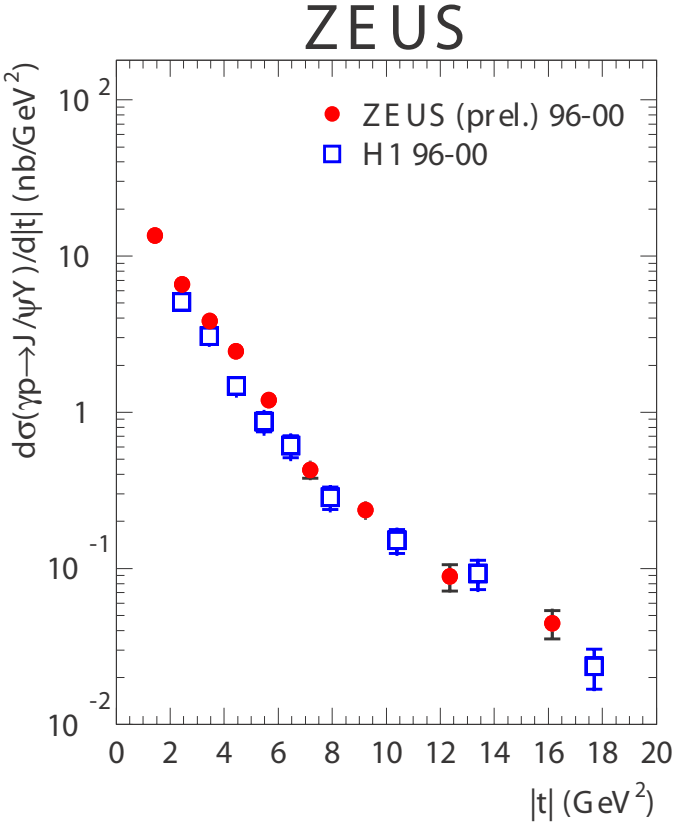
- Even more prominent in *W* dependence
- Normalise predictions at *W* = 90 GeV, compare shapes
- Access to gluon densities in regions poorly constrained by inclusive DIS data (very low *x*)
- Uncertainties on Gluon distributions not taken ito account

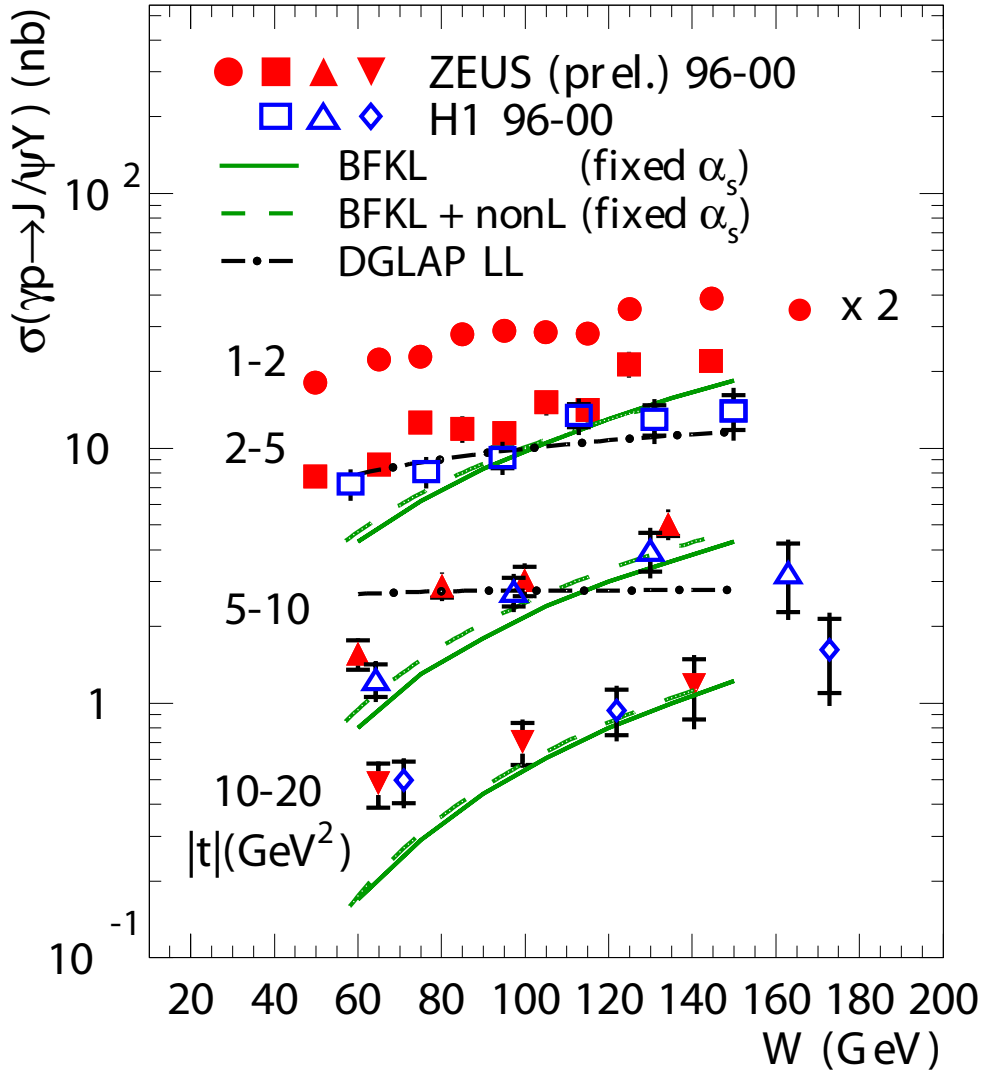
Theoretical alternative: Dipole model by Frankfurt, McDermott and Strikman (FMS)
(JHEP 0103 (2001) 045)
H1: To be published in Eur.Phys.J. C
ZEUS: Nucl. Phys. B 695 (2004) 3 (DIS)



J/Ψ at high *t*

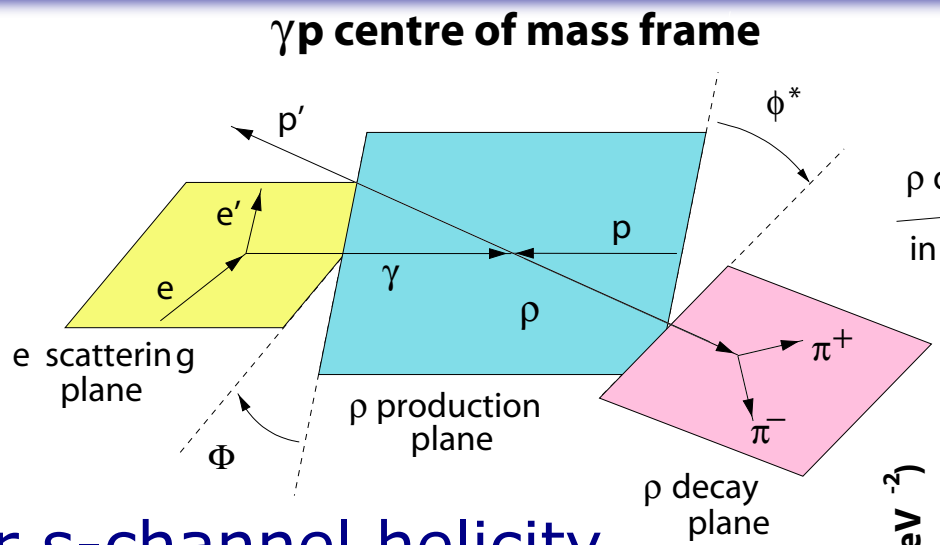
- ZEUS higher and steeper than H1
- BFKL better than DGLAP

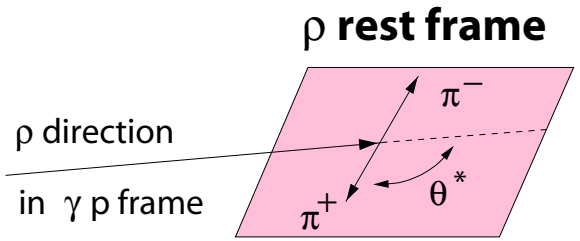




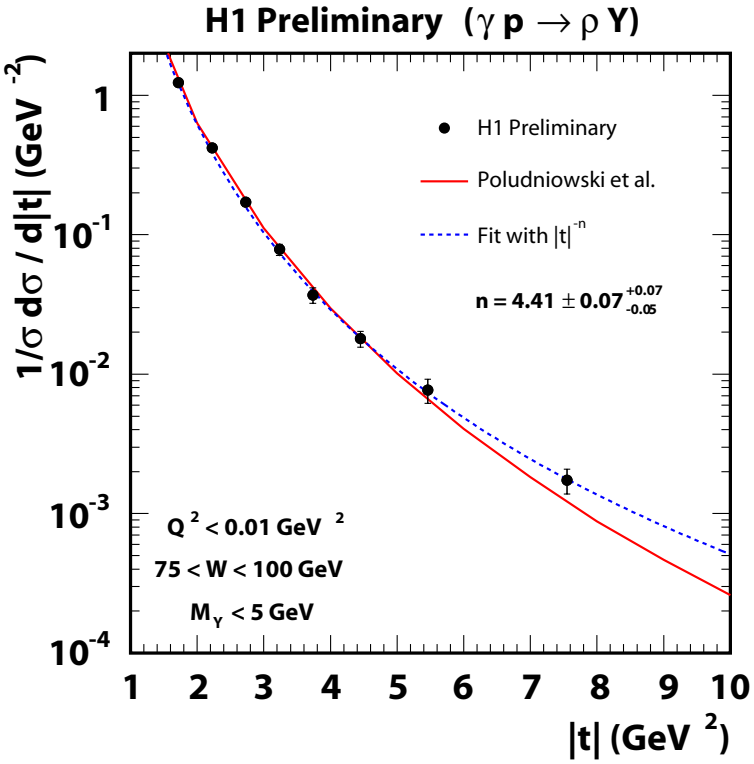
ZEUS: Preliminary, Lepton-Photon 2005 (291)
H1: Phys.Lett. B 568 (2003), 205

High t ρ in photoproduction





- Look for s-channel helicity NON-conservation (depar-ture from Vector Dominance)
- QCD predictions
  (G.G. Poludnikowski et al., JHEP 312 (2003) 002)
- Photoproduction: e escapes through beampipe; only ϕ* and θ* accessible

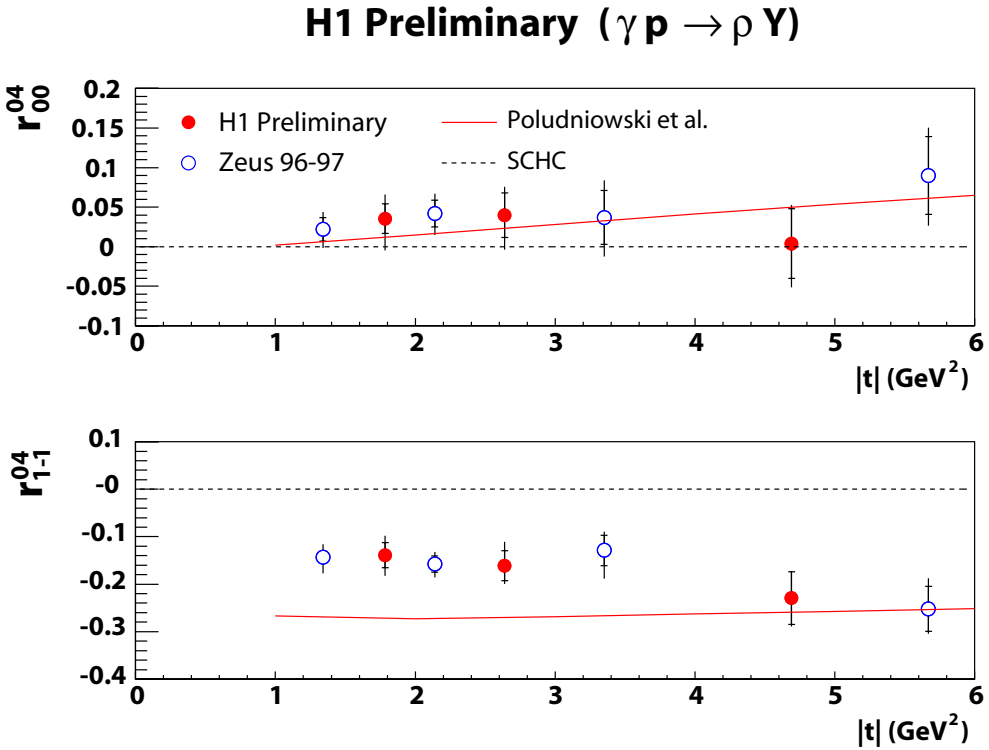


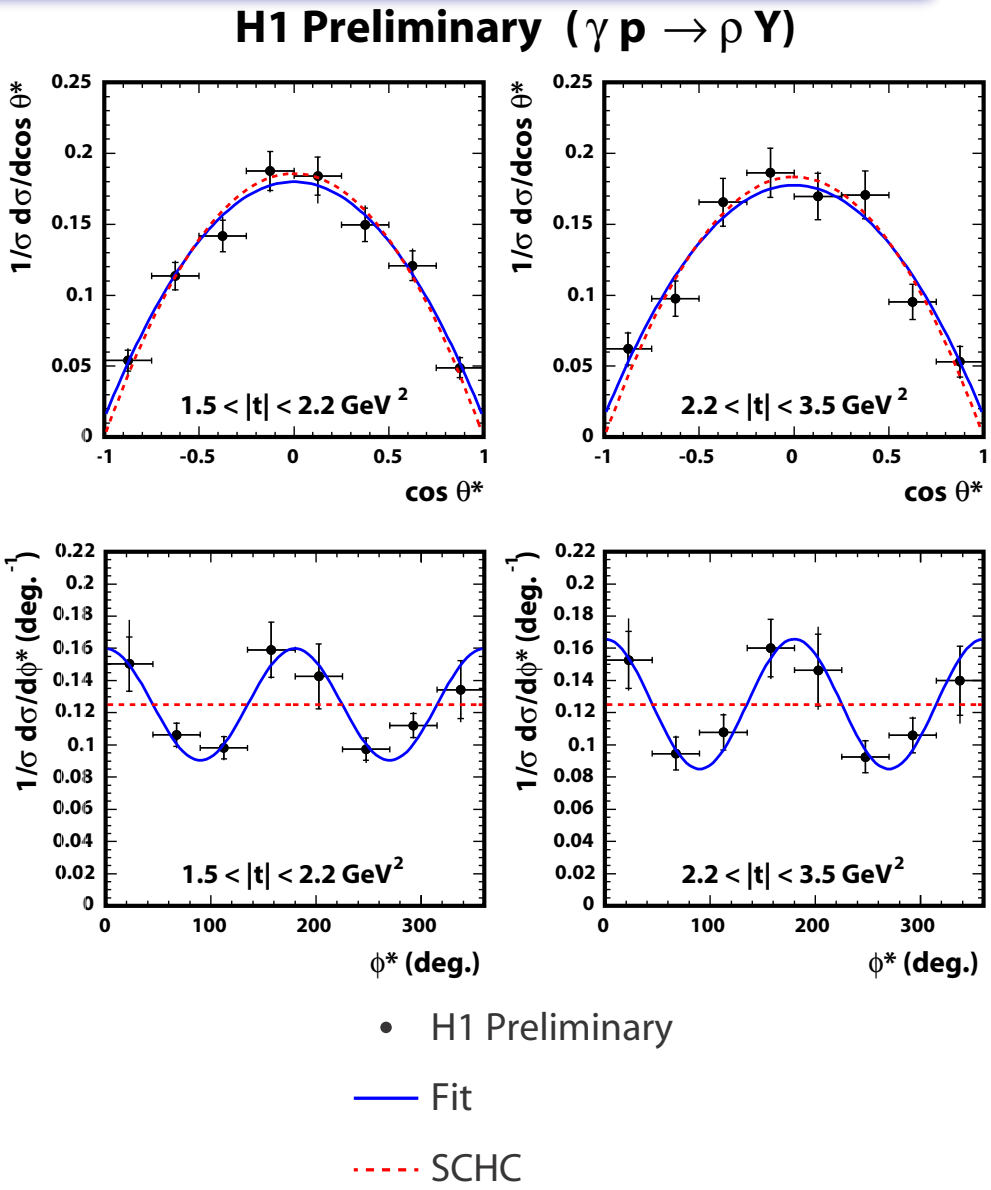
H1: Preliminary, LeptonPhoton 2005 (399)

High t ρ: SCH-Non-Conservation

- SCHC in θ*
- SCHC violated in φ*

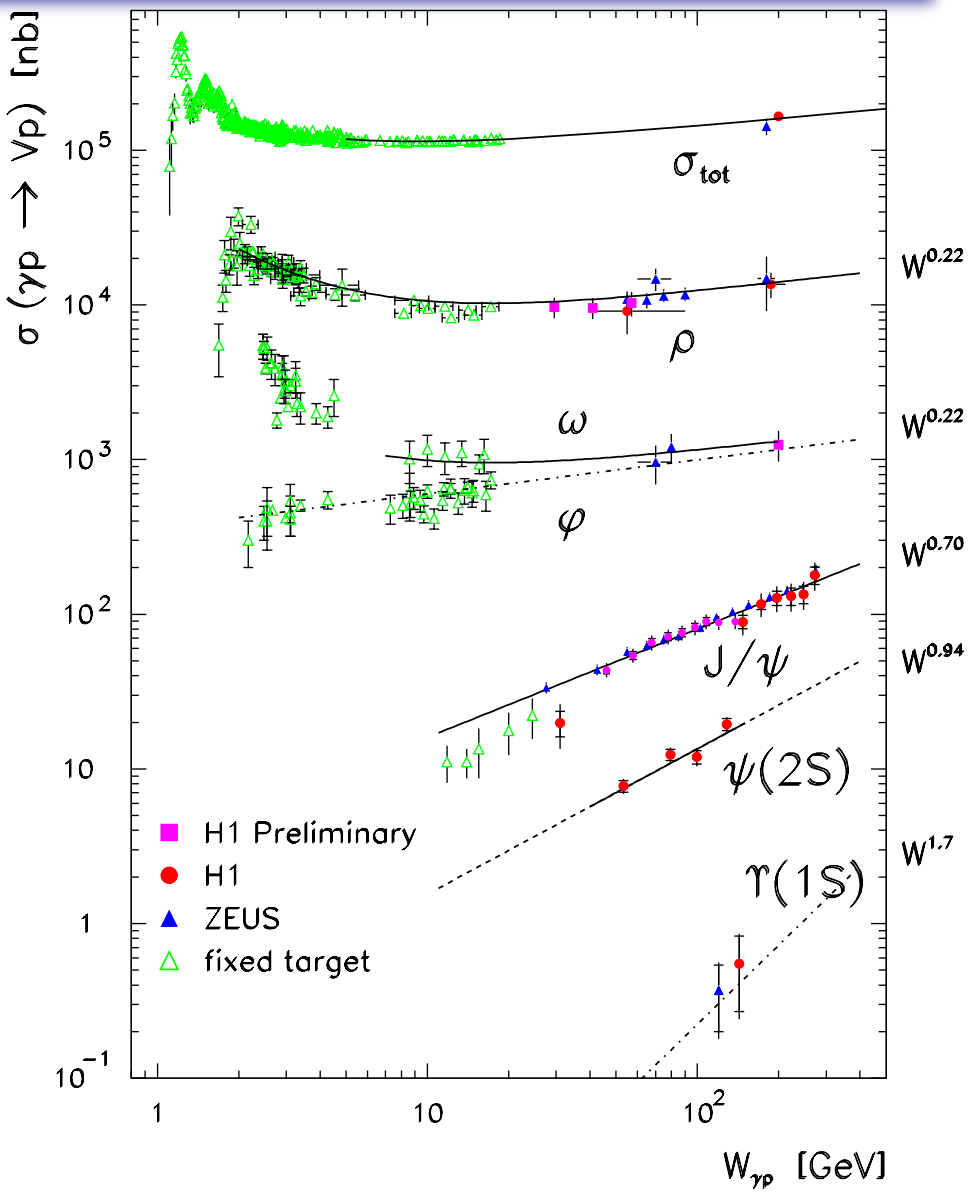
- QCD model describes r^{04}_{00}, r^{04}_{1-1} only at high t





Vector Mesons: Summary

- As soon as a hard scale is involved, measurements disagree with soft pomeron
- J/Ψ Measurements and theory together come close to constraining gluon densities
- Light vector mesons at high *t* or in electroproduction can shed light on soft-hard transition and test QCD models



Deeply Virtual Compton Scattering

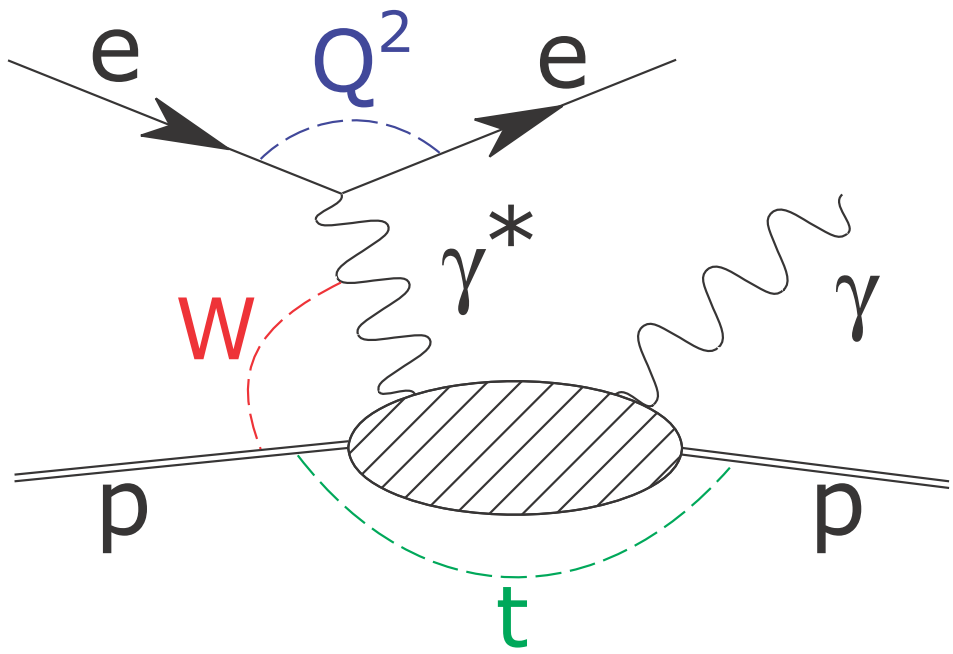
Scattering of a virtual photon off the proton:

$$e + p \rightarrow e + \gamma + p$$

In principle very clean channel:

- Factorisation theorem: First diffractive process fully calculable in QCD
- No uncertainty due to VM wave-function
- Access to Generalised Parton Distributions

H1: submitted to Eur.Phys.J. C
ZEUS: Phys.Lett. B 573 (2003) 46



NLO leading twist calculation by A. Freund and M. McDermott Eur. Phys. J. C23 (2002) 651
Factorisation Theorem:
Collins & Freund Phys.Rev.D 59 (1999) 074009
Ji & Osborne Phys.Rev. D 58 (1998) 094018

DVCS: Generalised Parton Distributions

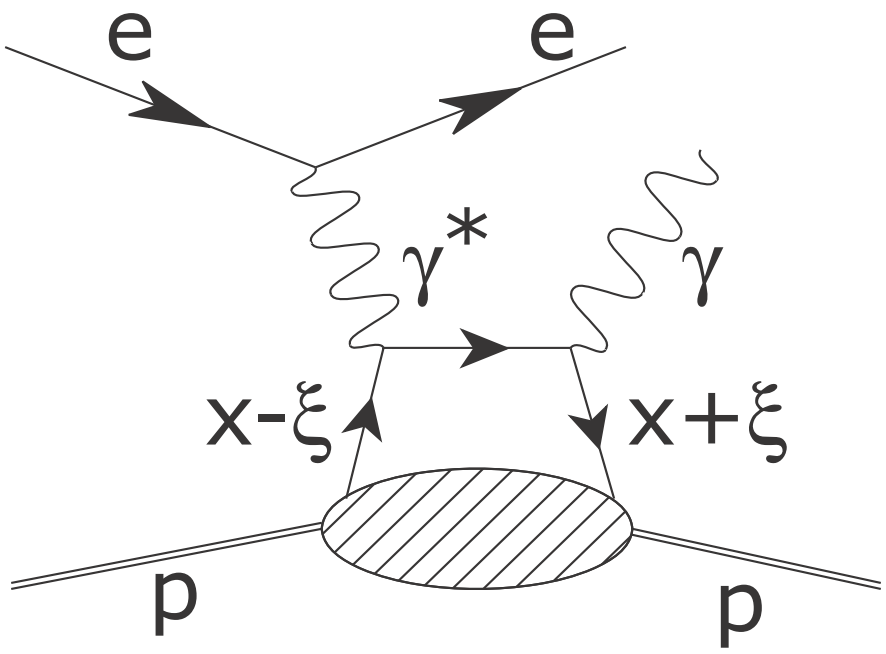
GPDs encode transverse motion of and correlations between partons

ξ - Skewedness: Momentum difference between emitted and absorbed Parton

GPDs : H, $\tilde{H}$, E, $\tilde{E}$

$$H^{q,g}(x,\xi,t) \qquad \xi \to 0 \qquad q(x), g(x)$$
$$\tilde{H}^{q,g}(x,\xi,t) \qquad \longrightarrow \qquad \Delta q(x), \Delta g(x)$$
$$t \to 0$$

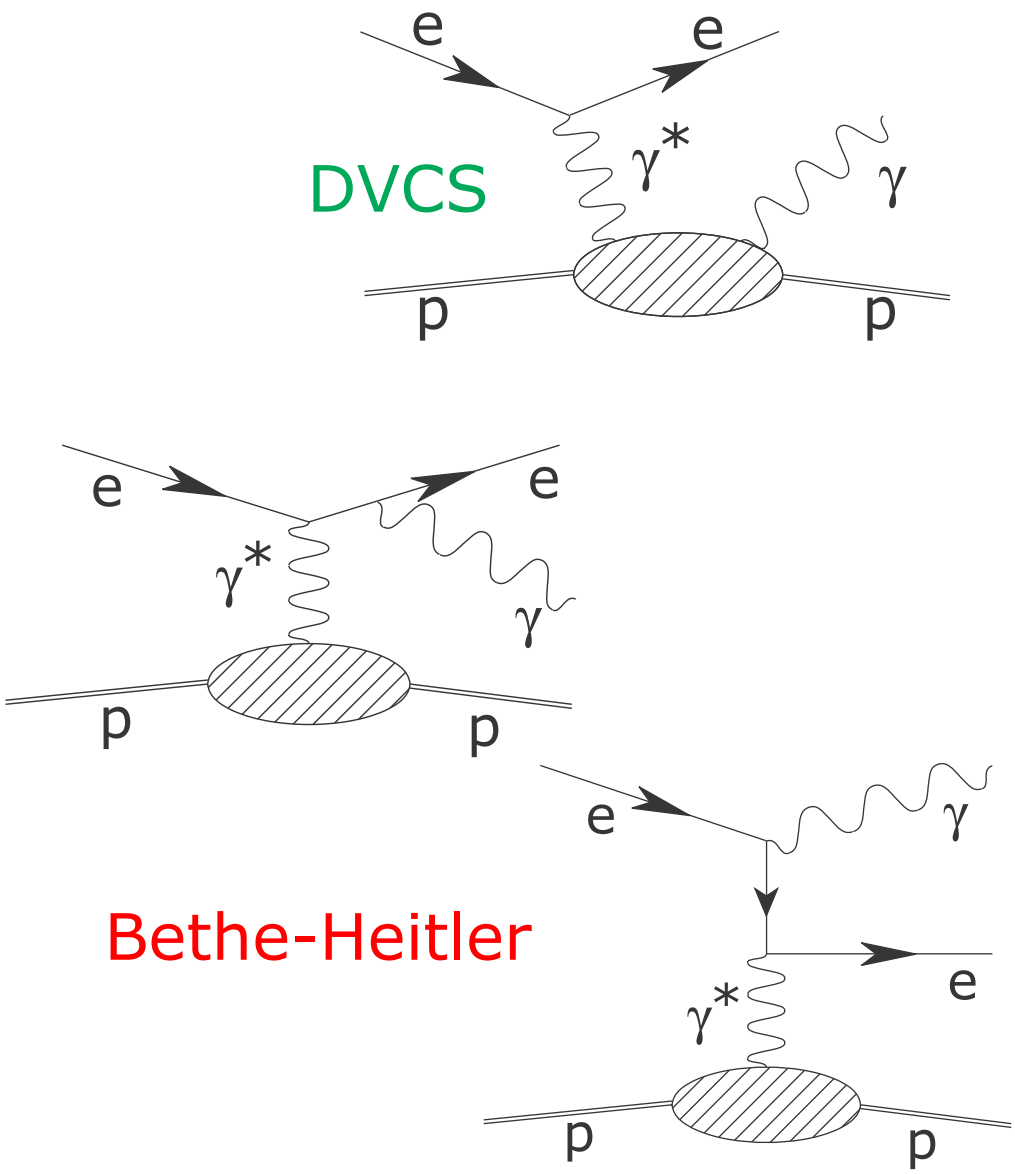
No PDF equivalent to E, $\tilde{E}$



DVCS and Bethe-Heitler

DVCS has the same final state as the Bethe-Heitler process:

- Interference gives access to amplitudes via asymmetries (HERMES)
- DVCS cross section via subtraction of B-H (calculable in QED) - Interference cancels in integration over angles



DVCS: Data selection

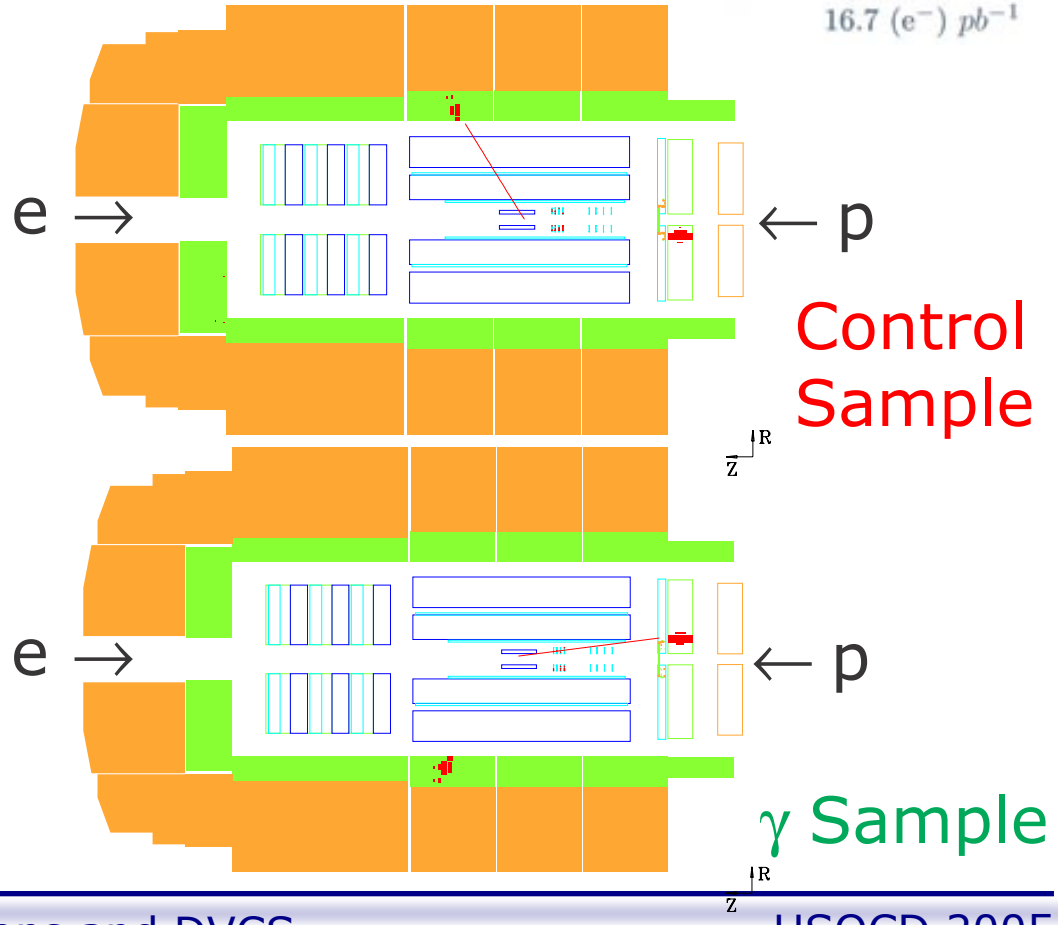
Expect one photon, one electron and nothing else in detector

	H1	ZEUS
$E_1 >$	15 GeV	10 GeV
$p_{T_2} >$	1 GeV	
$E_2 >$		3 GeV
$E_3 <$	0.5 GeV	0.2 GeV
elast.	no track, Fwd	no track
Lumi	46.5 pb^{-1} (e^+)	95 (e^+) pb^{-1}
		16.7 (e^-) pb^{-1}

Two samples:

- Electron in barrel, photon in backward direction (Mainly Bethe-Heitler)
- Photon in barrel, electron in backward direction (DVCS and Bethe-Heitler)

Use first sample to understand detector response etc.



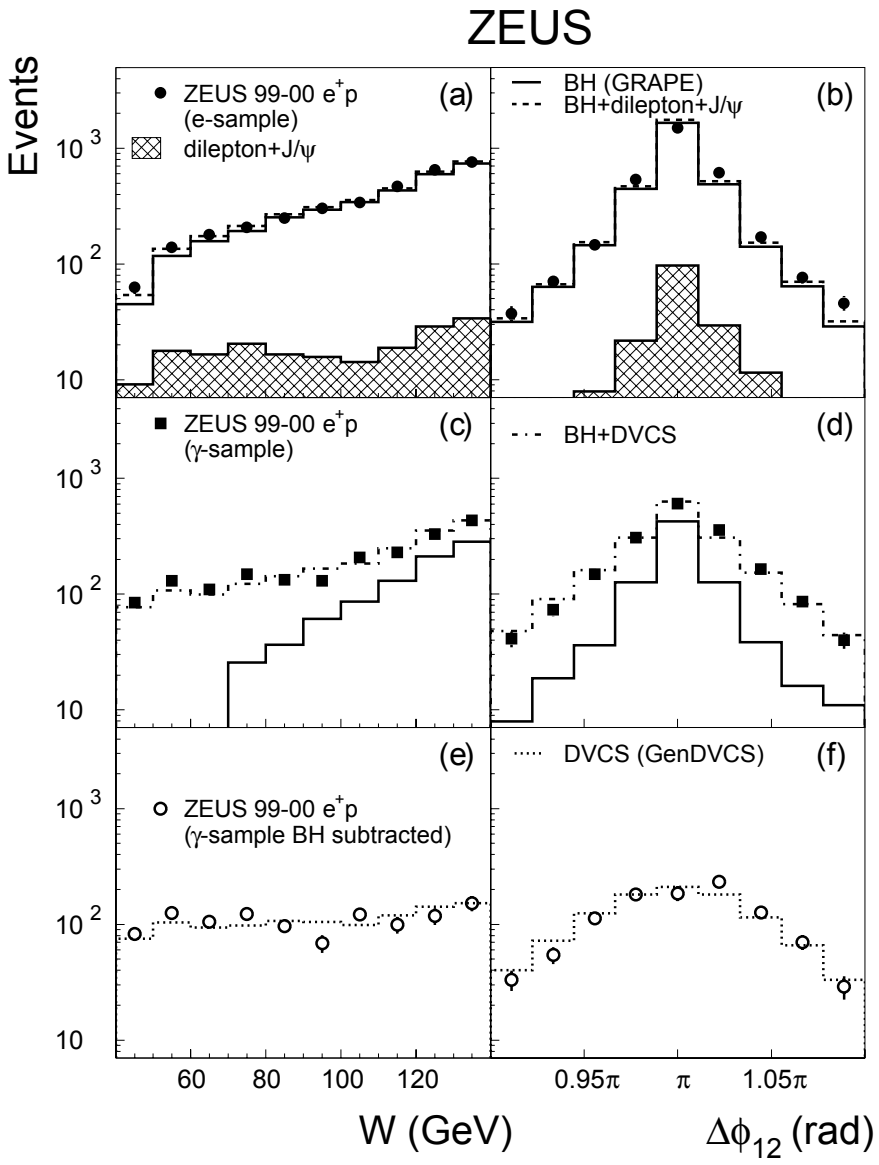
DVCS: Control Plots

- Control sample well described by Monte Carlo:
  $\Rightarrow$ Detector understood

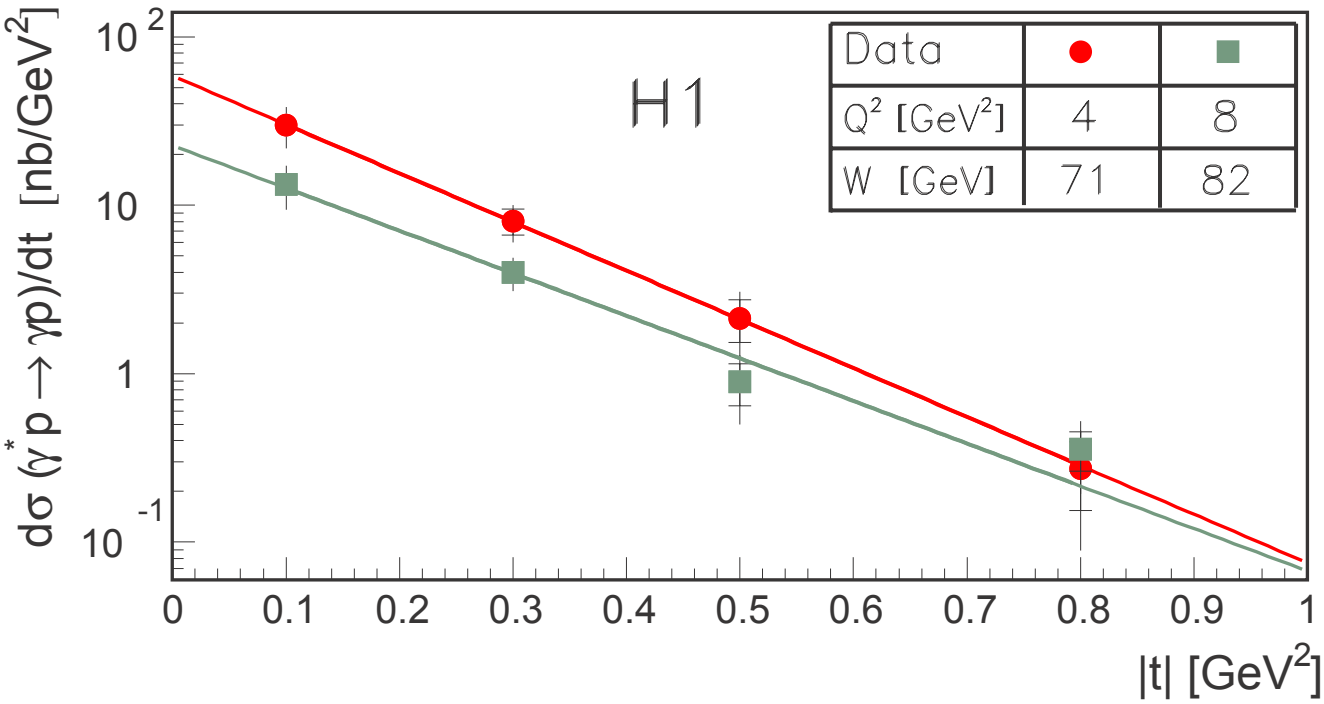
- Good description of γ sample by DVCS+B-H Monte Carlo

Extract DVCS cross section by:

- Subtracting B-H contribution
- $\sigma_{ep} \rightarrow \sigma_{\gamma^* p}$ (/flux factor)



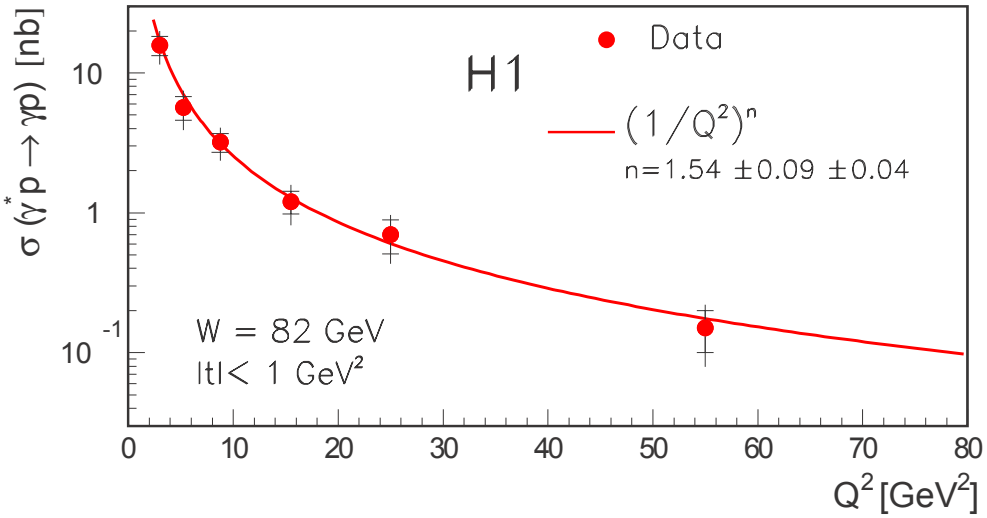
DVCS: t dependence



- First measurement of t dependence
- Exponential fit in t: $d\sigma/dt \propto e^{-bt}$
  $b = 6.02 \pm 0.35 \pm 0.39$ GeV^{-2} at $Q^2 = 8$ GeV
- No Q^2 dependence of b observed within errors
- Constrains theory normalisation

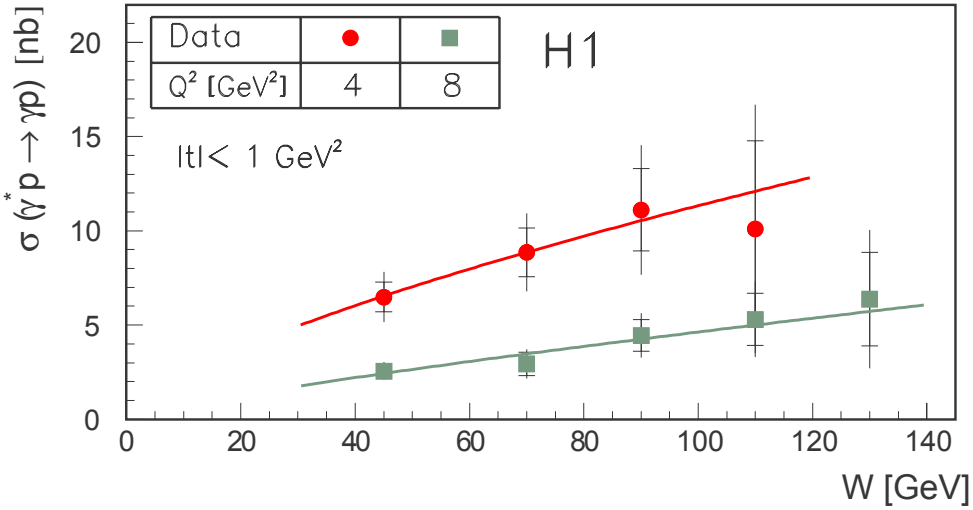
DVCS: Q^2 and W dependencies

- Fit in Q^2: $(1/Q^2)^n$
  $n = 1.54 \pm 0.09 \pm 0.04$



- W dependence for 2 Q^2 values - Fit W^δ
  $\delta = 0.77 \pm 0.23 \pm 0.19$

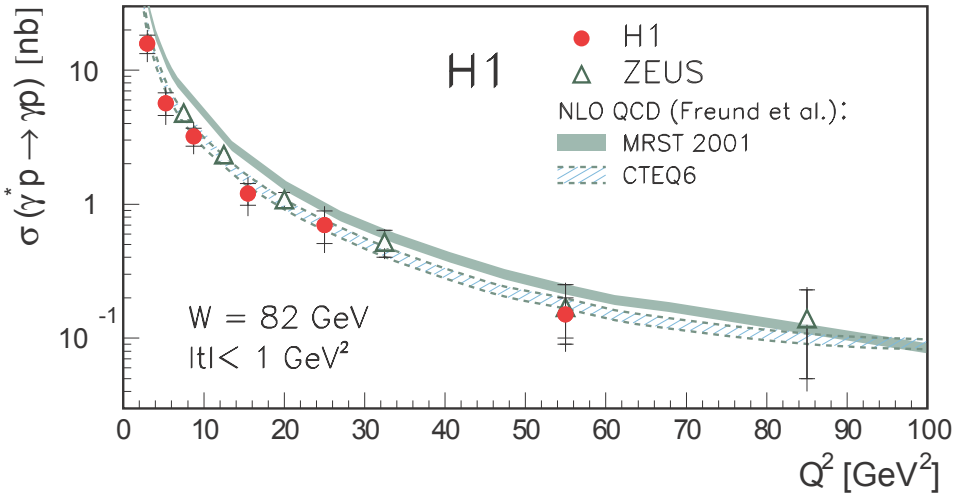
  Indicates hard regime (cf. J/Ψ Production)

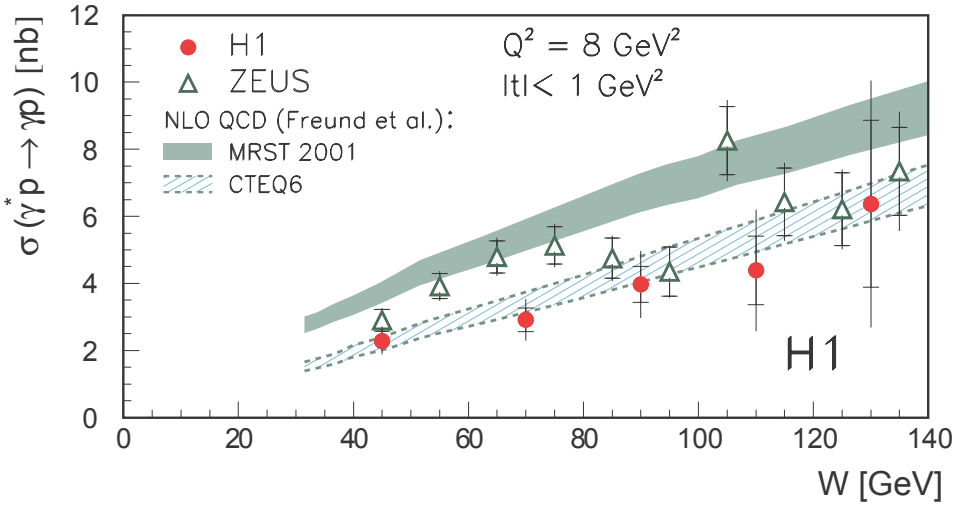


DVCS: Comparison with QCD Predictions

Comparison to NLO QCD:

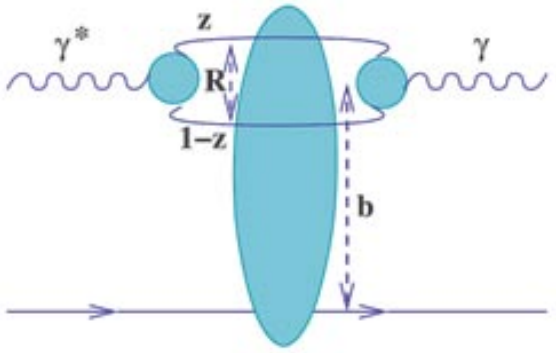
- Band width reduced by *t* slope measurement
- Good description of the data
- Sensitive to GPD parametri-sations?



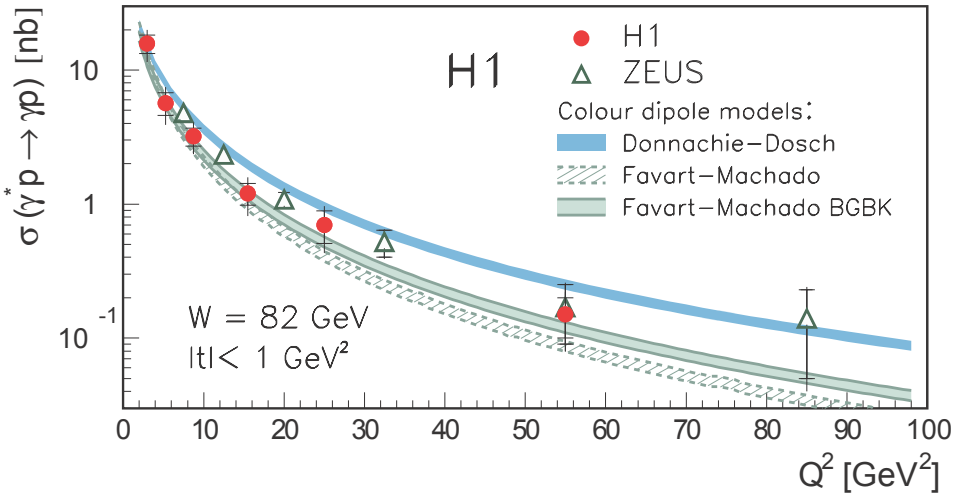


DVCS: Comparison with Colour Dipoles

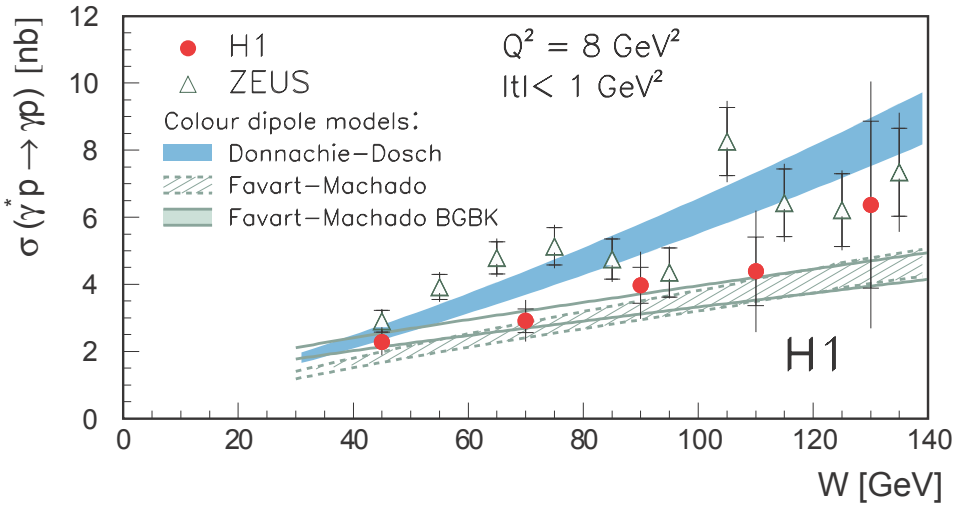
In proton rest frame:



Photon fluctuates to $q\bar{q}$



- Donnachie-Dosch: Hard and soft $I\!P$ (Phys.Lett. B502 (2001) 74)
- Favart-Machado: saturation model (Eur.Phys.J. C29 (2003) 365)
- Good description of shape and normalisation



Conclusion

- Experimental data from vector mesons and DVCS are beginning to constrain the proton structure
- Complimentary to inclusive analyses: Gluons at low x and transverse degrees of freedom become accessible
- Gain insight into transition from soft to pQCD region
- Transition is very gradual and all involved scales can make a process harder
- There is still a lot to be measured and to be calculated

Outlook

- HERA II is running well:
  95 pb^{-1} delivered in 2004
  160 pb^{-1} up to now in 2005

- DVCS will profit from higher statistics

H1: New Fast Track Trigger with much improved selectivity for exclusive final states:

- High statistics ρ and ϕ photoproduction samples
- J/Ψ and Υ to electrons are accessible