Elastic Vector Meson Production and DVCS at HERA

Jan Olsson, DESY

For the H1 and ZEUS Collaborations

New Results in

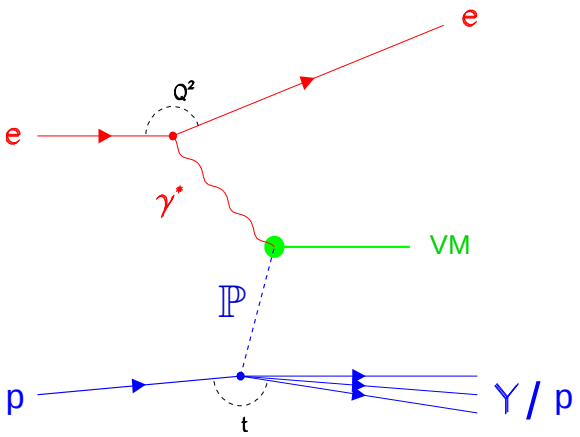
- ϕ electroproduction
- J/ψ photo- and electroproduction
- DVCS

EPS HEP2005

Lisboa, Portugal

21-27 July, 2005

ELASTIC VECTOR MESON PRODUCTION



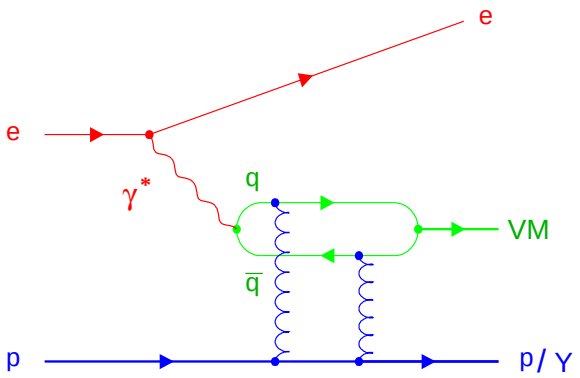
Q^2 **Photon Virtuality**

Photoproduction: $Q^2 \sim 0$

t **(Mom. transfer at** p **– vertex)²**

large $|t| \Rightarrow$ **Proton dissociates**

W **CM – energy of** γp **– system**



Regge Approach: **"Soft ℙomeron" exchange**

Slow rise of σ **with increasing** W

$$\sigma \propto W^{0.22}$$

Shrinkage of forward peak with increasing W

$$d\sigma/dt \propto e^{bt}\,(W/W_0)^{4(\alpha_{I\!P}(t)-1)}$$

$$\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P}\,t \qquad (\alpha'_{I\!P} = 0.25)$$

$$b = b_0 + 4\,\alpha'_{I\!P}\,ln(W/W_0)$$

S-Channel Helicity Conservation, SCHC

pQCD Approach: **Exchange of Gluons**

Steep rise of σ **with increasing** W

increasing gluon density in the proton at small x

$$(xW^2 \approx Q^2)$$

No (or little) shrinkage of the diffractive peak

SCHC violation

pQCD needs a hard scale: $Q^2,\ M^2_{VM},\ t,\ (Q^2+M^2_{VM})$

EXCLUSIVE ELECTROPRODUCTION OF ϕ MESONS

ZEUS Collaboration, DESY-05-038 hep-ex/0504010

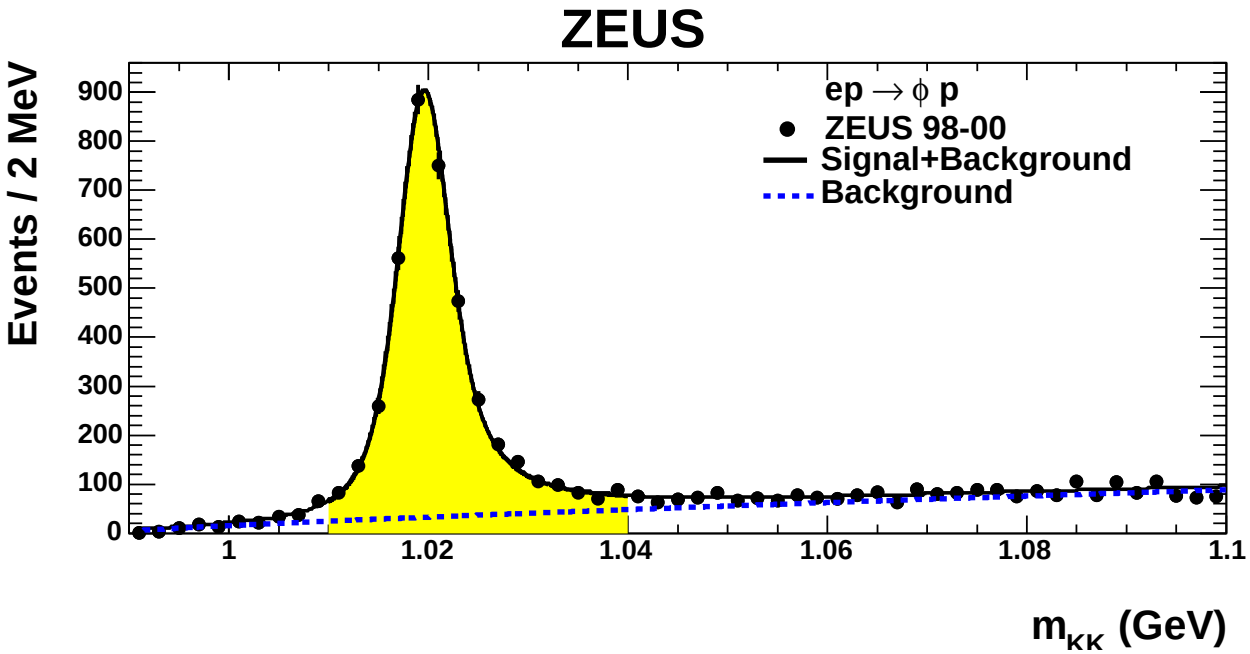
DATA

1998-2000 $e^{\pm}p$

65.1 pb^{-1}

$\sim$4000 events

$\phi \rightarrow K^+K^-$

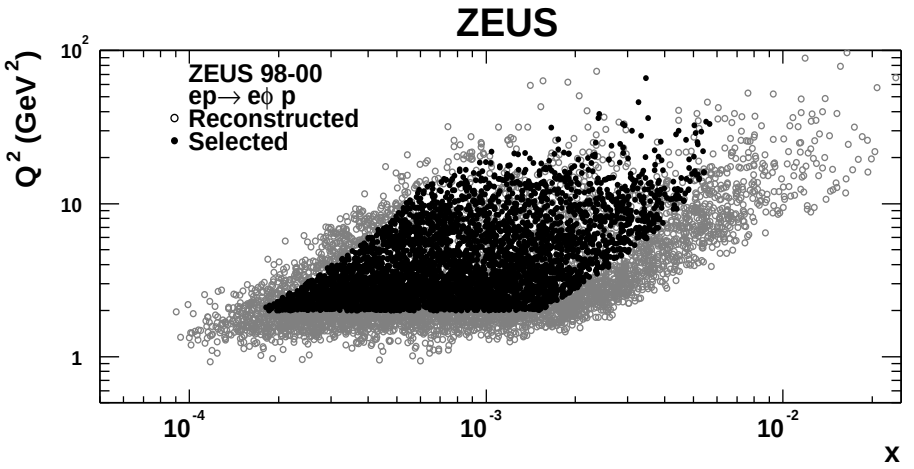


$2 < Q^2 < 70$ GeV^2 $\quad \langle Q^2 \rangle = 5$ GeV^2

$35 < W < 145$ GeV

$|t| < 0.6$ GeV^2

(suppress $p-$dissociation bkgr.)



EXCLUSIVE ELECTROPRODUCTION OF ϕ MESONS

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

Fit in bins of Q^2

Weak dependence on Q^2

$b \sim 5 - 6\ \mathrm{GeV}^{-2}$

relate to radii of scattering particles

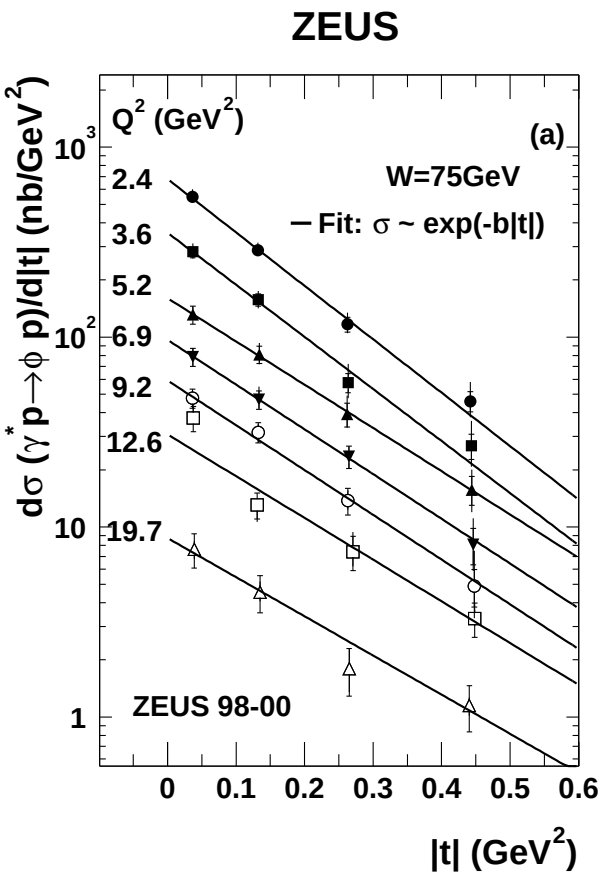
$b \propto R_p^2 + R_{q\bar{q}}^2 \qquad R_p^2 \sim 4\ \mathrm{GeV}^{-2}$

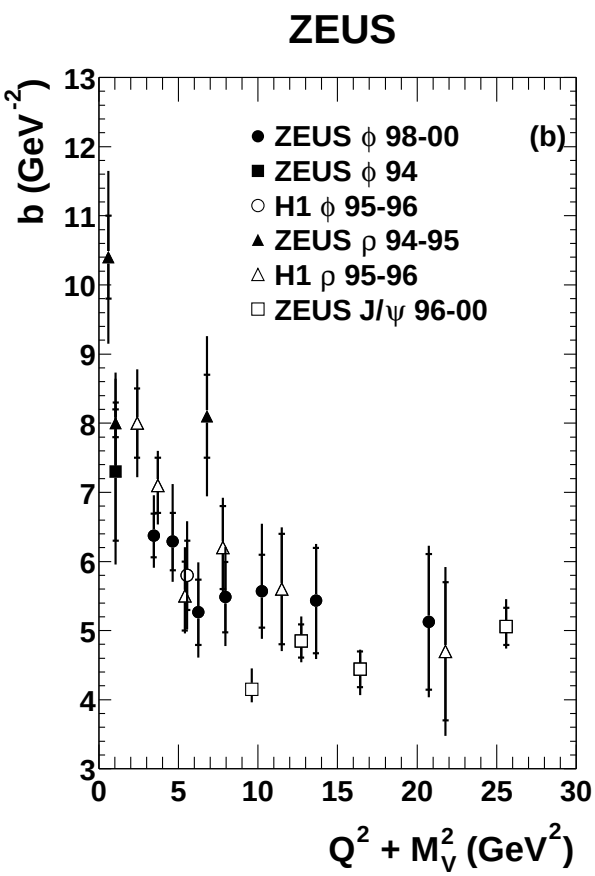
$\sigma(W) \sim W^{\delta}$

Fit in bins of Q^2

No dependence on Q^2

$\delta \sim 0.4$



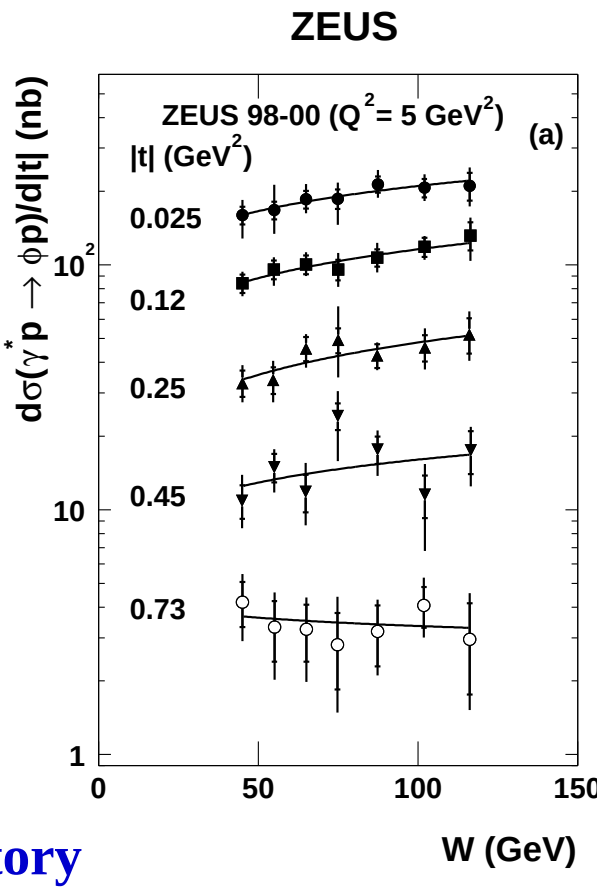


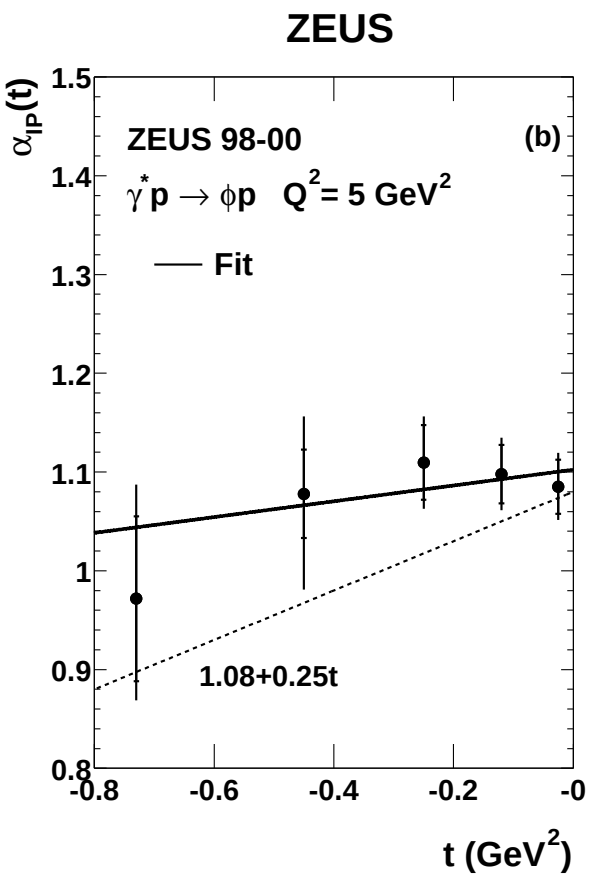
ϕ production: Data confirm transition from soft to hard scattering

EXCLUSIVE ELECTROPRODUCTION OF ϕ MESONS

$$d\sigma/d|t| \sim W^{\delta}$$
$$= W^{4(\alpha(t)-1)}$$

Fit in bins of $|t|$





Extract the "effective" trajectory

$$\alpha(t) = 1.10 + (0.08 \pm 0.09 \pm 0.08)\, t$$

Value of α' smaller than the "soft pomeron" value (0.25)

Decay Angular Distributions

Provide information about the Spin Density Matrix Elements

r_{00}^{04} : **probability to produce longitudinal ϕ, from either transverse or longitudinal γ^***

$$d\sigma/d\cos\theta^* \propto 1 + r_{00}^{04} + (1 - 3r_{00}^{04})\cos^2\theta^*$$

Assuming SCHC,

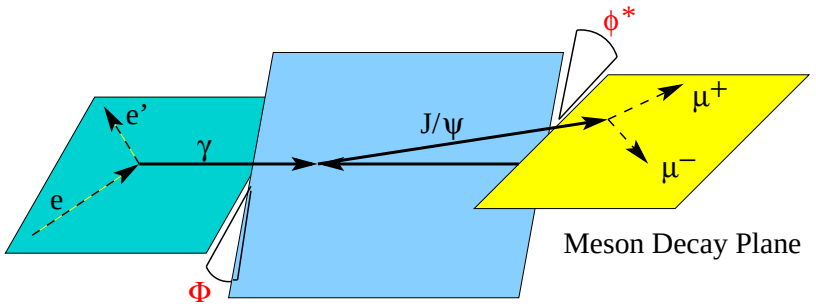
$$R = \sigma_L/\sigma_T = \frac{1}{\epsilon}\frac{r_{00}^{04}}{(1-r_{00}^{04})}$$

$$\sigma = \sigma_T + \epsilon\sigma_L$$

$(\epsilon \simeq 0.99)$

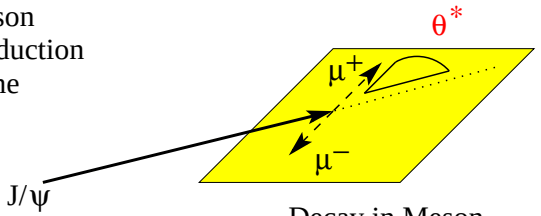
σ_L and σ_T separately measurable

HELICITY SYSTEM

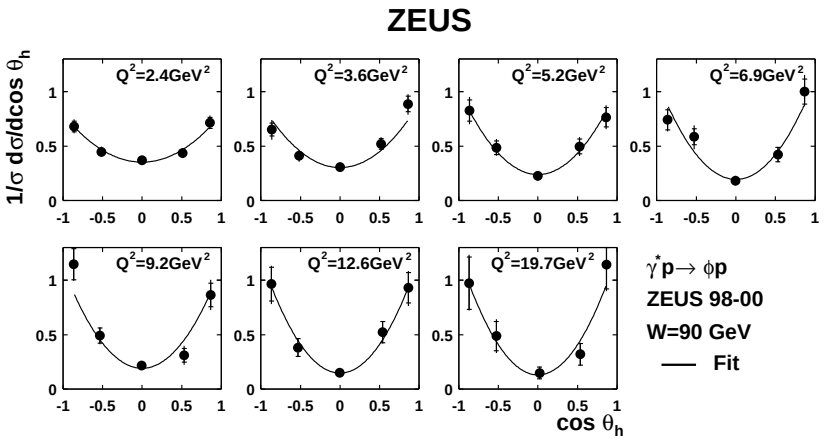


Lepton Scattering Plane

Meson Production Plane



Decay in Meson Rest Frame

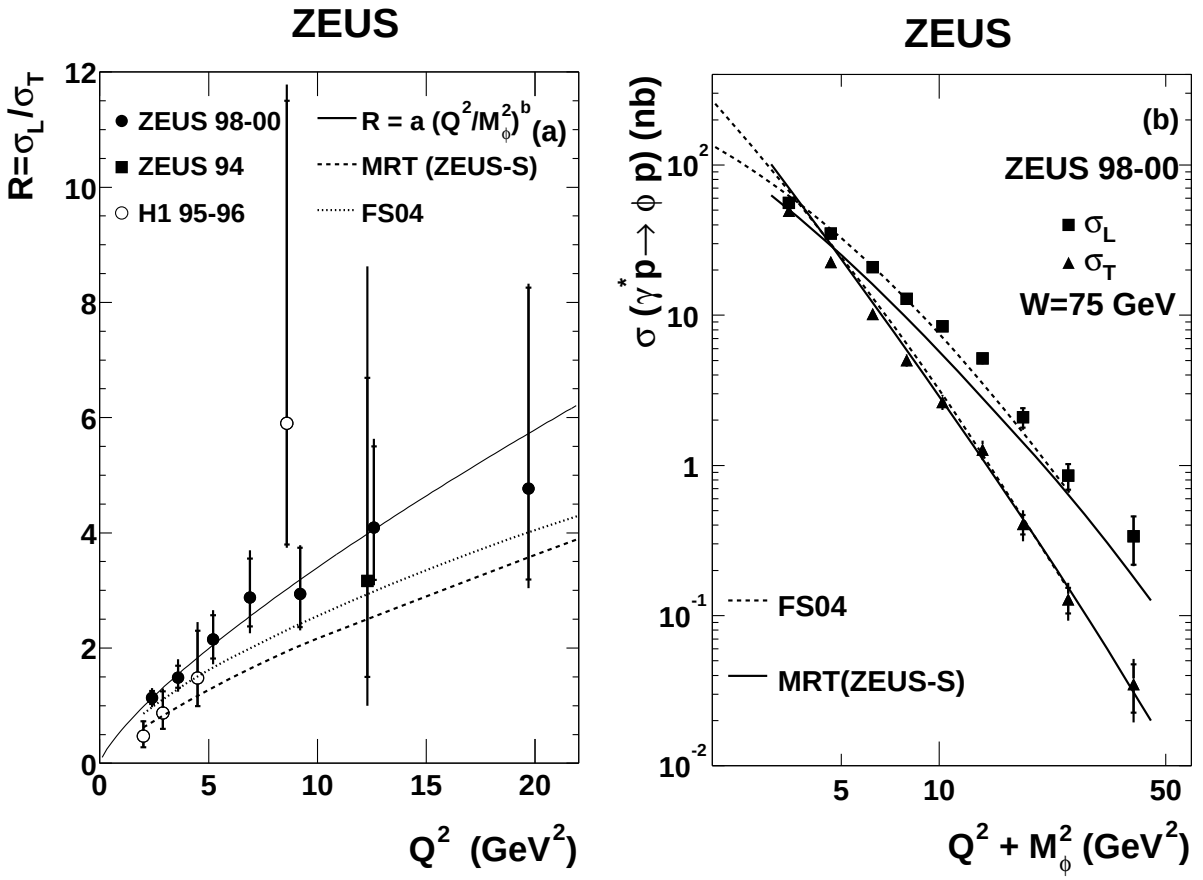


EXCLUSIVE ELECTROPRODUCTION OF ϕ MESONS

R increases with increasing Q^2

Q^2 dependences different for σ_L, σ_T
At large Q^2, σ_L dominates over σ_T

pQCD models ★ agree with trend of data



★ **Forshaw, Shaw** **Martin, Ryskin, Teubner**

EXCLUSIVE PHOTO- AND ELECTROPRODUCTION OF J/ψ MESONS

H1 Collaboration, Preliminary

DATA

1999-2000 **55 pb^{-1}**

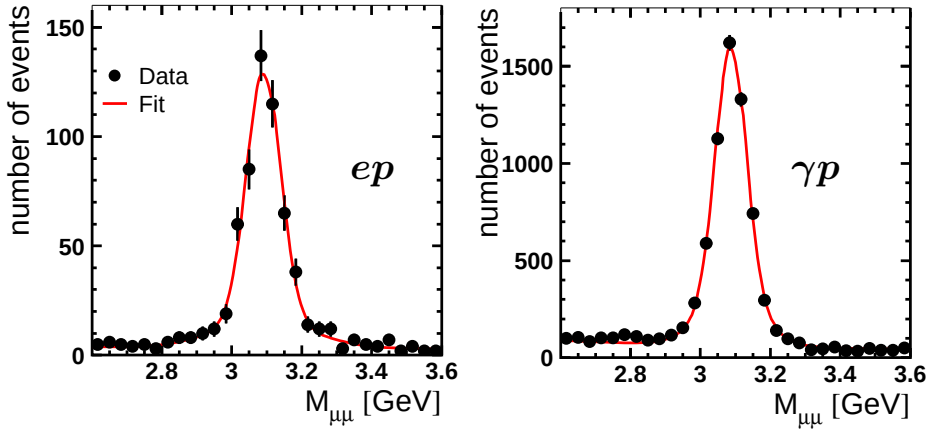
Electroproduction:

- $2 < Q^2 < 80$ **GeV**^{2} $\quad \langle Q^2 \rangle = 8.9$ **GeV**^{2}
- $40 < W < 160$ **GeV**
- $J/\psi \to \mu^+\mu^-$

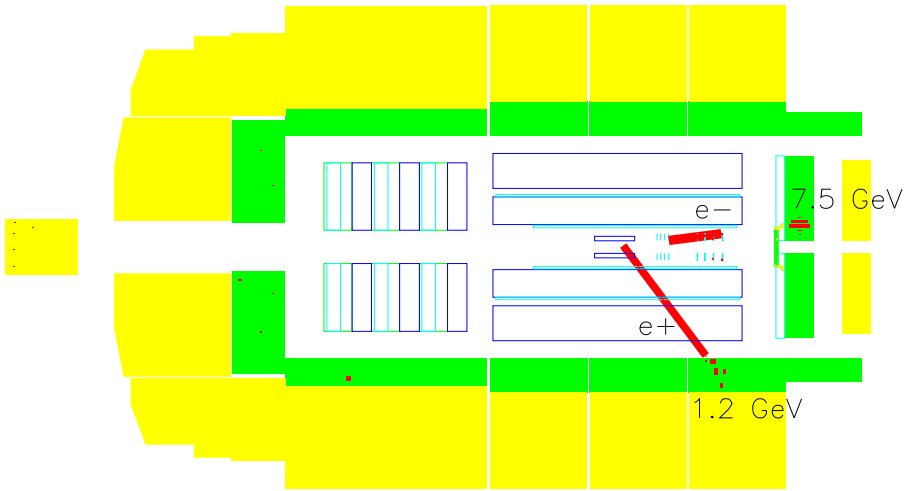
Photoproduction:

- $40 < W < 305$ **GeV**
- $J/\psi \to \mu^+\mu^-,\ e^+e^-$
- **Topologies in detector:**
  Track-Track, Track-Cluster, Cluster-Cluster

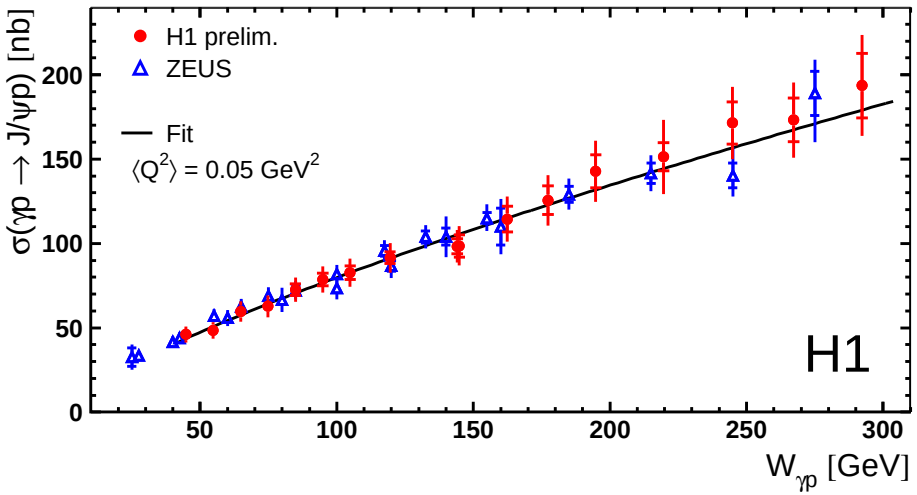
All samples: $|t| < 1.2$ **GeV**^{2}
(Suppress p-dissociation background)

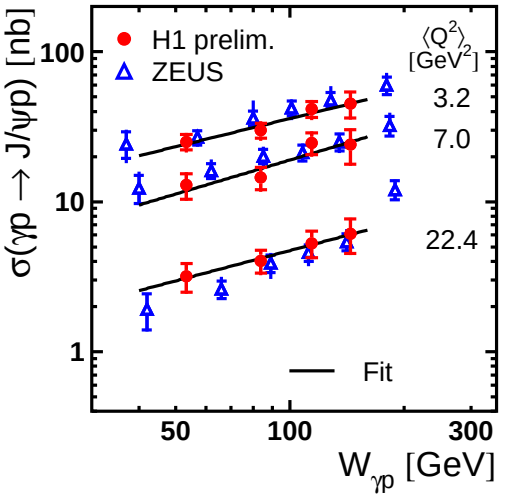


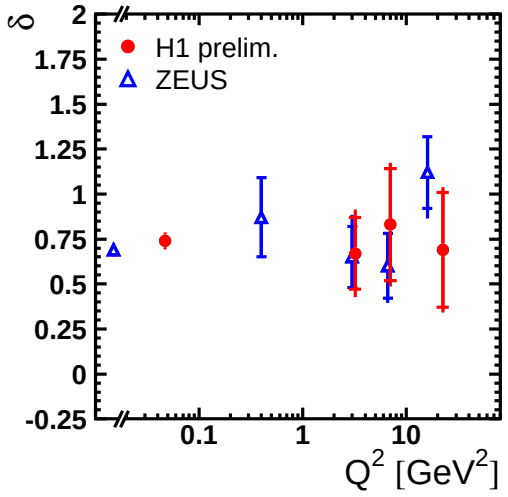
a photoproduction event, $J/\Psi \to e^+e^-$

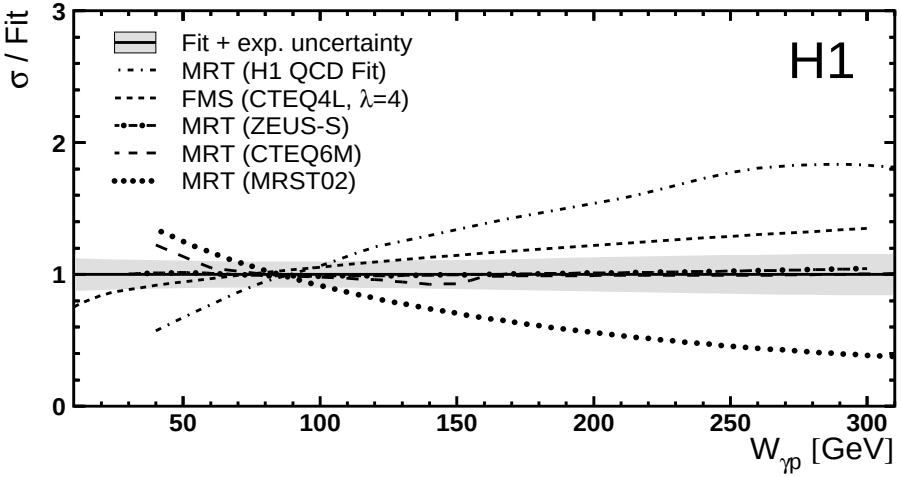


EXCLUSIVE PHOTO- AND ELECTROPRODUCTION OF J/ψ MESONS









W – dependence

Fit $\sigma(W) \propto W^{\delta}$

in photoproduction and in bins of Q^2

No Q^2**–dependence,** $\delta \sim 0.75$

J/ψ **"pointlike" already in photoproduction**

Data sensitive to Gluon distribution in proton

$W-t-$dependence

2-dimensional fits,

$$d\sigma/dt(W,t) \propto e^{b_0 t} W^{\delta}$$

where $\delta = 4(\alpha(t)-1)$

$$\alpha(t) = \alpha_0 + \alpha' t$$

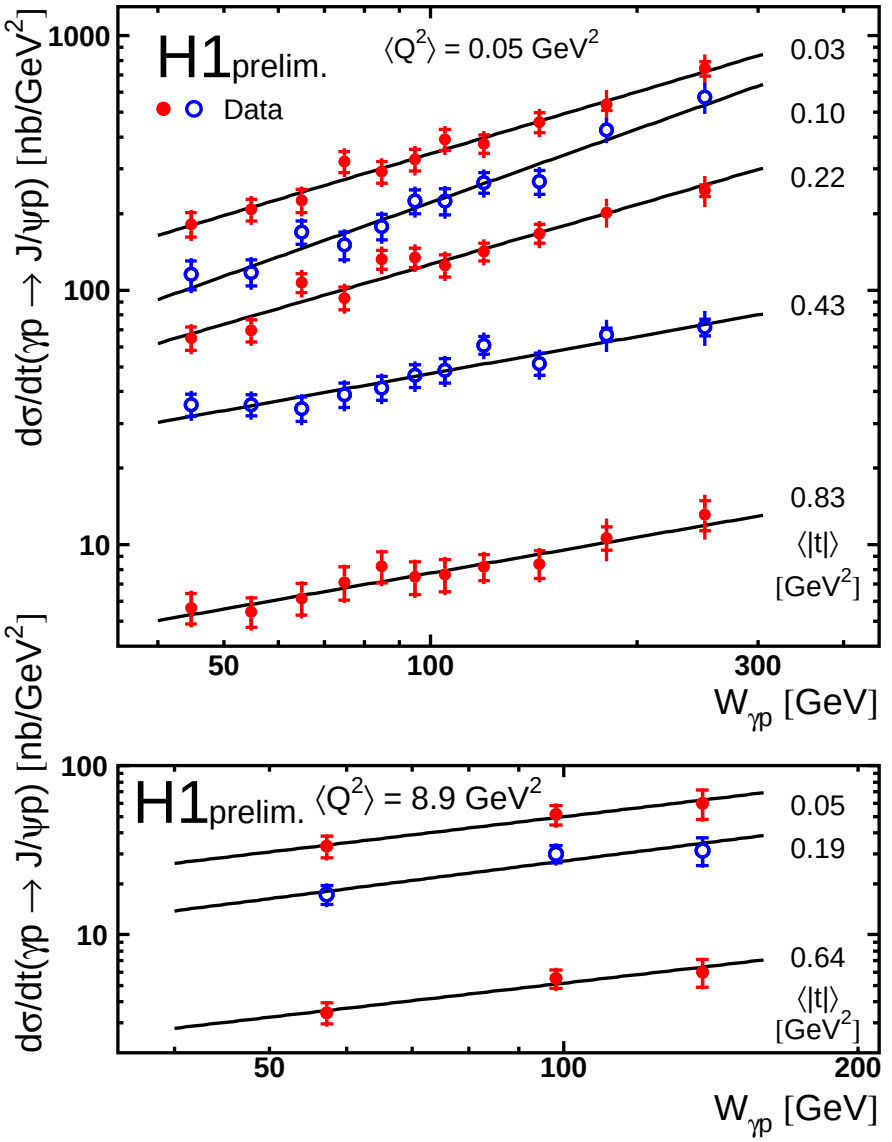
"effective" Pomeron trajectory

1-dimensional fits,

$d\sigma/dt \propto W^{\delta}$ **in bins of** t

(curves in figures)

$d\sigma/dt \propto e^{b(W)t}$ **in bins of** W



"effective" Pomeron trajectory

Photoproduction:

$$\alpha(t) = 1.224 \pm (0.164 \pm 0.028 \pm 0.030)t$$

Electroproduction:

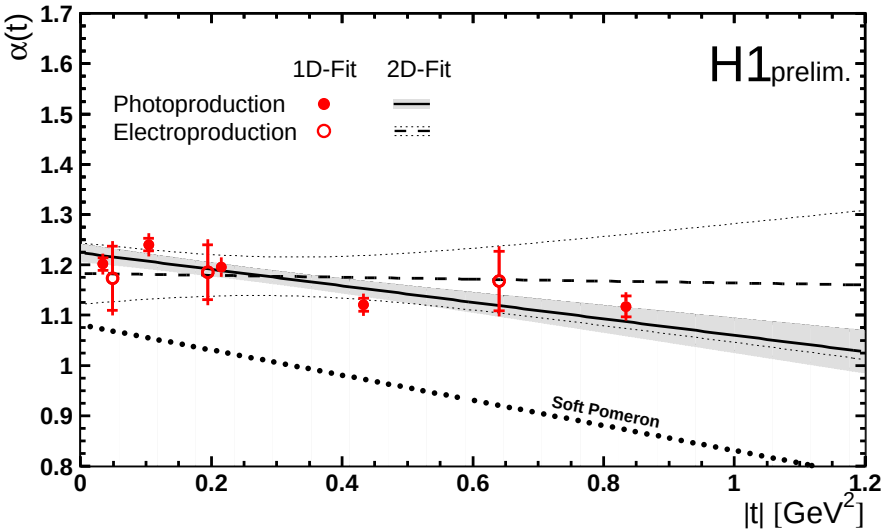
$$\alpha(t) = 1.183 \pm (0.019 \pm 0.139 \pm 0.076)t$$

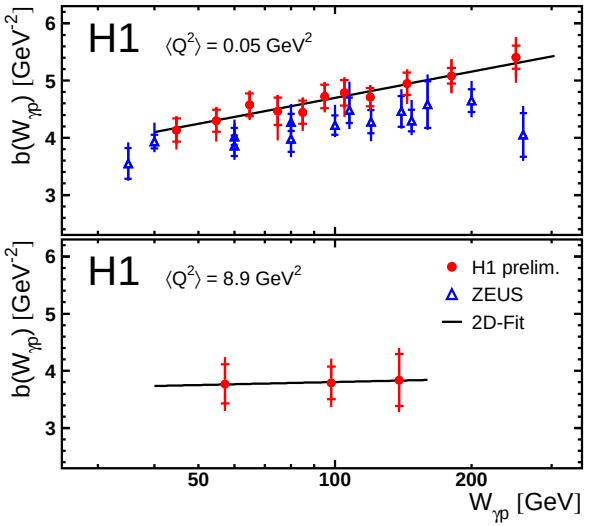
Within errors, the trajectories are similar

Shrinkage: **Seen in Photoproduction**

Cf. alternative $d\sigma/dt \propto e^{b(W)t}$

$\Longrightarrow$ b **increases with** W





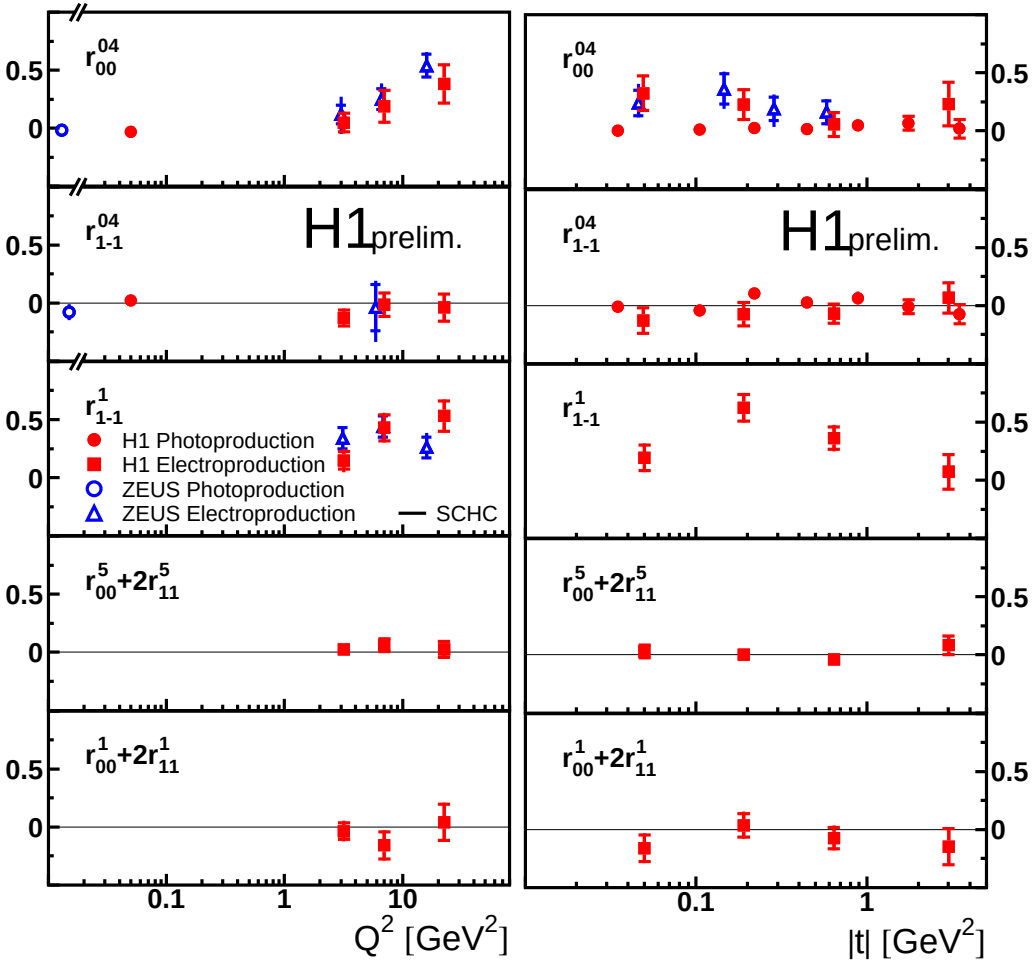
Helicity Analysis

Q^2- and $t-$dependence of Spin Density Matrix Elements

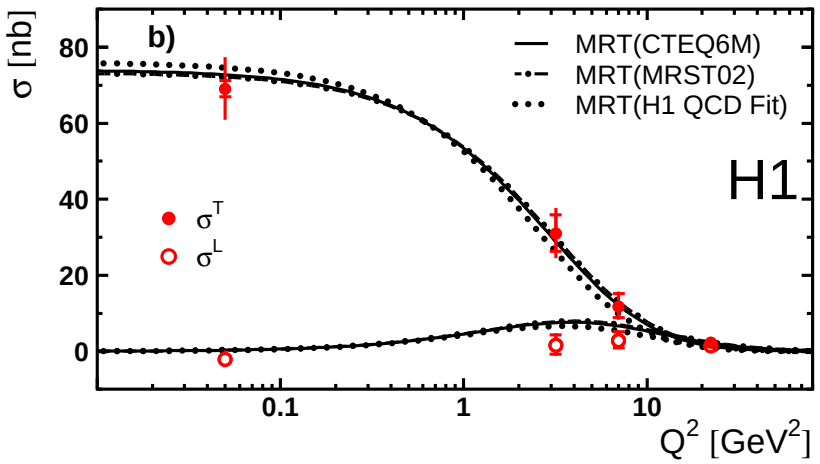
Data agree with

S-Channel Helicity Conservation

$\Longrightarrow$ **Use r_{00}^{04} to extract σ_L and σ_T**



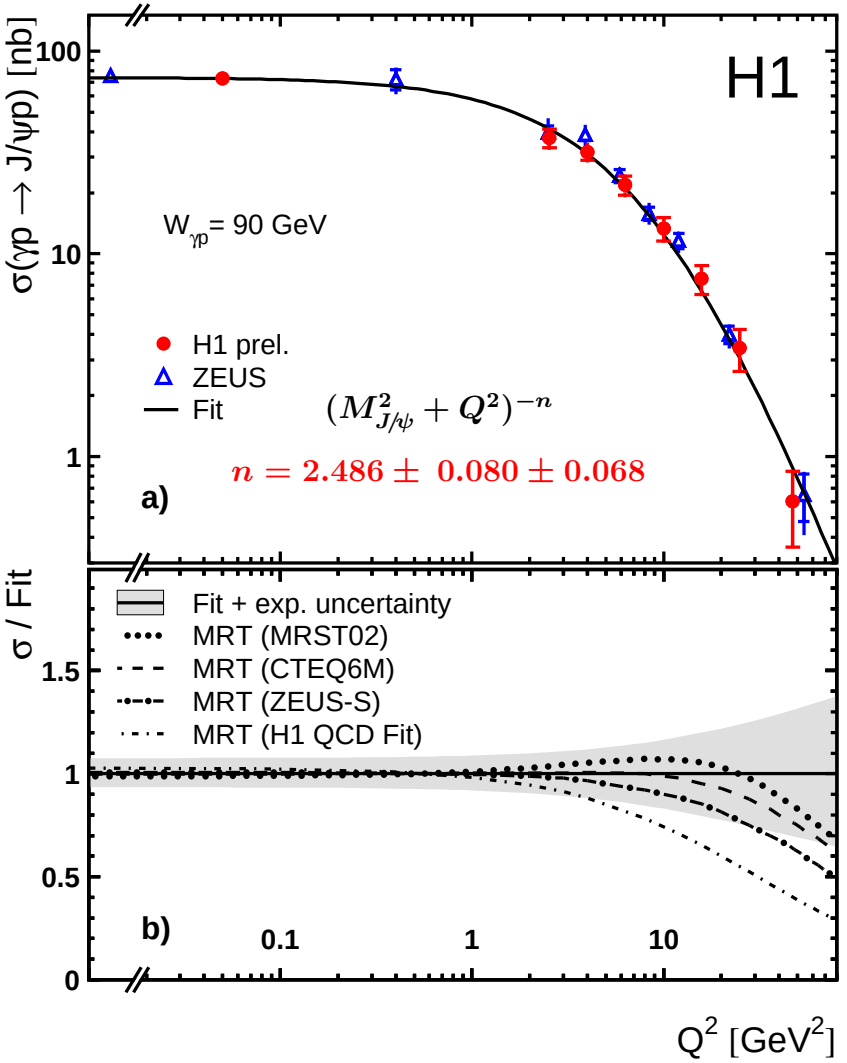
EXCLUSIVE PHOTO- AND ELECTROPRODUCTION OF J/ψ MESONS



At large Q^2, $\sigma_L \sim \sigma_T$

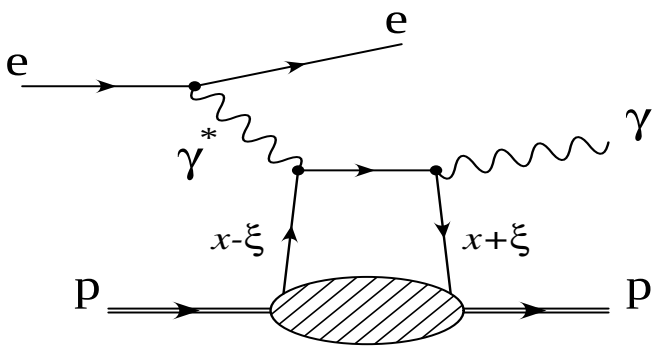
MRT* pQCD predictions:

Separate calculation of σ_T and σ_L
Good description of data
At large Q^2, data sensitive to Gluon distribution

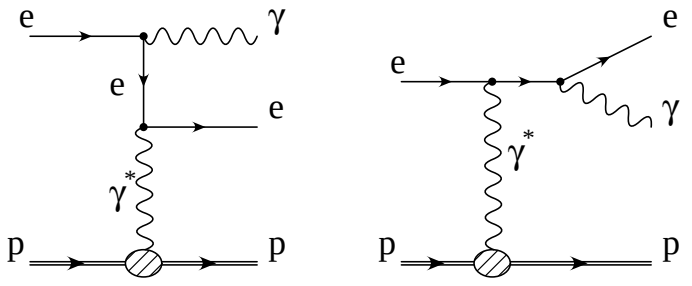


* **Martin, Ryskin, Teubner**

DVCS: $e + p \rightarrow e + p + \gamma$



- **Simplest scattering process**
- **Fully calculable in pQCD**
  since no Vectormeson Wave-function
- **Skewedness ξ non-zero**
  since γ^*-mass non-zero
- **Access to GPDs (Generalized Parton Distributions)**
- **Access to Scattering Amplitude**
  - ▷ **via Interference with the Bethe-Heitler process**
  - ▷ **via Asymmetry measurements with different beam charges and polarizations**



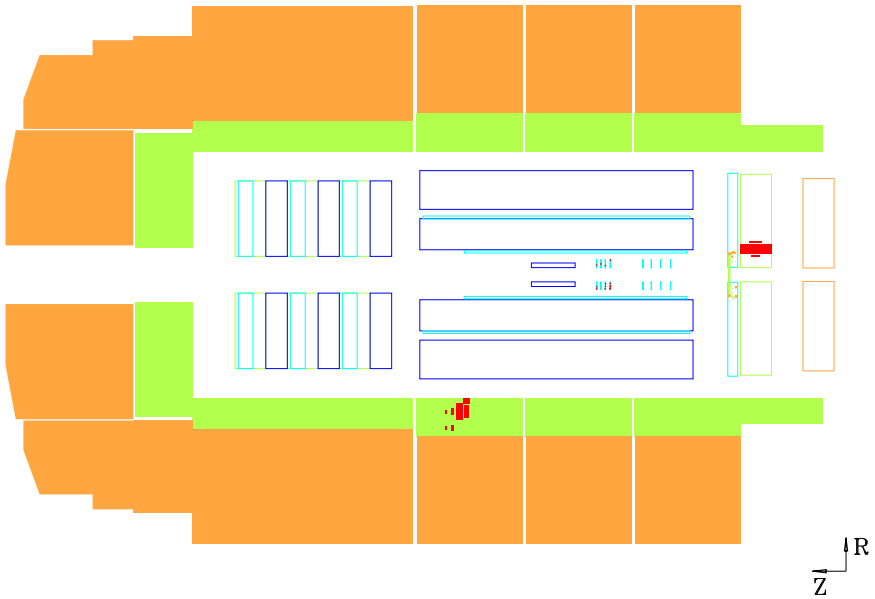
H1 Collaboration, DESY-05-065 hep-ex/0505061

DATA

1996-1997, 1999-2000 e^+p

$E_{e^+} = 27.6$ GeV,
$E_p = 820,\ 920$ GeV
11.5, 35 pb^{-1}
$\sim$1240 events

$2 < Q^2 < 80$ GeV^2 (1996-1997)
$4 < Q^2 < 80$ GeV^2 (1999-2000)
$3 < W < 140$ GeV
$|t| < 1$ GeV^2



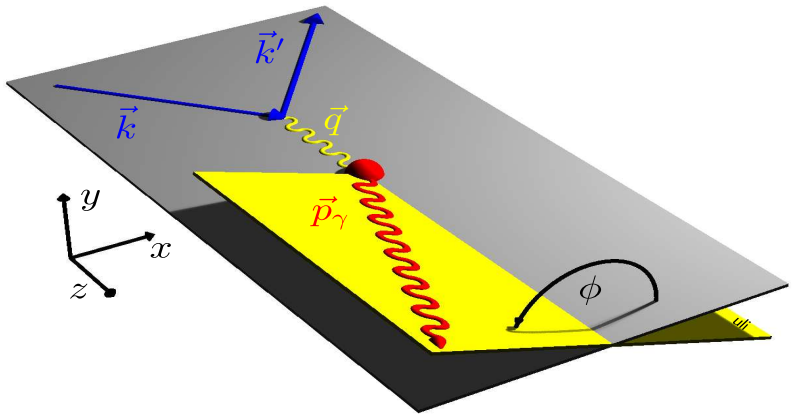
DVCS sample: e^+ in SpaCal, γ in LAr
BH Control sample: γ in SpaCal, e^+ in LAr

$$\sigma = \sigma_{DVCS} + \sigma_{BH} + I_{BH,DVCS}$$

σ_{BH} calculable, using proton form factors: subtract

I depends on angle ϕ: here $I \sim 0$

$\Longrightarrow$ σ_{DVCS} can be measured



$t-$ dependence

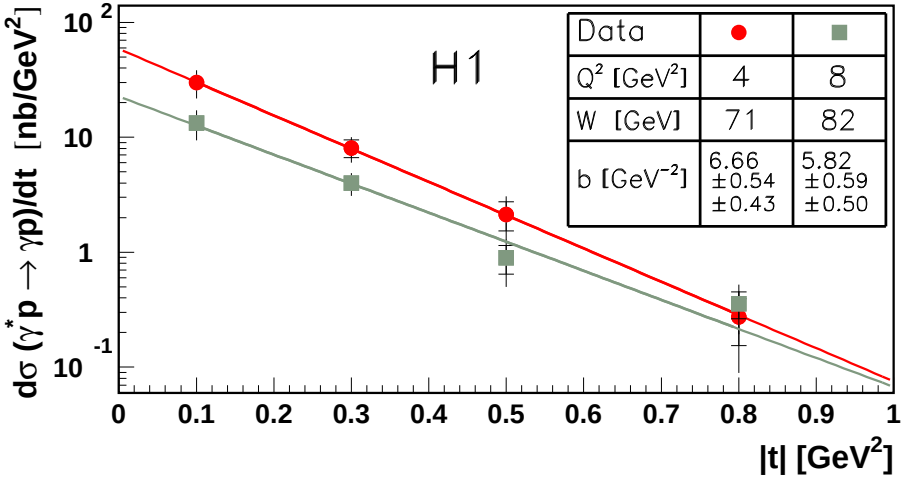
Measured for the first time

Combined value at $\langle Q^2 \rangle = 8$ GeV^2:

$$b = 6.02 \pm 0.35 \pm 0.39 \ \text{GeV}^{-2}$$

Model calculations: Normalisation possible!

(Previously used $b = 7 \pm 2$ GeV^{-2})

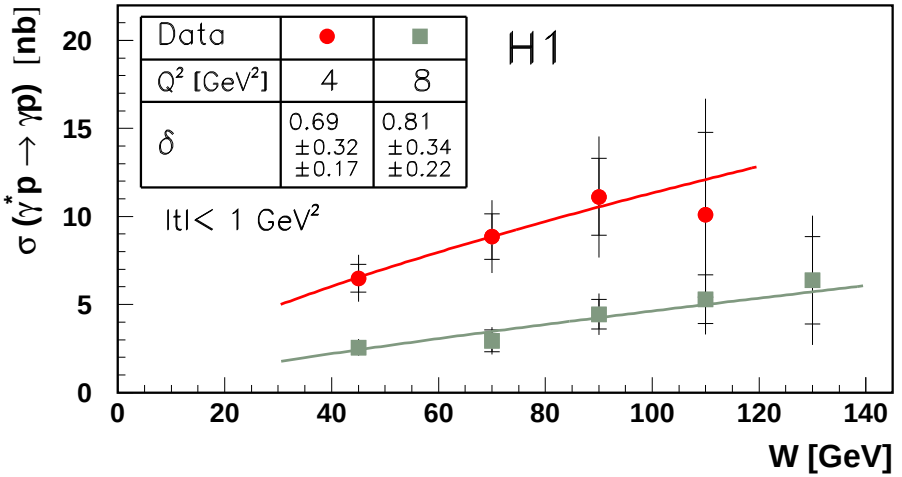


$W-$ dependence

Steep, similar to J/ψ

Combined value at $\langle Q^2 \rangle = 8$ GeV^2:

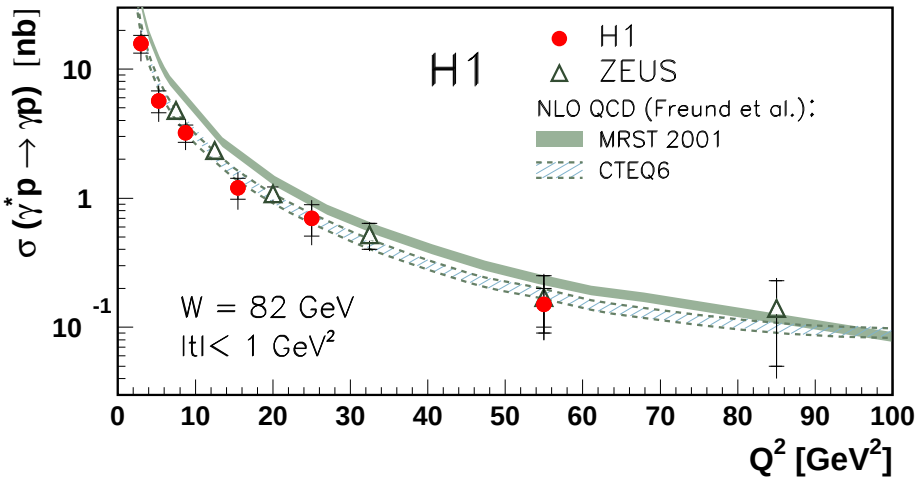
$$\delta = 0.77 \pm 0.23 \pm 0.19$$

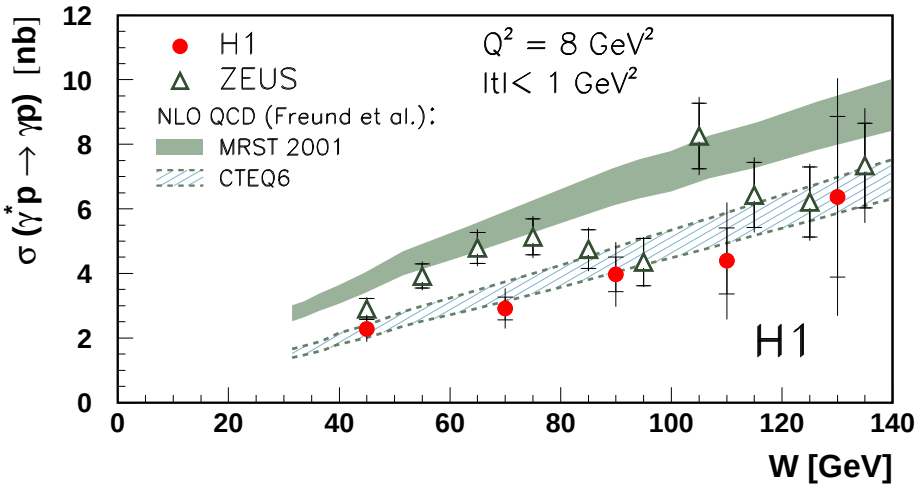


pQCD Calculations★

- NLO leading twist, hard scale Q^2
- Use measured t: normalisation possible
- factorize into hard scattering and non-perturbative GPDs
- GPDs depend on
  - ▷ longitudinal momentum fraction ξ
  - ▷ momentum exchange at $p-$vertex, t
- Starting point of GPDs: normal PDFs, here CTEQ6, MRST2001
- Dynamic generation of ξ; No intrinsic Skewedness

Fair description of data
Potential sensitivity to GPDs





★ **Freund, McDermott, Strikman**

S U M M A R Y

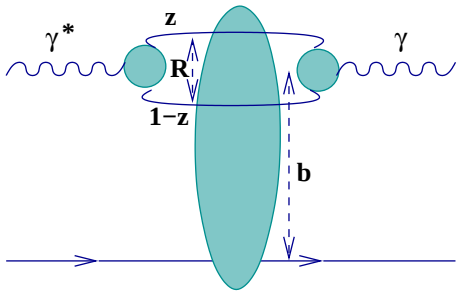
Elastic Vector Meson Production

- **New Measurements:**
  - ▷ **Electroproduction of** ϕ
  - ▷ **Photo- and Electroproduction of** J/ψ**,**
  - ▷ **as function of** W, Q^2 **and** t
- **"Effective" trajectories determined from** $W - t-$**dependence: harder than "soft Pomeron"**
- σ_L **and** σ_T **measured via Helicity Analysis**
- **pQCD and** Q^2-**dependence: Fair descriptions of** J/ψ **and** ϕ **data**

DVCS

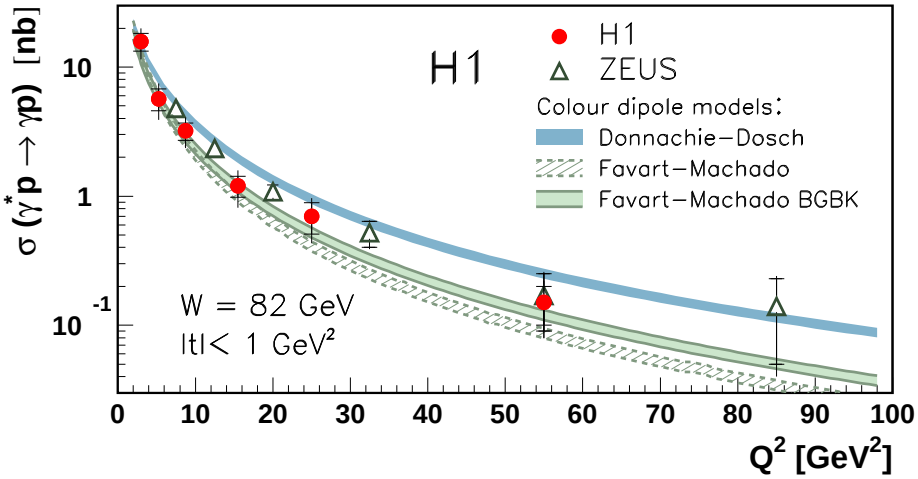
- **New measurement of the cross section, as function** W, Q^2 **and** t
- **First measurement of** $t-$**dependence:** $\Longrightarrow$ **Normalisation of models possible**
- **Data potentially sensitive to GPDs: pQCD NLO calculations agree well with measurements**
- **Colour Dipole models also describe the data**

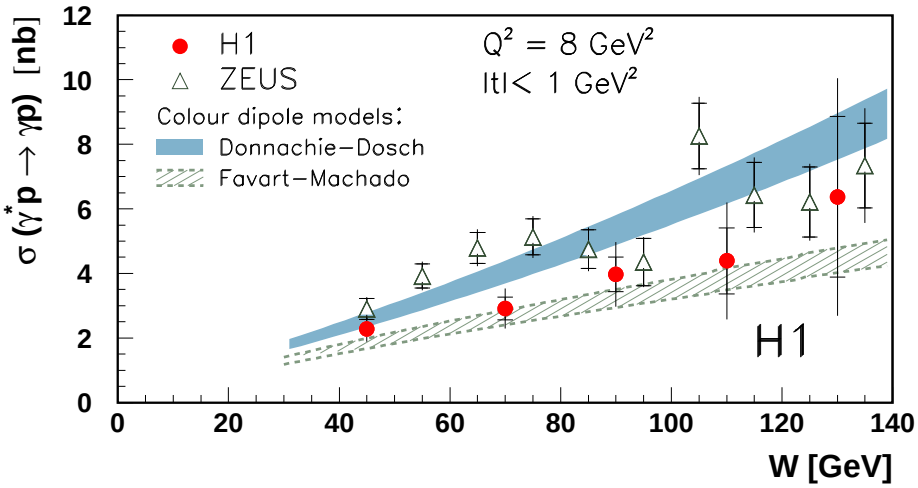
Colour Dipole Model Calculations★



- **Factorize DVCS amplitude:**
  - ▷ γ^* **fluctuates to** $q\bar{q}, q\bar{q}g$**...**
  - ▷ **dipole interacts with proton**
- **Probe transition soft → hard interactions**
- σ_{dipole} **modelled in several ways**

Fair description of data





★ **Donnachie, Dosch** **Favart, Machado**