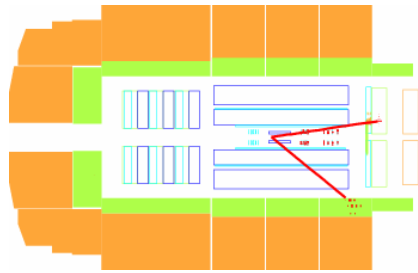
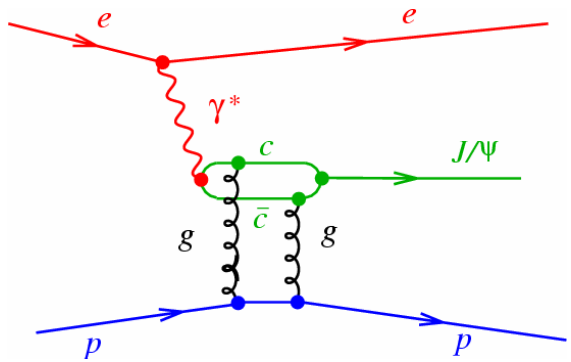
New Data on Elastic J/ψ Production from H1 at HERA

Christian Kiesling, MPI München

- Introduction
- Analysis
  - e- and γ-production: $J/\psi \to e^+e^-, \mu^+\mu^-$
  - backward Si-tracker for High W
  - separation of proton dissociation



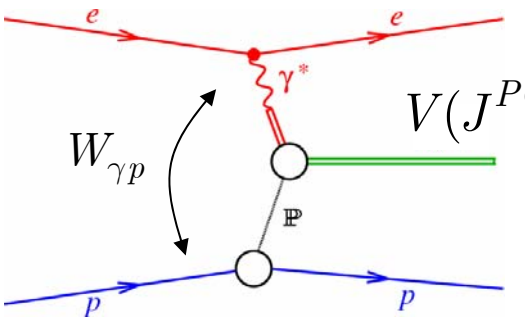
- Results
  - Q^2-dependence
  - W-dependence
  - t- dependence
  - effective Regge trajectory
  - helicity analysis



- Conclusions

Introduction: Vector Mesons at HERA

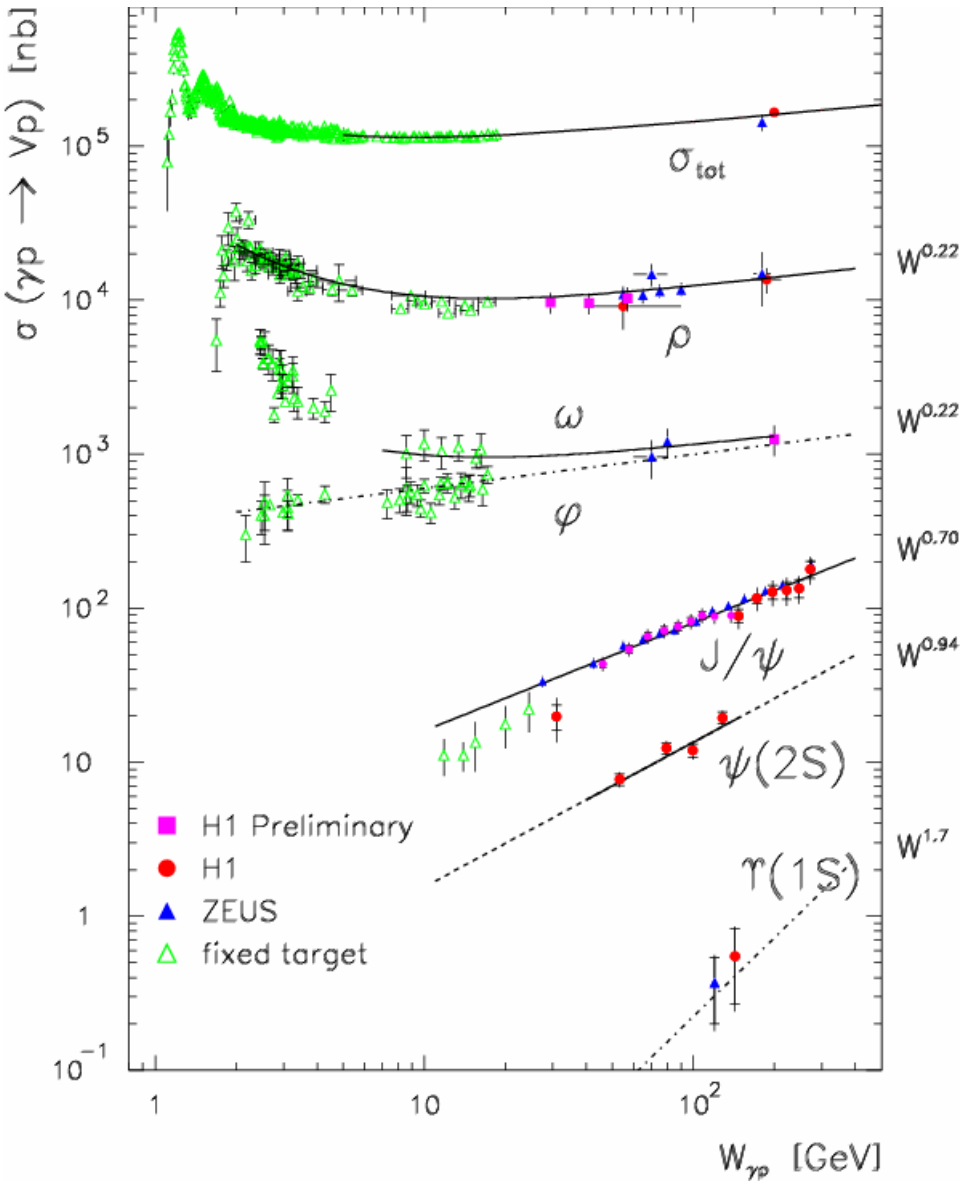
Regge picture



Total cross sections for photoproduction of vector mesons:

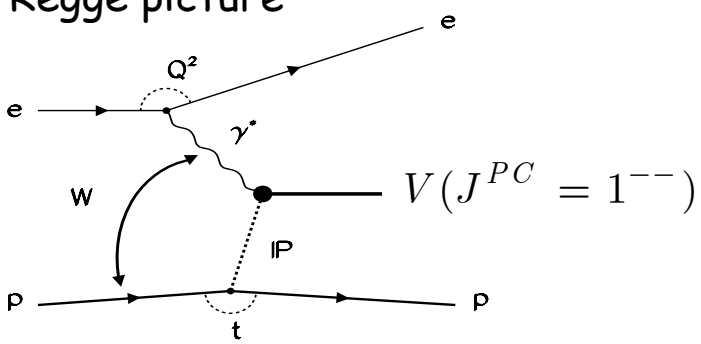
- ρ , ω , ϕ show Regge behaviour
  $\sigma(\gamma p \to Vp) \propto W^{0.22}$
- J/ψ not described by Regge, strong rise of cross section
  $\sigma(\gamma p \to J/\psi p) \propto W^{0.8}$

Break-down of Pomeron Universality



Theoretical Concepts of Exclusive VM Production

Regge picture



→ slow rise of total cross section with W

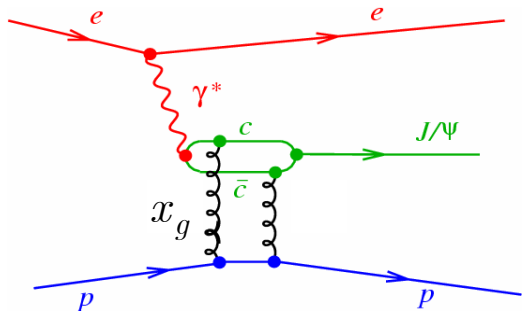
$$\sigma(W) \propto \frac{W^{4(\alpha_{\mathbf{P}}(0)-1)}}{b(W)} \sim W_{\gamma p}^{0.20}$$

→ shrinkage of differential xsection

$$\frac{d\sigma}{dt} \propto e^{-b|t|} \;,\; b = b(W_0) + 2\alpha' \ln\left(\frac{W^2}{W_0^2}\right)$$

→ s-channel helicity conservation (SCHC)

QCD picture



need hard scale:

Q^2

M_V^2

t

steep rise of total cross section with W, in leading order:

$$\sigma(W) \propto \left(\alpha_S(\tilde{Q}^2) x_g g(x_g, \tilde{Q}^2)\right)^2 \qquad \tilde{Q}^2 \sim Q^2 + M_V^2$$

universal slope of t distribution, independent of flavor and energy W

some models: $\frac{d\sigma}{dt} \sim |t|^{-n}$

violation of s-channel helicity conservation

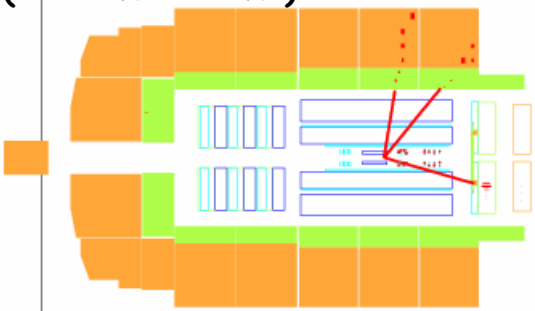
- access to Generalized Parton Distributions

Analysis Strategy

data from 1999/2000 (HERA I): 55 pb^{-1} central, 30 pb^{-1} backward

electroproduction (TT)

("track-track")

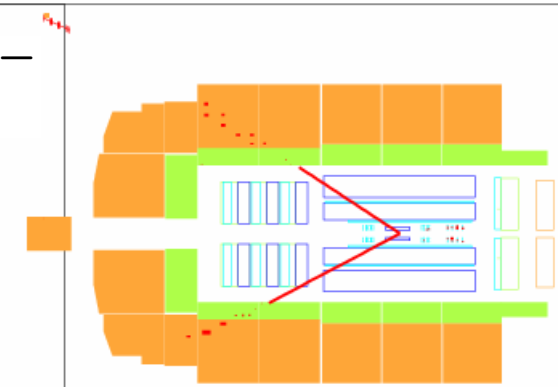


$40 < W_{\gamma p} < 160$ GeV

$J/\psi \rightarrow \mu^+\mu^-$

2 tracks
$\geq$ 1 muon
+ scatt. electron

photoproduction (TT)



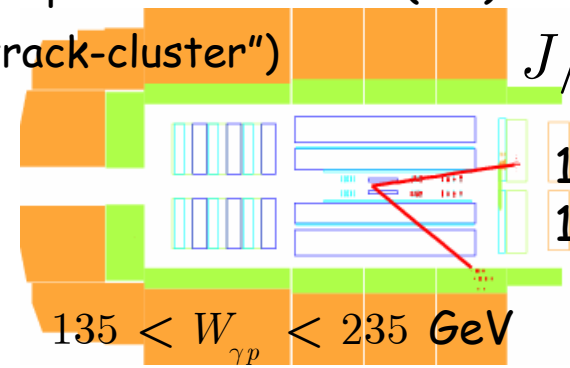
$40 < W_{\gamma p} < 160$ GeV

Muon analysis

2 tracks
$\geq$ 1 muon

photoproduction (TC)

("track-cluster")



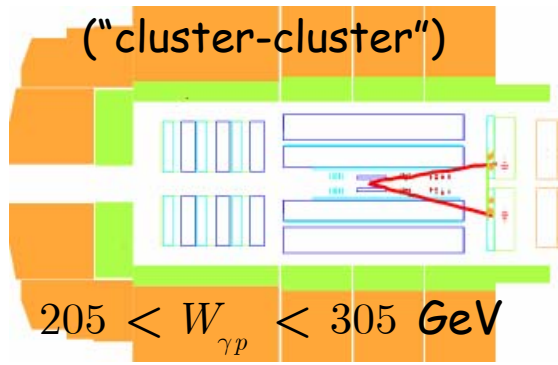
$135 < W_{\gamma p} < 235$ GeV

$J/\psi \rightarrow e^+e^-$

1 cluster
1 track

photoproduction (CC)

("cluster-cluster")

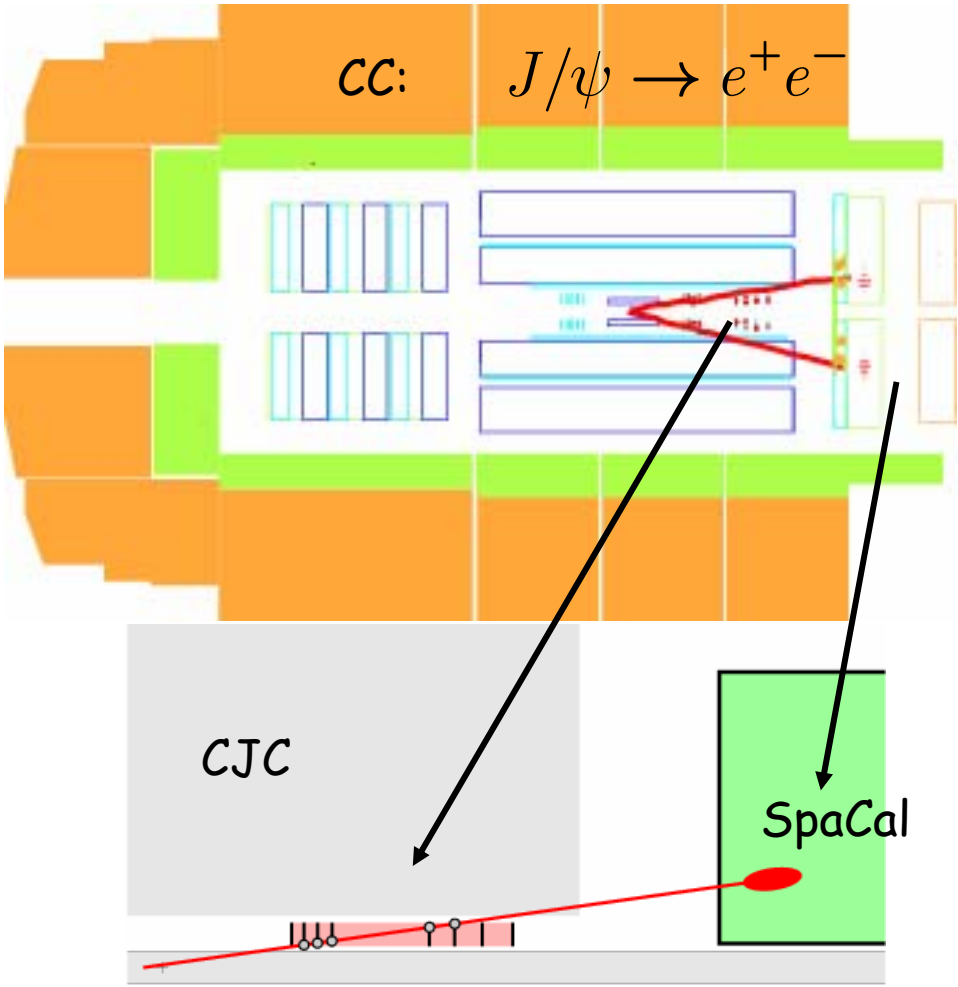


$205 < W_{\gamma p} < 305$ GeV

Electron analysis

2 clusters

High W: Tracking in the Backward Silicon Tracker (BST)

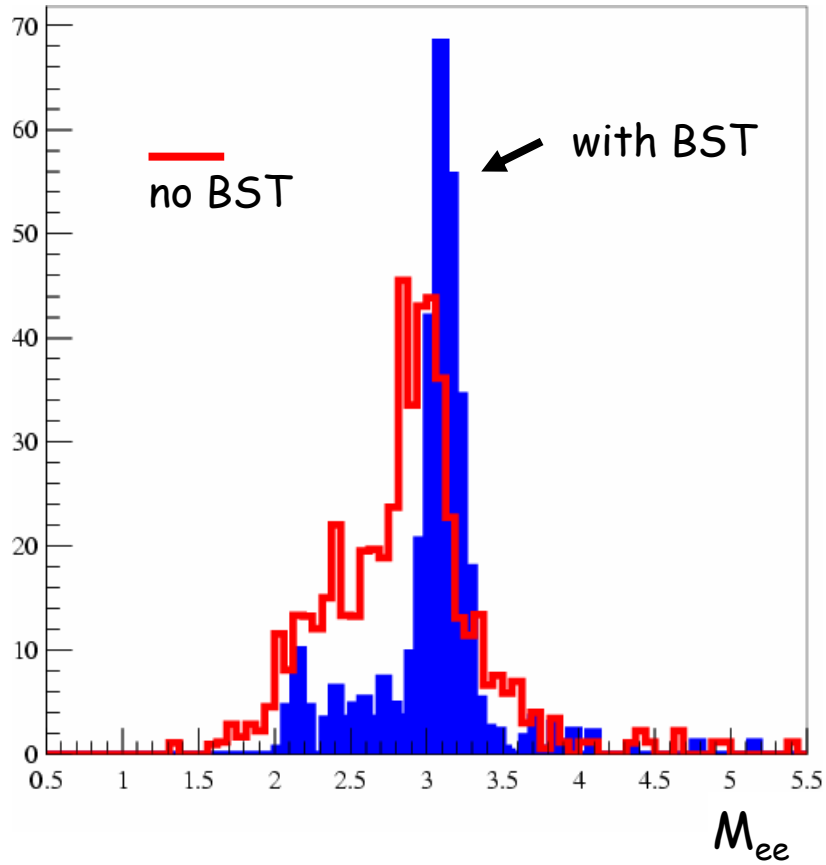


$\sigma_r \approx 12\ \mu\mathrm{m}$

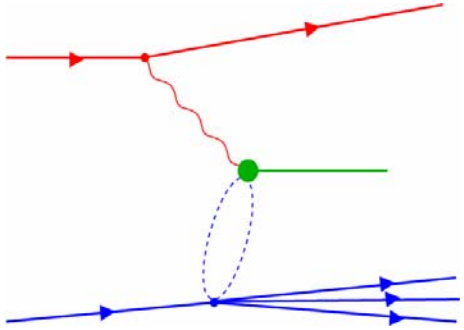
$$\frac{\delta E}{E} = \frac{7\%}{\sqrt{E\,[\mathrm{GeV}]}}$$

use of the BST:

- measure event vertex
- improve mass resolution
- reject Compton backgr.



Tagging of Proton Dissociation



M_Y

proton dissociation ("pd") background:

suppressed by kinematic cut:

$|t| < 1.2$ GeV

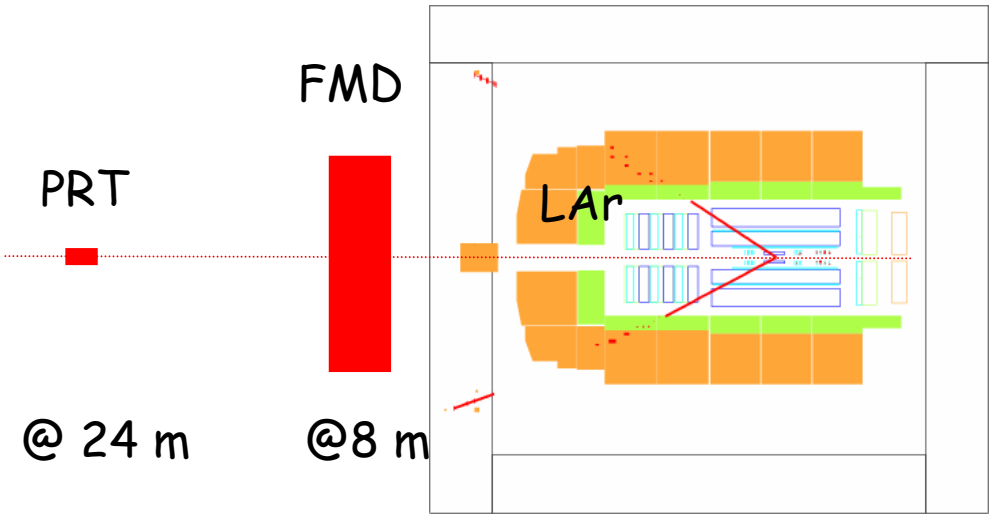
further cuts:

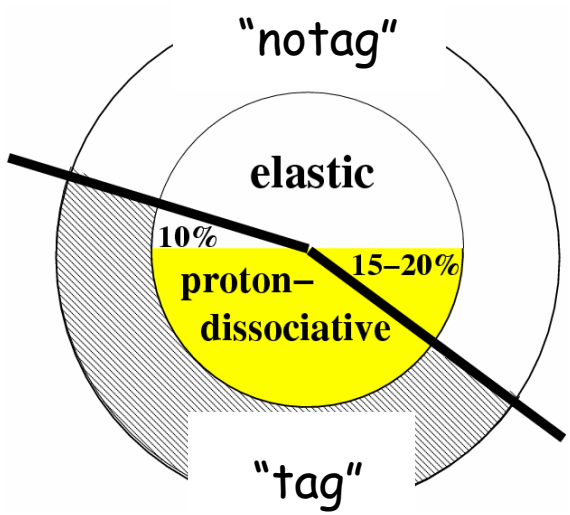
$E_{\text{LAr}(<10°)} < 0.75$ GeV

$N_{\text{FMD}} \leq 1$ hit

$N_{\text{PRT}} = 0$ hits

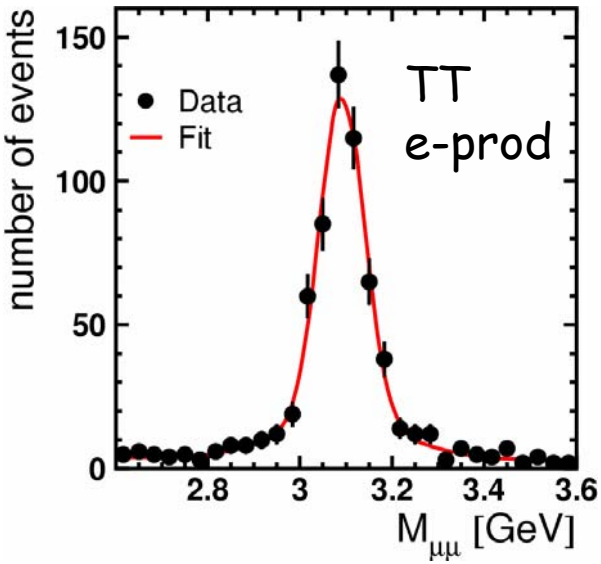
forward detectors used :





→ $M_Y > 1.6$ GeV excluded

Signal Extraction



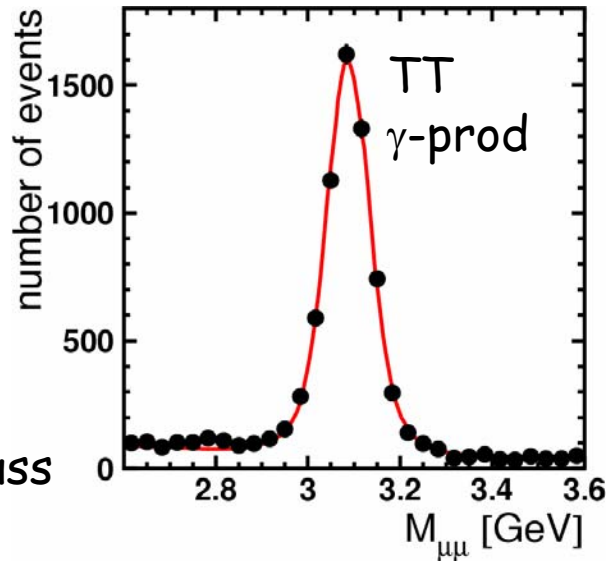
all data

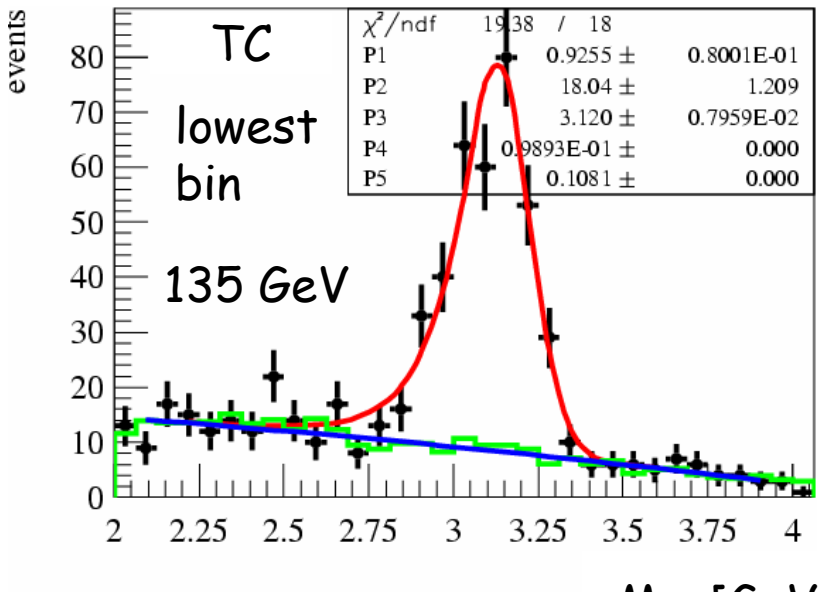
$\langle W_{\gamma p} \rangle = 90$ GeV

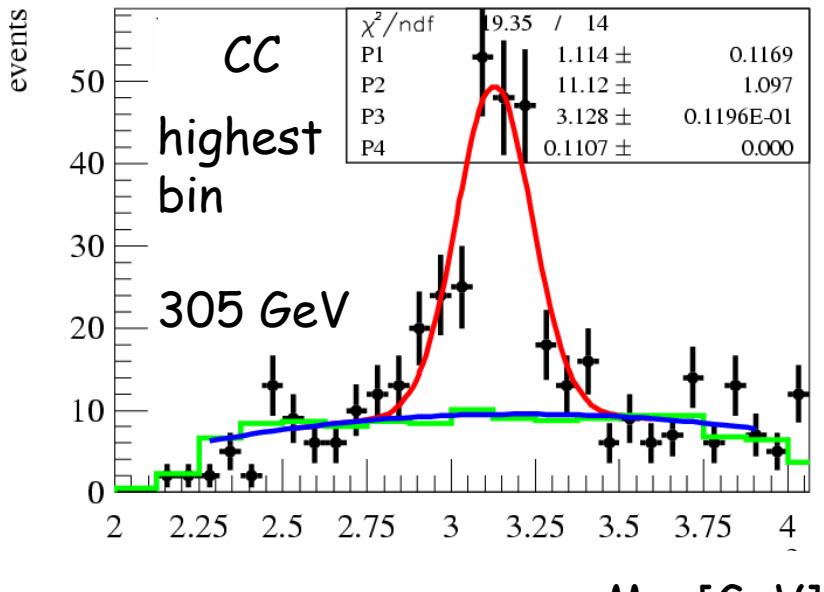
QED bg MC

Polynom fit to bg

bg + (skewed) Gauss







Determination of Cross Sections

kinematics: Jacquet-Blondel (γ-prod), double angle (e-prod)

$$\sigma_{\gamma^* p \to J/\psi p} = \frac{N_{\mathrm{notag}}(1 - f_{\psi'})(1 - f_{\mathrm{pd}})}{F \cdot \varepsilon_{\mathrm{tot}} \cdot B \cdot L} C_{\mathrm{rad}}$$

$f_{\psi'}$: contamination from $\psi' \to \psi + \mathrm{neutrals}$ (4% -> 0.5 %)

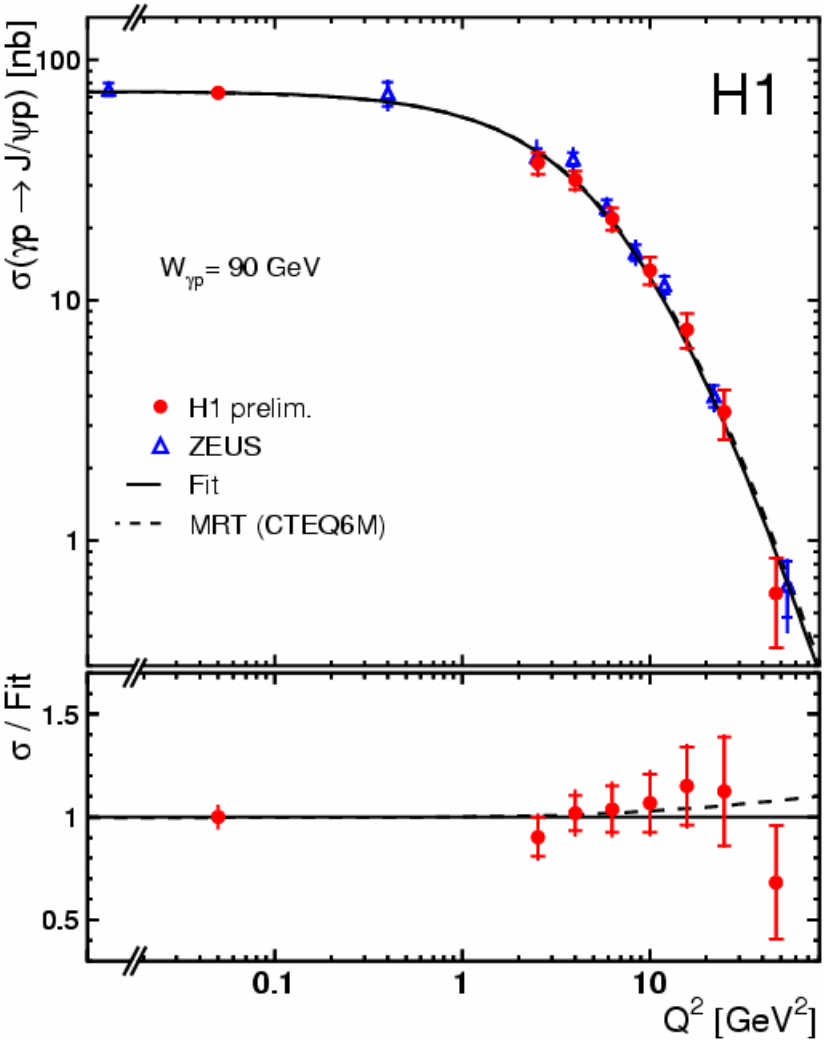
f_{pd} : residual proton dissociation background ($M_Y < 1.6\ \mathrm{GeV}$)

$\varepsilon_{\mathrm{tot}}$: total efficiency (typically ~ 25 %)

main systematic uncertainties:

trigger efficiency :	< 6.5 %
signal extraction (form of background) :	< 6 %
pd separation :	5 %

Results: Q^2-Dependence



$$2 < Q^2 < 80 \text{ GeV}^2$$

Fit: $\sigma \propto (Q^2 + M_V^2)^{-n}$

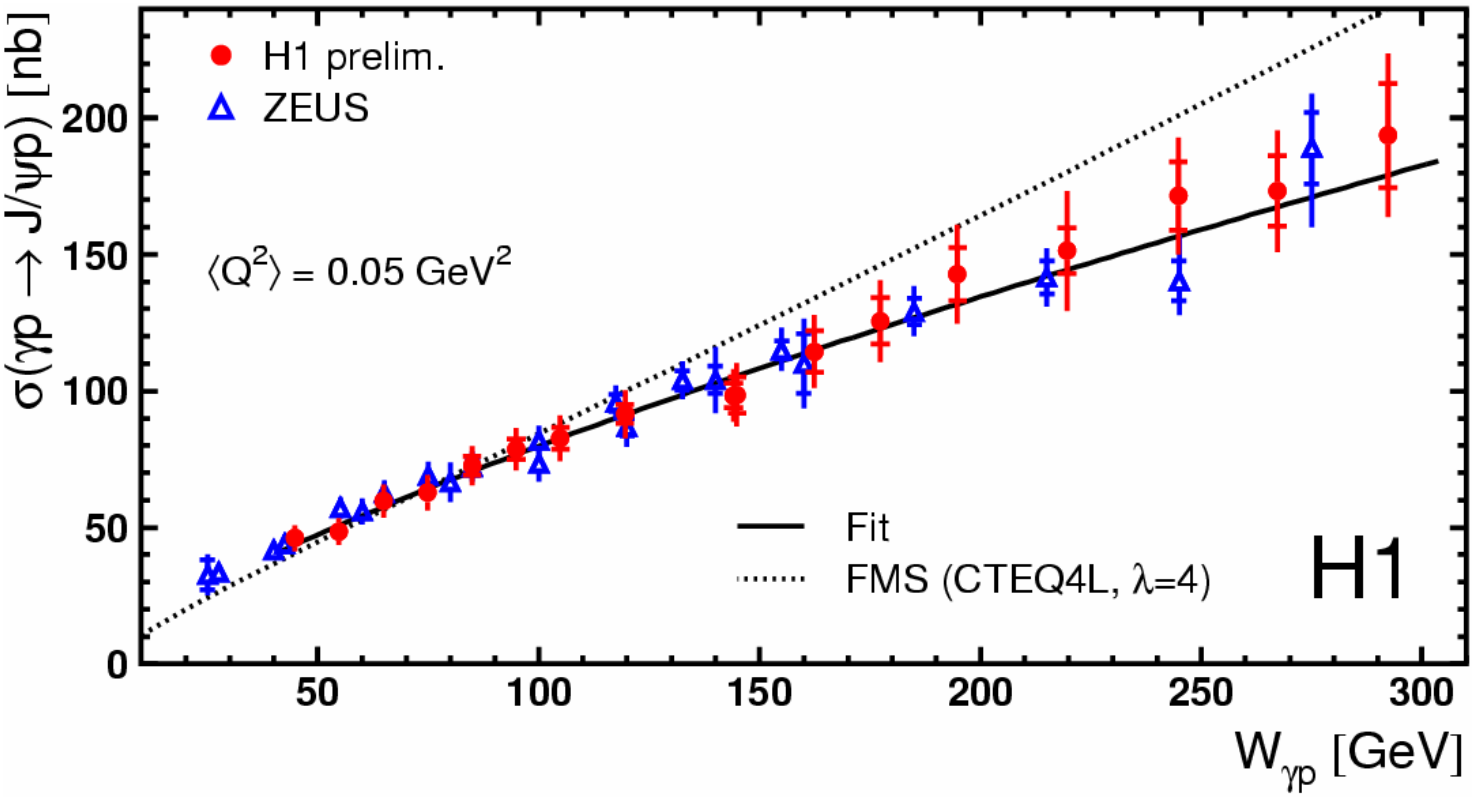
$$n = 2.486 \pm 0.080 \pm 0.068$$

(in agreement with ZEUS)

QCD-prediction (MRT) normalized to γ-prod point

small downward shift compared to old H1 data (also seen in γ-prod), but in agreement within the errors

W-Dependence (Photoproduction)



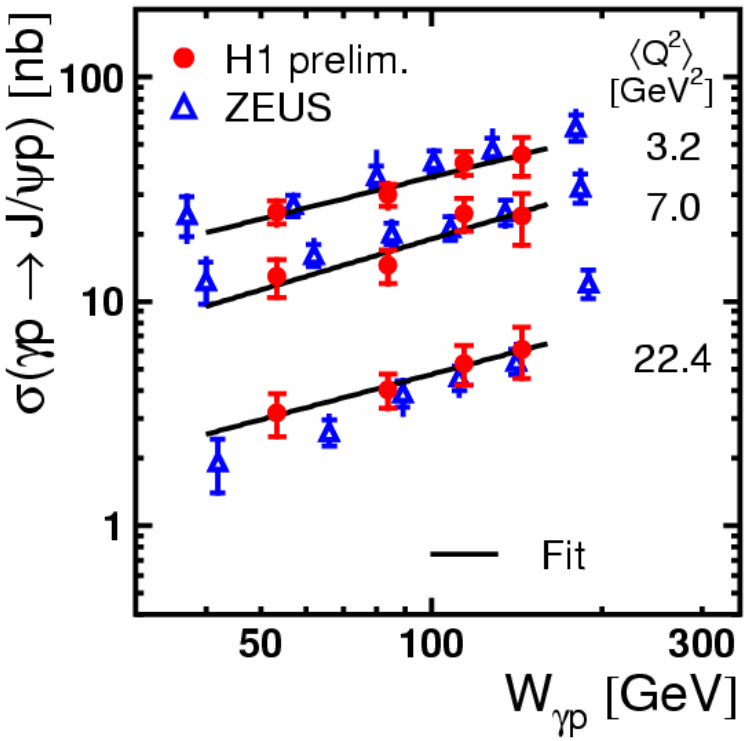
Fit: $\sigma \propto W^{\delta}$ $\delta = 0.740 \pm 0.034 \pm 0.034$ (from H1 alone)

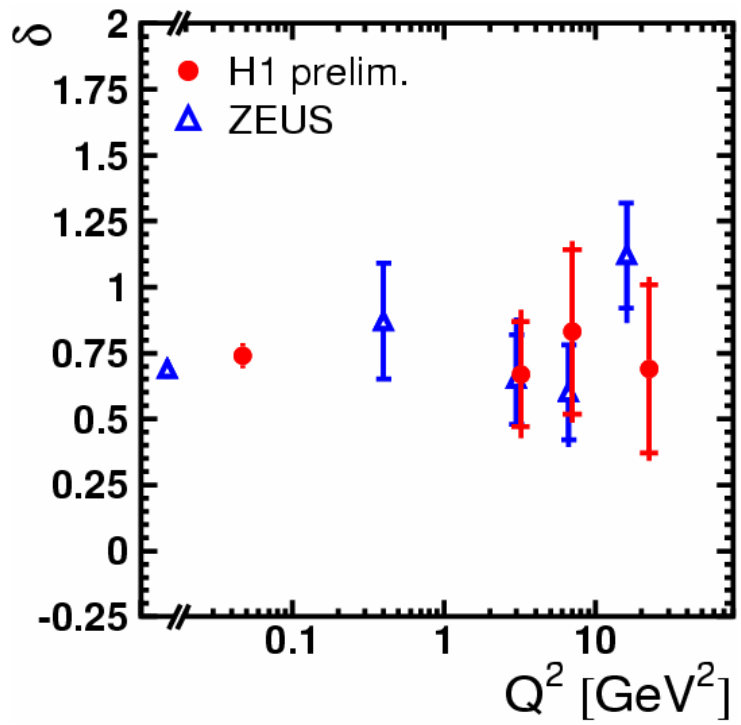
(soft Pomeron: $\delta \sim 0.22 - 0.32$)

note: theory curve gives no absolute prediction
(see also T. Teubner's talk)

W-Dependence (Electroproduction)

e.g. at Q^2=3.2 GeV^2 : $\delta = 0.67 \pm 0.20 \pm 0.14$





- no dependence on Q^2 within the errors
- note: the scale is already "hard", set by the mass of the J/Ψ (10 GeV^2), combined scale ~ (M^2 + Q^2)

t-Dependence (Photo- and Electroproduction)

$$|t| = (\vec{p}_{T,e'} + \vec{p}_{T,J/\psi})^2 \qquad \text{e-production}$$

$$\approx \vec{p}^{\,2}_{T,J/\psi} \qquad \gamma\text{-production}$$

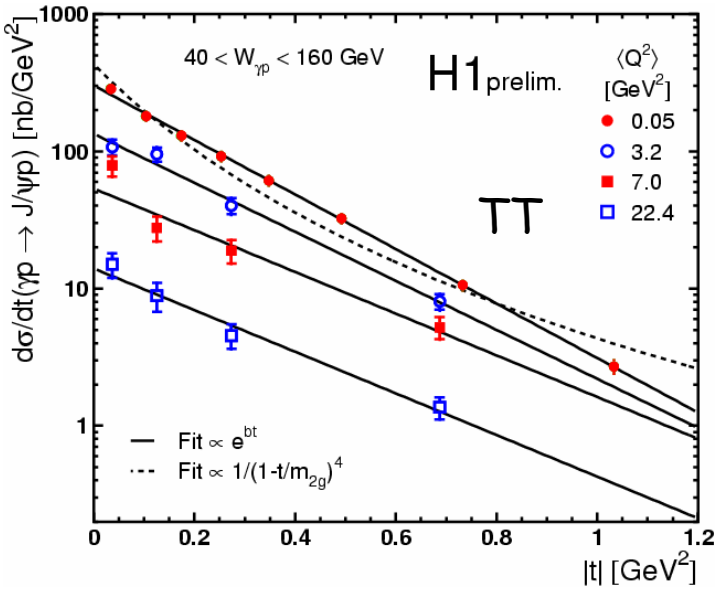
- simple exponential describes data

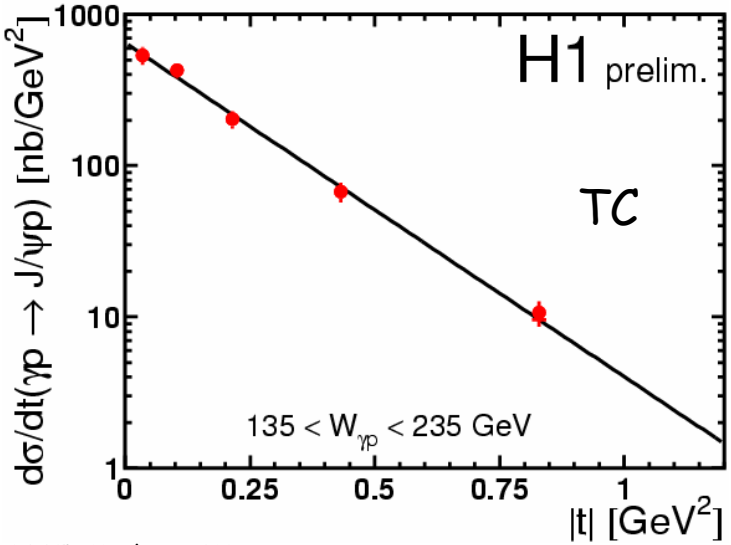
  $\chi^2 / \mathrm{ndf} = 0.25$

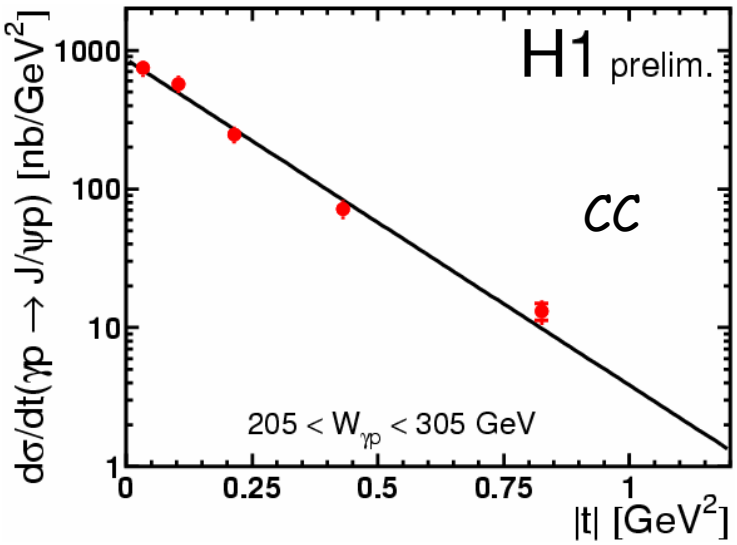
- dipole form clearly disfavoured

  $m_{2g} = (0.679 \pm 0.006 \pm 0.011)\ \mathrm{GeV}$

  $\chi^2 / \mathrm{ndf} = 5.5$







W-t Dependence

lines from 1 dim. fits:

$$\frac{d\sigma}{dW}(W,\langle t\rangle) \propto W^{4(\alpha(\langle t\rangle)-1)}$$

$$\frac{d\sigma}{dt}(t,\langle W\rangle) \propto e^{b(\langle W\rangle)t}$$

2 dim. fits ("effective Pomeron Trajectory"):

$$\frac{d\sigma}{dt}(W,t) \propto e^{b_0 t} W^{4(\alpha(t)-1)}$$

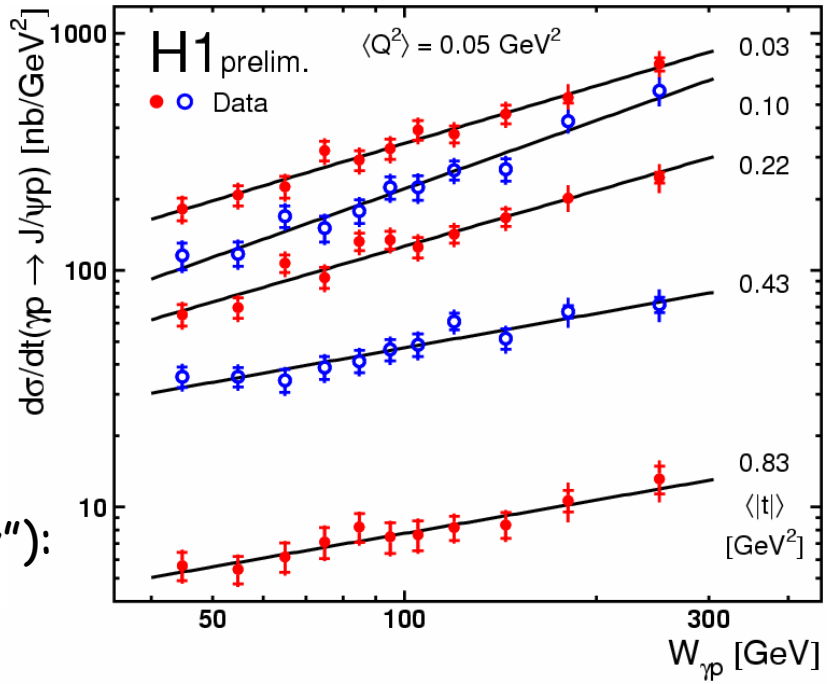
with

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

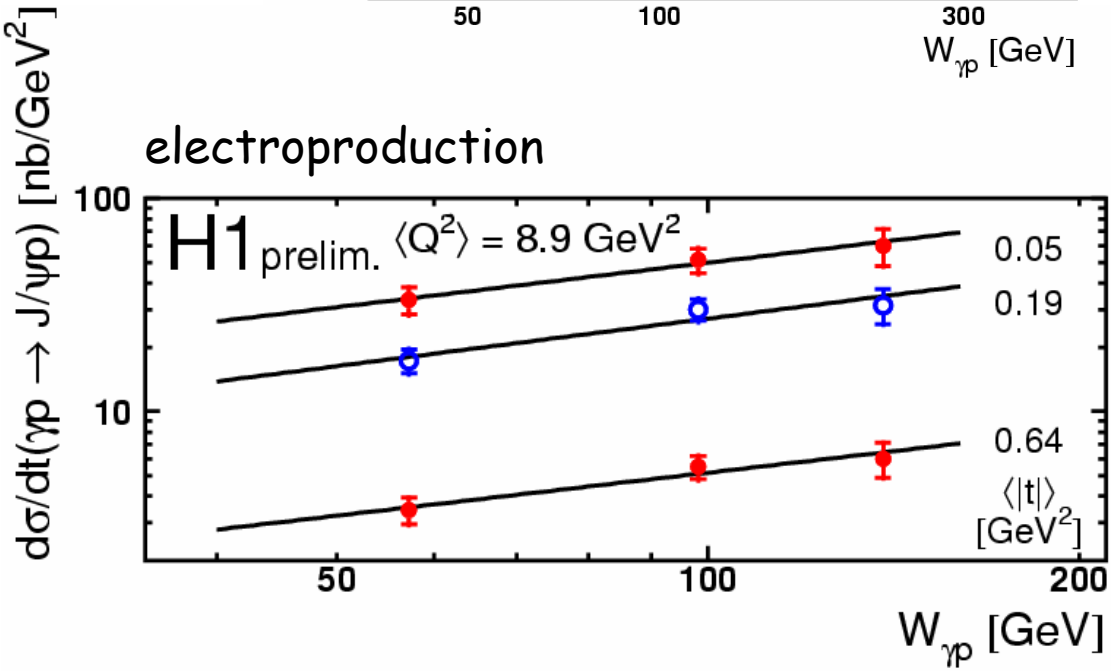
fit for α_0, α', b_0

(+ 3 norm. params: TT,TC,CC)

photoproduction

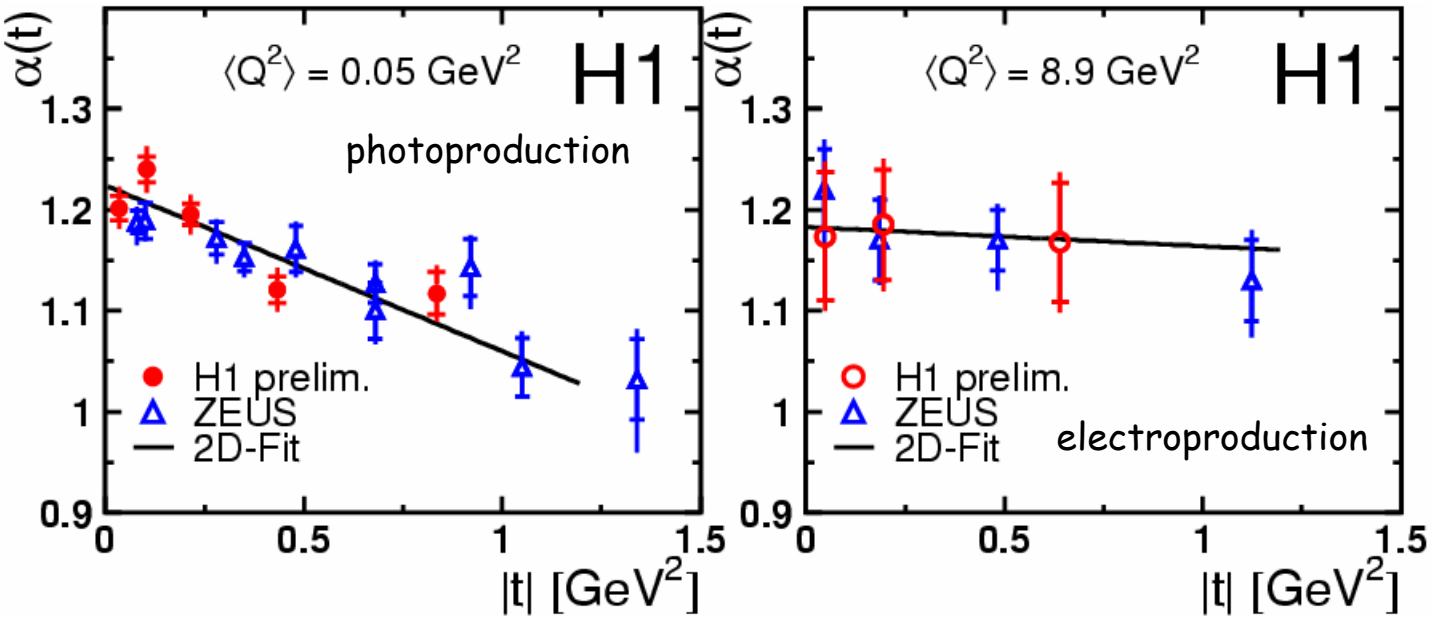


electroproduction



Effective Pomeron Trajectory

2 dim. fit: $\alpha(t) = \alpha_0 + \alpha' t$



photoproduction:

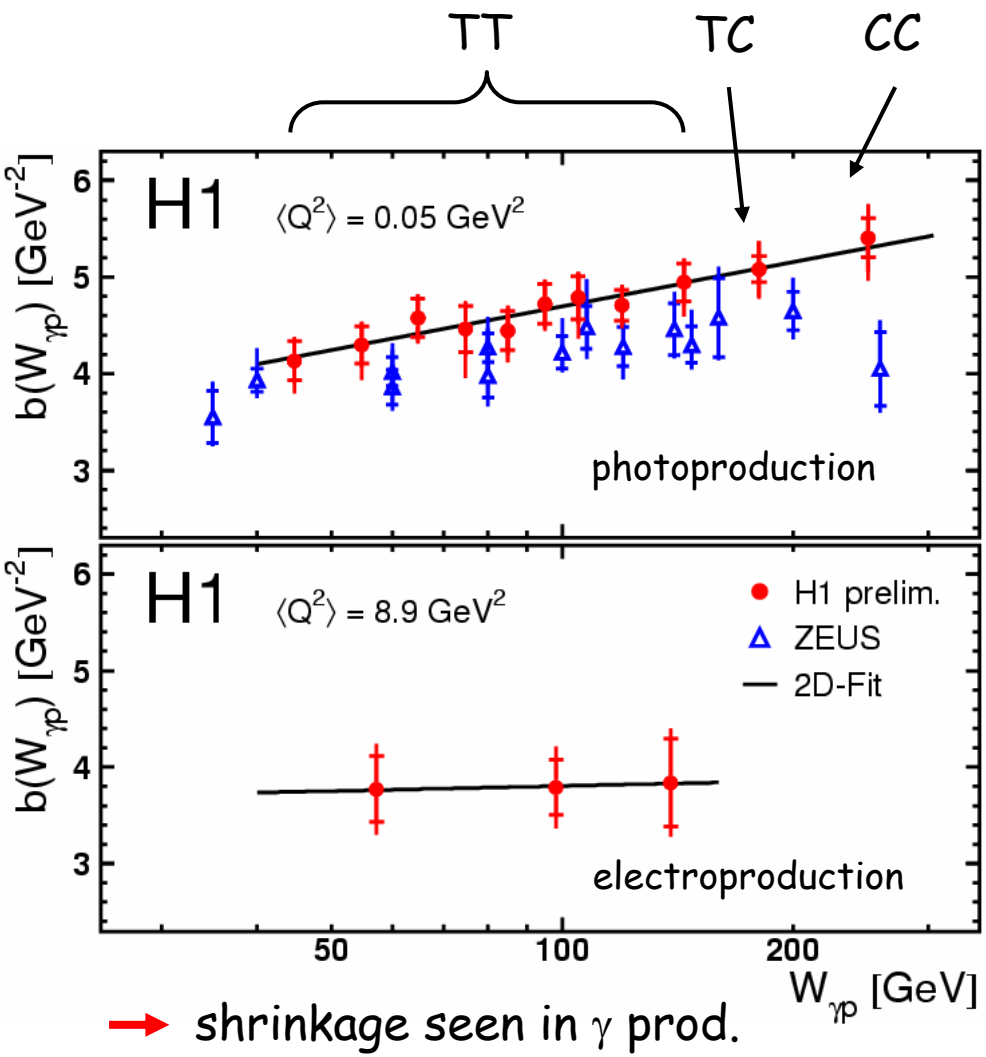
$$\alpha(t) = (1.224 \pm 0.010 \pm 0.012) + (0.164 \pm 0.028 \pm 0.030)\ \text{GeV}^{-2}\ t$$

electroproduction:

$$\alpha(t) = (1.183 \pm 0.054 \pm 0.030) + (0.019 \pm 0.139 \pm 0.076)\ \text{GeV}^{-2}\ t$$

→ trajectories similar within errors

Shrinkage of the Forward Peak



→ shrinkage seen in γ prod.

data point from 1D fits to $e^{-b|t|}$

line from a 2D Fit (W and t) :

$$b(W) = b_0 + 4\alpha' \ln \frac{W}{W_0}$$

photoproduction

$$b_0 = 4.630 \pm 0.060 \,{}^{+0.043}_{-0.163}$$

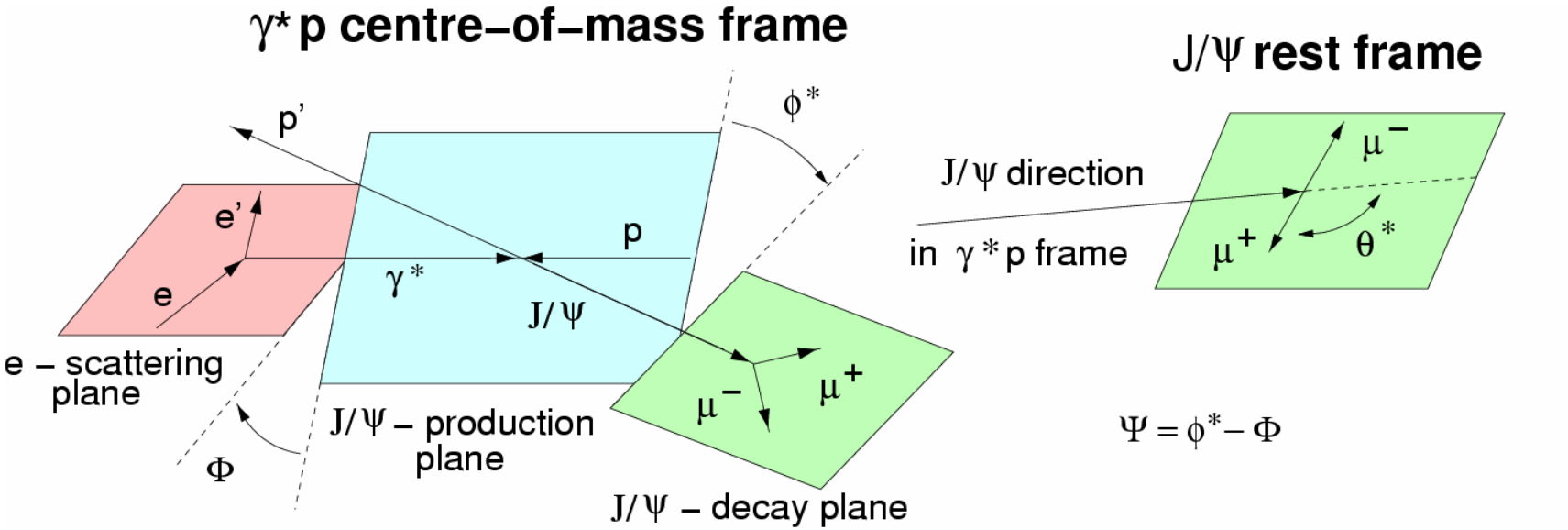
$$\alpha' = (0.164 \pm 0.028 \pm 0.030)\ \text{GeV}^{-2}$$

electroproduction

$$b_0 = 3.86 \pm 0.13 \pm 0.31$$

$$\alpha' = (0.019 \pm 0.139 \pm 0.076)\ \text{GeV}^{-2}$$

s-Channel Helicity Conservation



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

transverse γ : $r_{00}^{04} = 0$

$$\frac{d\sigma}{d\Psi} \propto 1 - \varepsilon r_{1-1}^{1}\cos(2\Psi)$$

non-flat for longitudinal γ

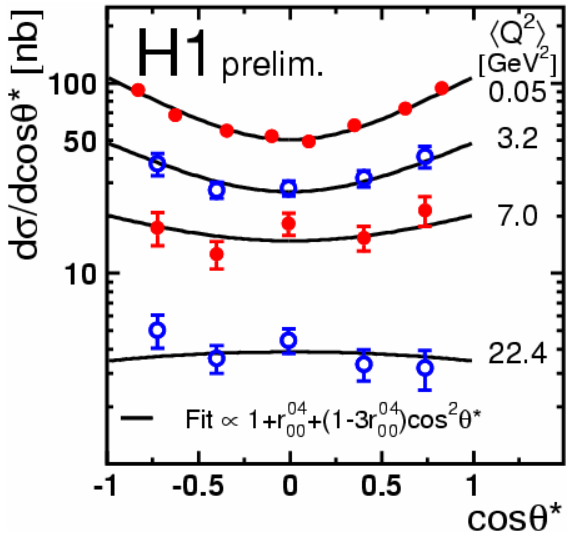
$$\frac{d\sigma}{d\phi^*} \propto 1 + r_{1-1}^{04}\cos(2\phi^*)$$

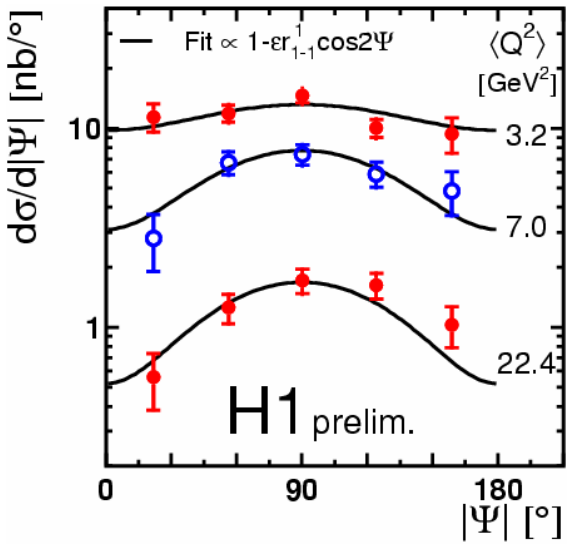
should be flat if SCHC holds

$$\frac{d\sigma}{d\Phi} \propto 1 - \varepsilon(r_{00}^{1} + 2r_{11}^{1})\cos(2\Phi) + \sqrt{2\varepsilon(1+\varepsilon)}(r_{00}^{5} + 2r_{11}^{5})\cos(\Phi)$$

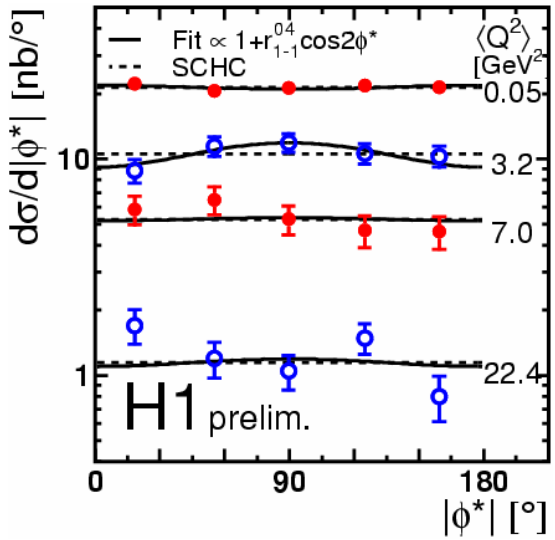
Fits to the Angular Distributions

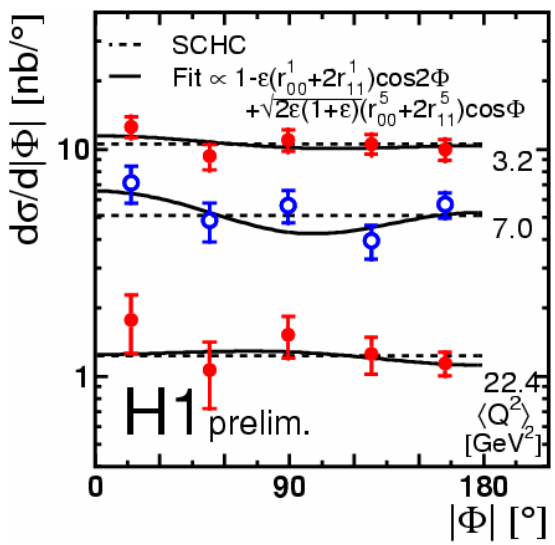
sensitive to longitudinal γ





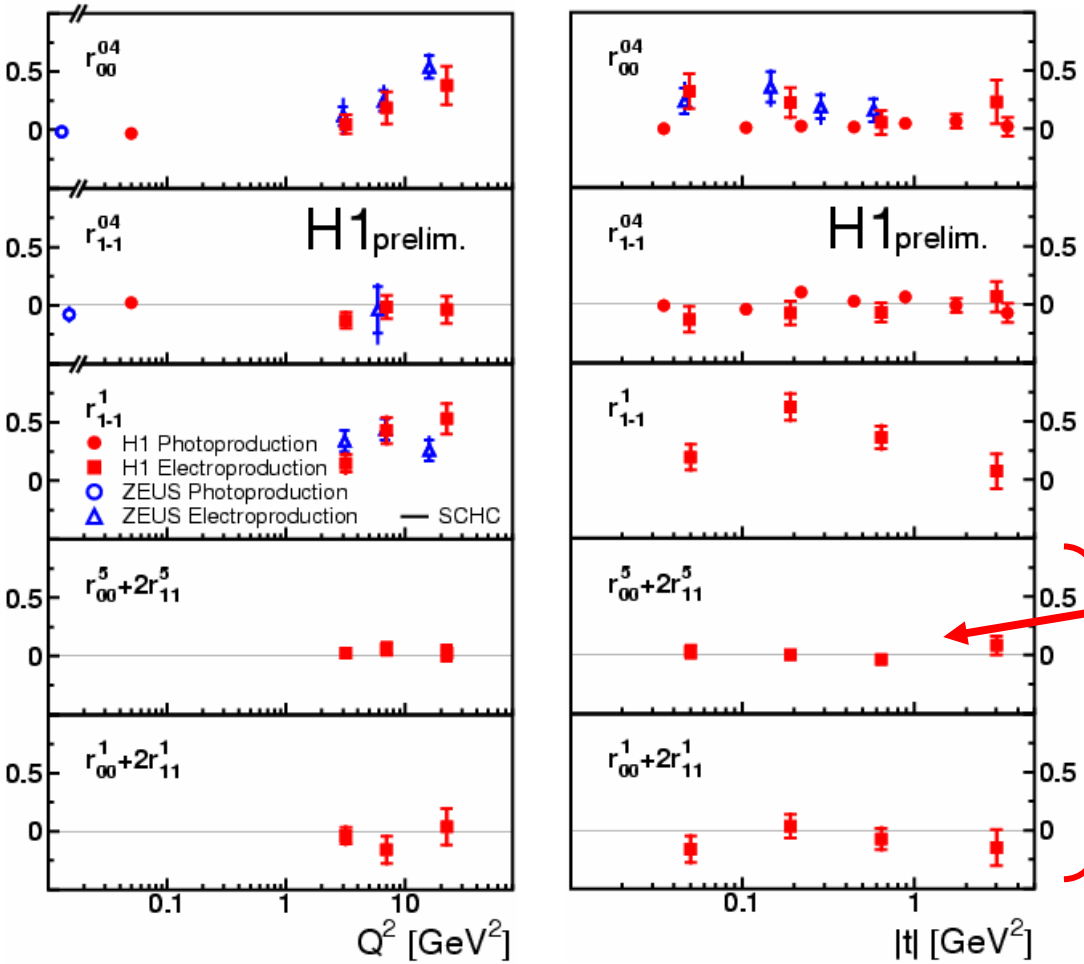
sensitive to SCHC





Spin Density Matrix elements

$r_{00}^{04} > 0$ → γ develops longitudinal component with increasing Q^2



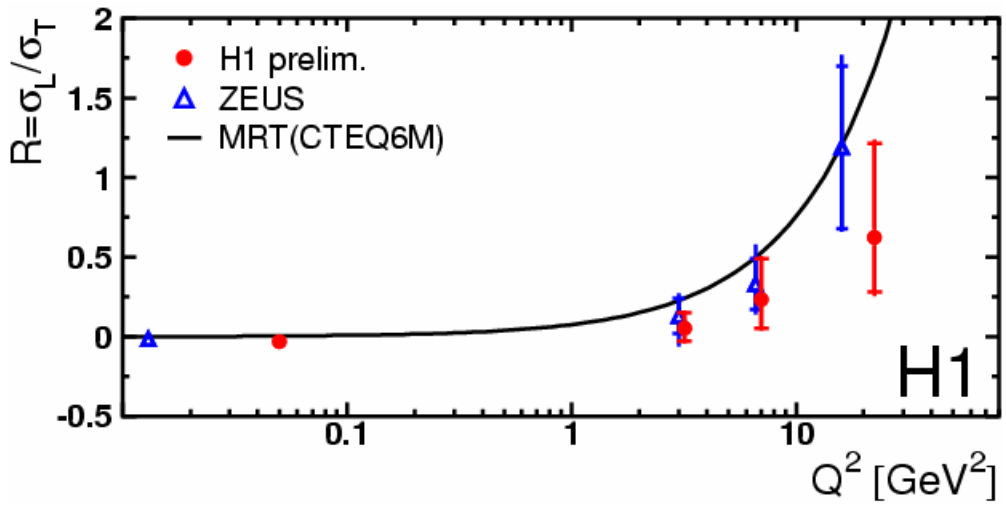
SCHC + natural parity exchange:

$$r_{1-1}^{1} = \frac{1 - r_{00}^{04}}{2}$$

deviation from 0 seen in ρ analysis

SCHC: vanishing combination of elements

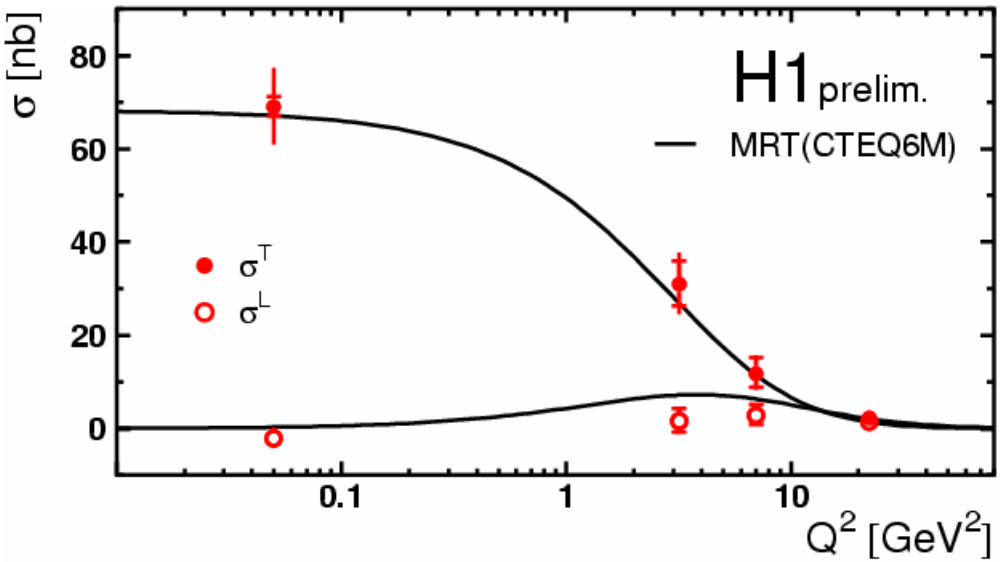
Longitudinal and Transverse Cross Sections



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

$$\varepsilon = \frac{1-y}{1-y+y^2/2}$$

(ε very close to 1 over entire kinematic range)



$$\sigma_{\gamma p} = \sigma_T + \varepsilon\sigma_L$$

→ extract σ_T and σ_L

data reasonably well described by MRT

Summary and Conclusions

- New measurements of elastic J/Ψ photoproduction for $40 < W_{\gamma p} < 305$ GeV, and electroproduction for $0 < Q^2 < 80$ GeV^2
- Improved statistics, reduced systematics:
  Final (but still preliminary) answer from H1 @ HERA I
- New data in good agreement with previous measurements at HERA,
  strong rise of photoproduction cross section with W confirmed
- W, Q^2 dependences well described by QCD calculations
- t dependences well described by a single exponentials,
  dipole forms clearly disfavored
- Extracted spin density matrix elements show no violation of
  s-channel helicity conservation
- high sensitivity of elastic J/Ψ production to $g(x,Q^2)$? -> talk by T. Teubner in this session