Vector Mesons at

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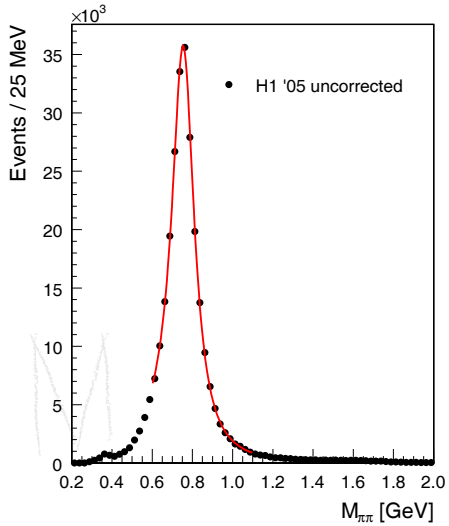
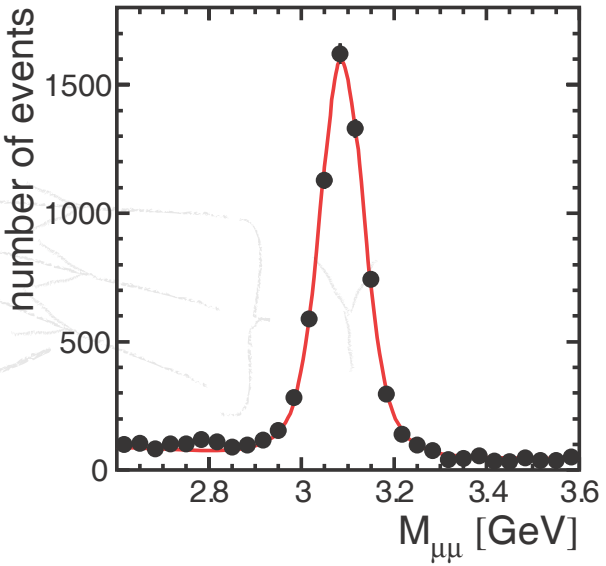
ETH Institute for Particle Physics

Diffraction 2006

Vector mesons at H1: Recent Results

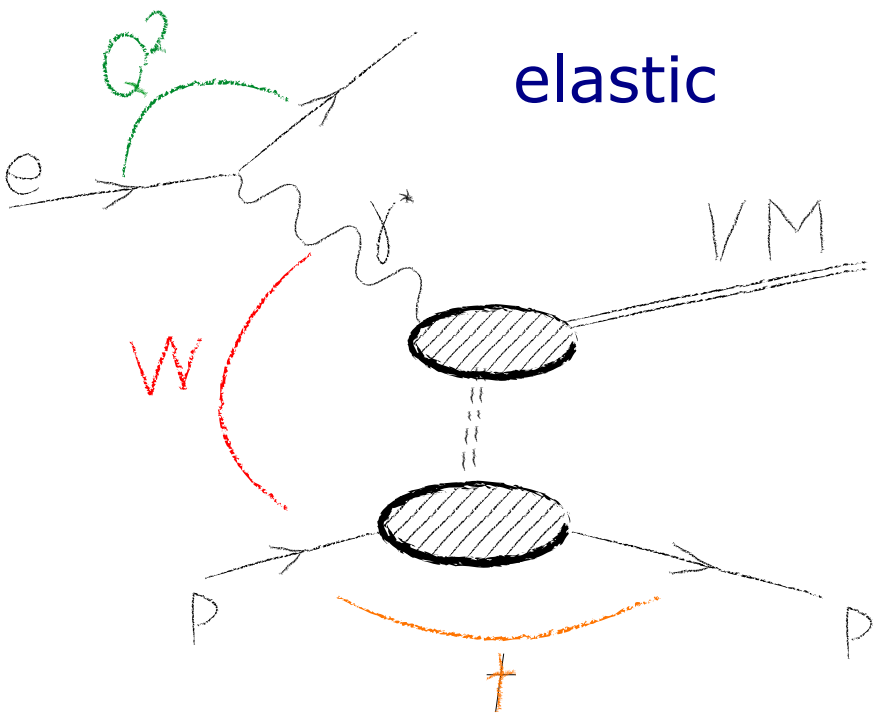
- ρ^0 in photoproduction
- high t ρ^0 in photoproduction
- J/ψ in photo- and electroproduction
- Conclusion and outlook

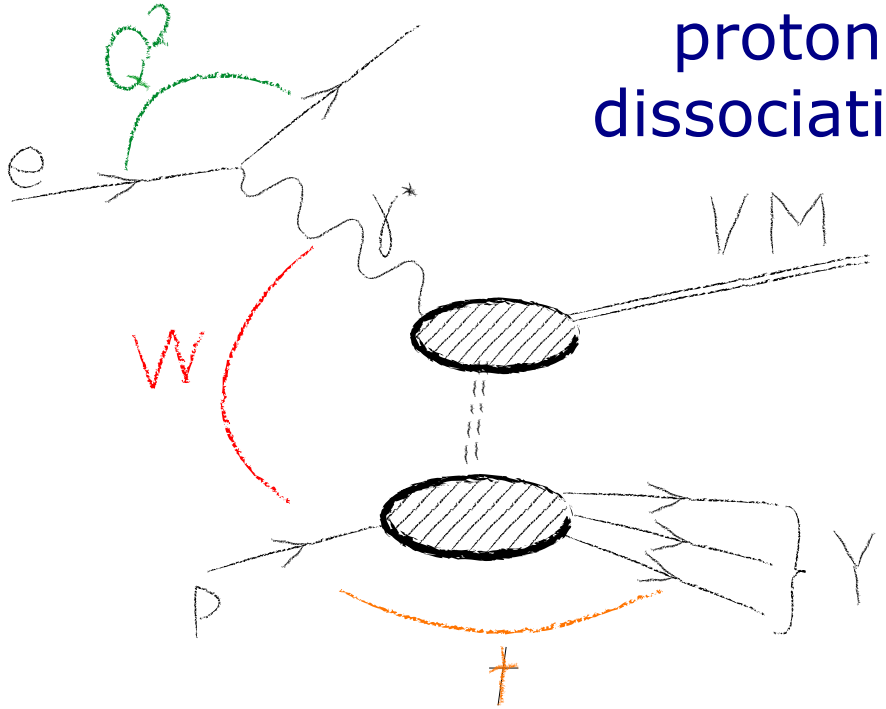




HERA and H1

Diffractive Vector Meson Production



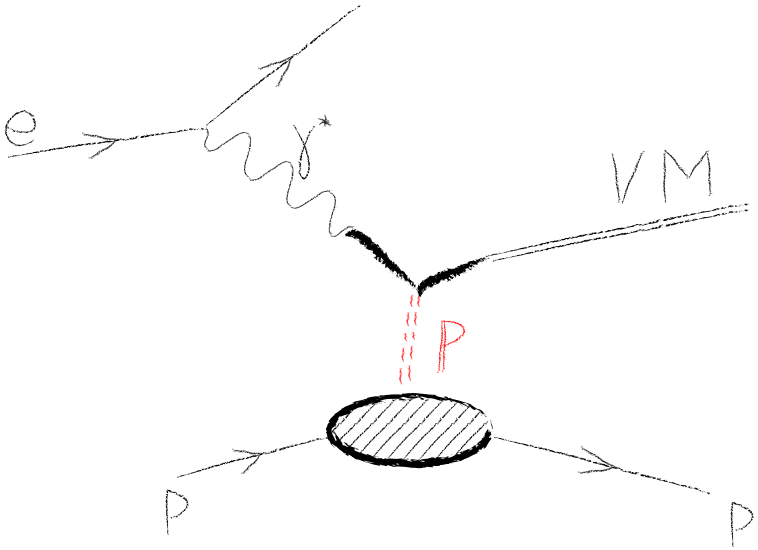


Q^2	γ^* Virtuality	$\sim 0 < Q^2 < 80$ GeV^2
W	γ^*p CM Energy	$20 < W < 305$ GeV
t	(4-mom. transfer at p vertex)^2	$\sim 0 < \lvert t \rvert < 20$ GeV^2
VM	Vector Meson	ρ^0, ω, ϕ, J/ψ, ψ', Υ

Probe wide ranges of scales: Q^2, t, M_{VM}

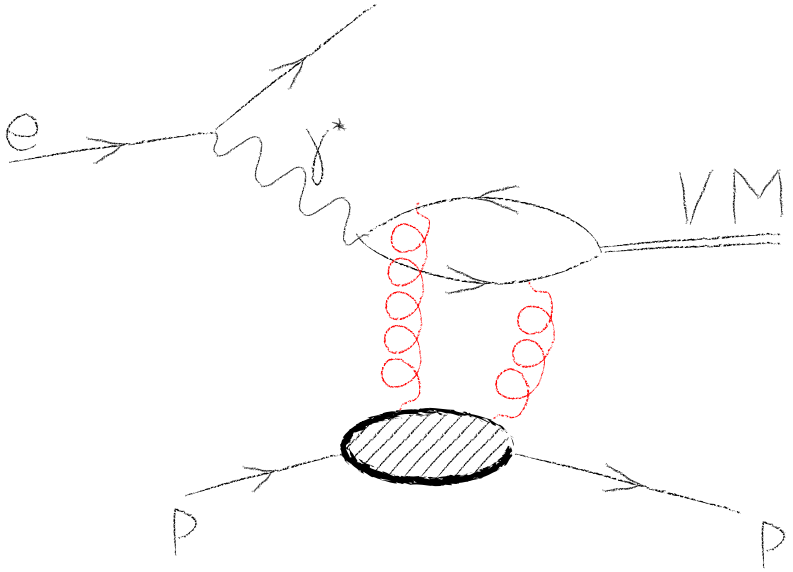
Theoretical Frameworks

"Soft" processes
Regge Theory (Soft Pomeron)



Pomeron trajectory

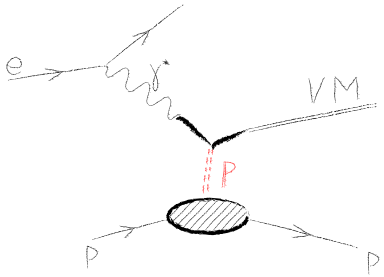
"Hard" processes
calculable in pQCD



Gluon density,
evolution equations

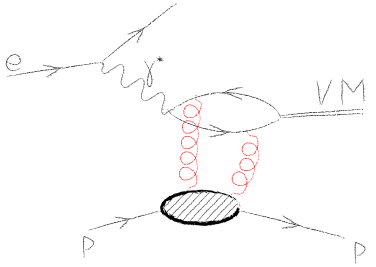
Expectations

"Soft" processes
Regge Theory (Soft Pomeron)



$$\frac{d\sigma}{dt} \propto e^{bt} \left(\frac{W}{W_0}\right)^{4(\alpha_0-1)}$$

"Hard" processes
calculable in pQCD



exchange of ≥ 2 gluons

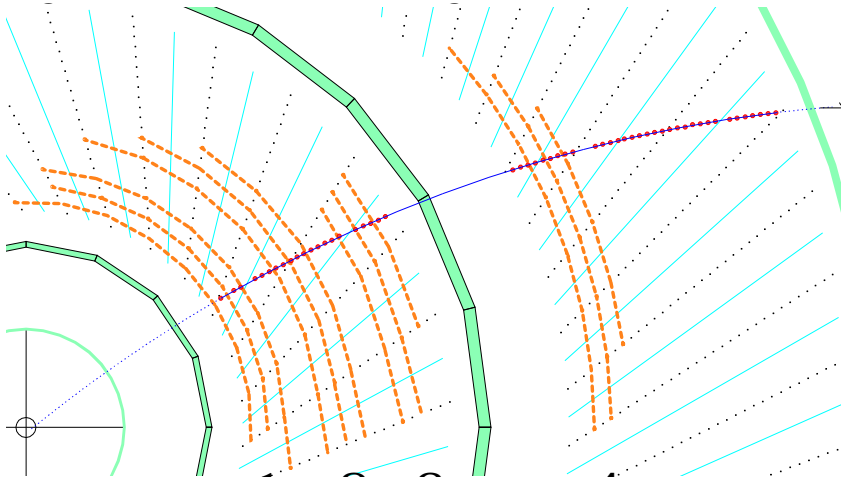
$$\sigma \propto (xg(x,Q^2))^2$$

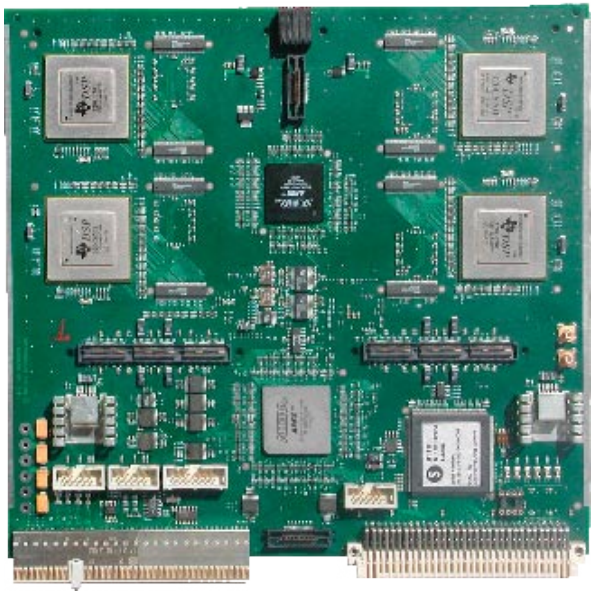
Shrinkage: $b = b(W)$	no shrinkage
Slow rise: $\sigma \propto W^{0.22\ldots0.32}$	steep rise due to $xg(x,Q^2)$
S-channel helicity conservation	SCHC may be violated
Light VMs at $Q^2 \approx 0$, $t \approx 0$	Presence of a hard scale

The new Fast Track Trigger at H1

New H1 Fast Track Trigger for HERA II:

- Threshold p_T > 100 MeV
- Track counting
- Single track efficiency > 90%





r-φ track reconstruction in 2 μs
Full 3-D track reconstruction with almost offline precison in 20 μs, including 2-Track invariant masses

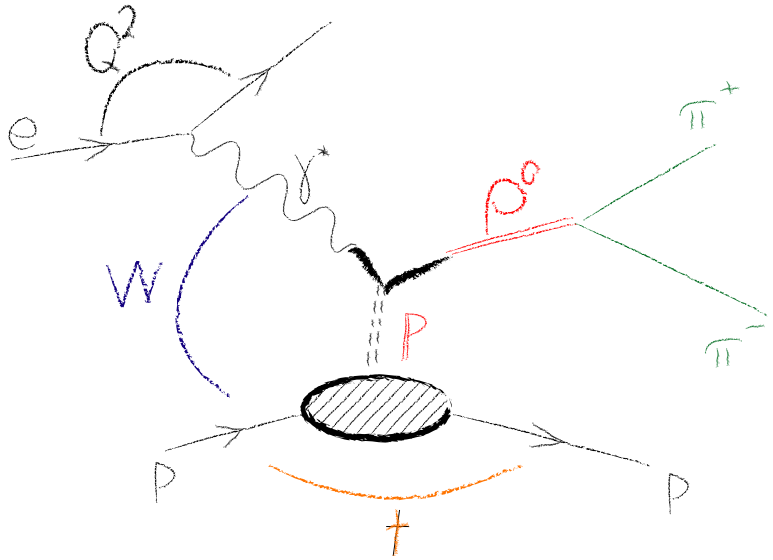
Diffractive ρ^0 photoproduction

H1 Fast Track Trigger:

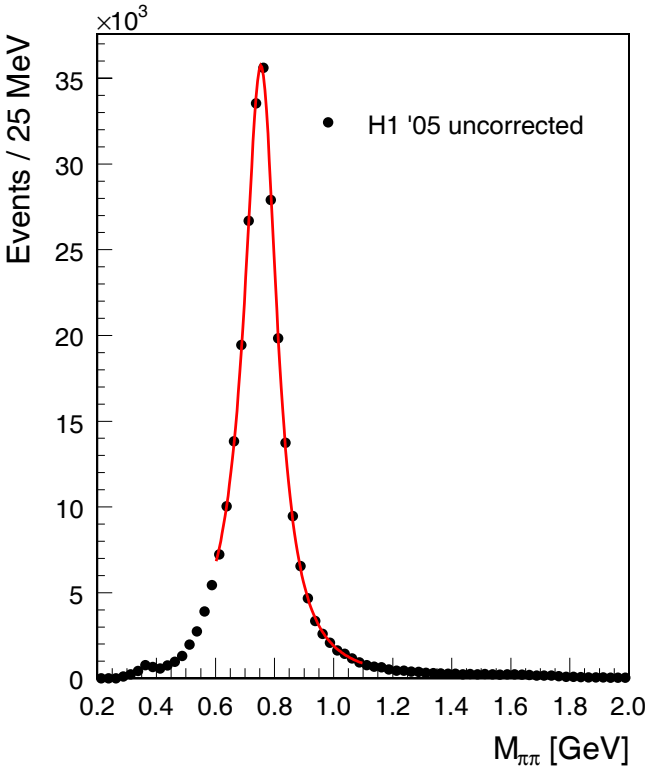
$Q^2 < 4$ GeV^2
$20 < W < 90$ GeV

~ 250'000 $\rho^0 \to \pi^+\pi^-$ candidates

taken in 3 months
570 nb^{-1} (prescaled)



H1 Preliminary 06-011, DIS2006



Extract Pomeron trajectory from data from a single experiment

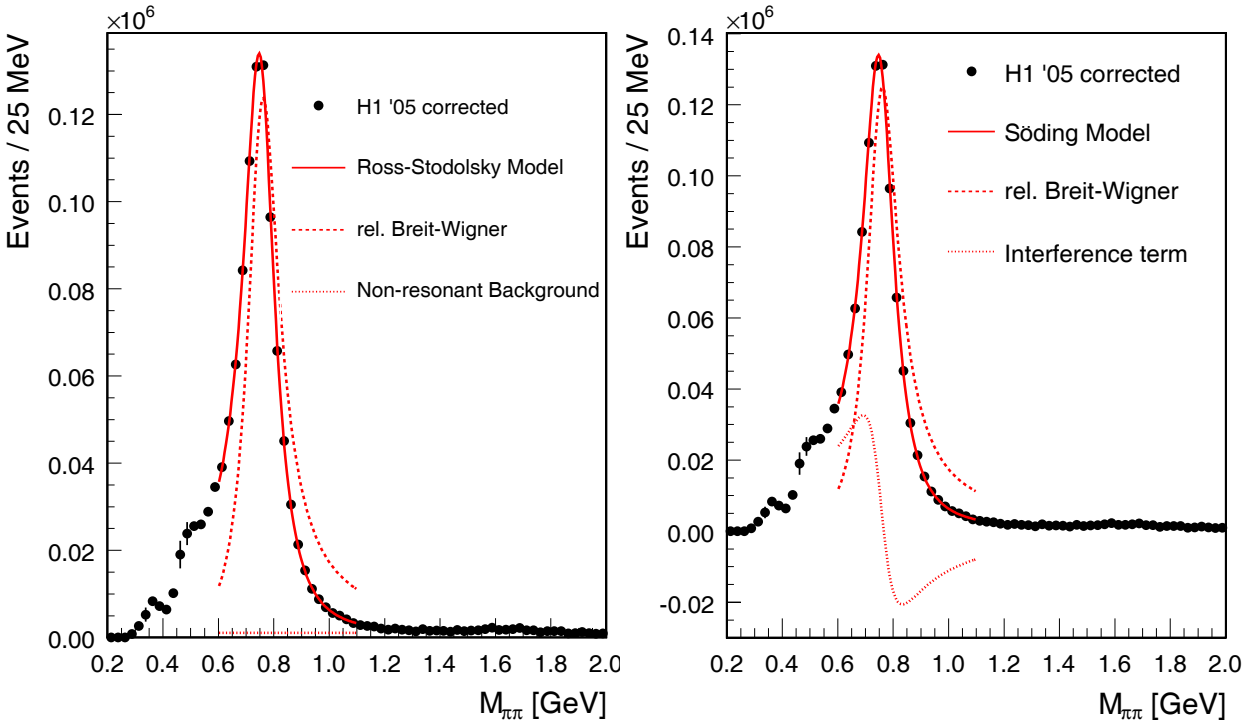
Diffractive ρ^0 photoproduction

Select events with 2 Tracks

- Track p_T > 200 MeV
- Opposite charge
- $20° < \vartheta < 160°$
- No scattered electron
- No unassociated energy in calorimeter above noise

Correct for inefficiencies

ρ^0 shape distorted due to nonresonant pion production



Fit skewed rel. Breit Wigner (Ross-Stodolsky)
or with an interference term (Söding)
Results compatible

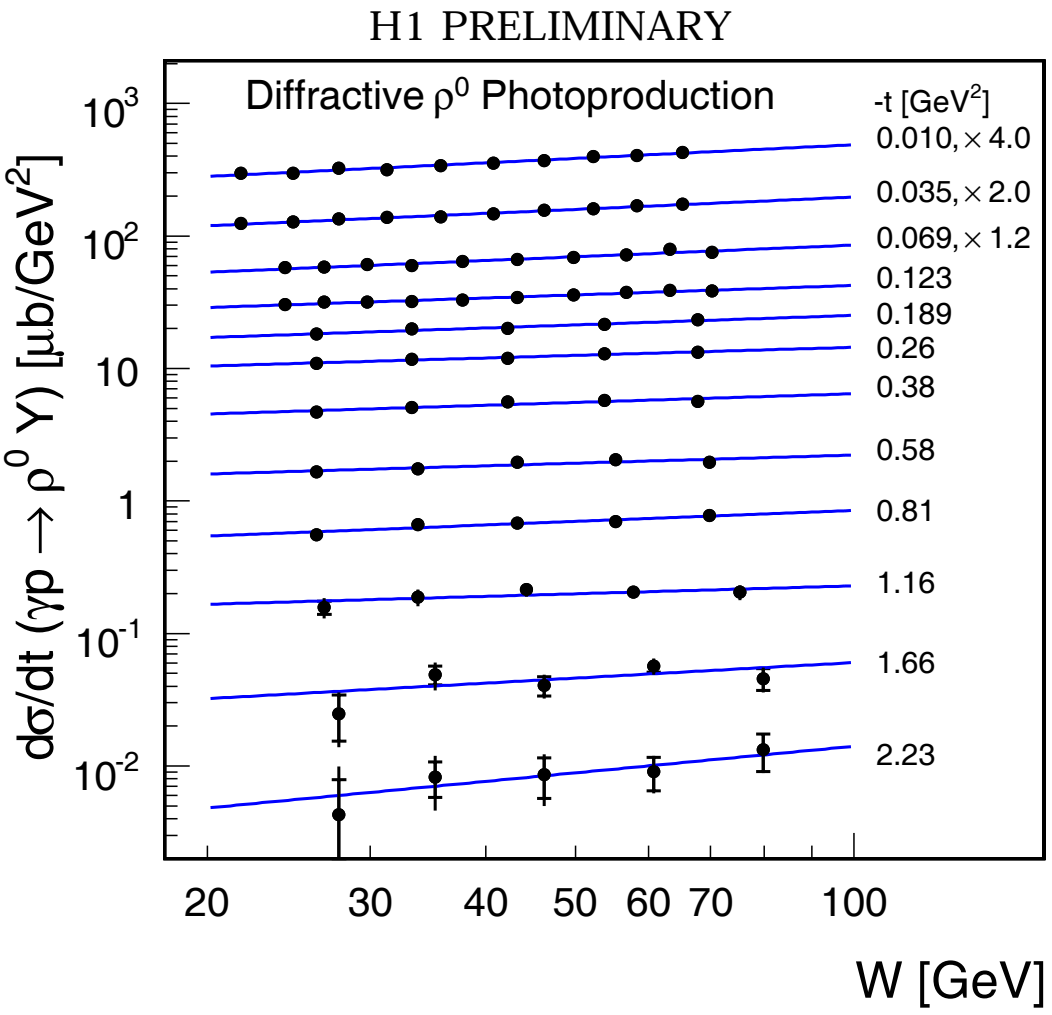
Diffractive ρ^0 photoproduction

Signal definition:
$Q^2 < 4$ GeV^2
$(M_\Upsilon^2 + Q^2)/(W^2 + Q^2) < 0.01$

Extract cross-section for diffractive (elastic and proton dissociative) ρ^0

12 bins in t - in total 80 bins in W and t
Fit $\sigma \propto W^{(4\alpha(t)-1)}$

Next step: Separate elastic from proton dissociative events using forward detectors



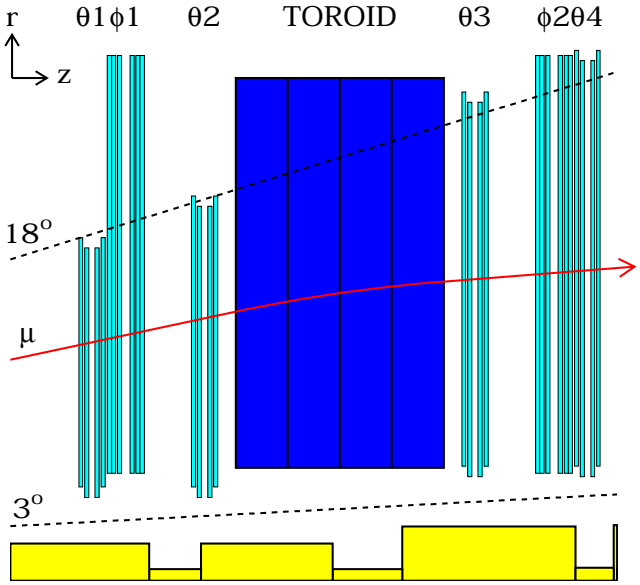
Elastic ρ^0 photoproduction

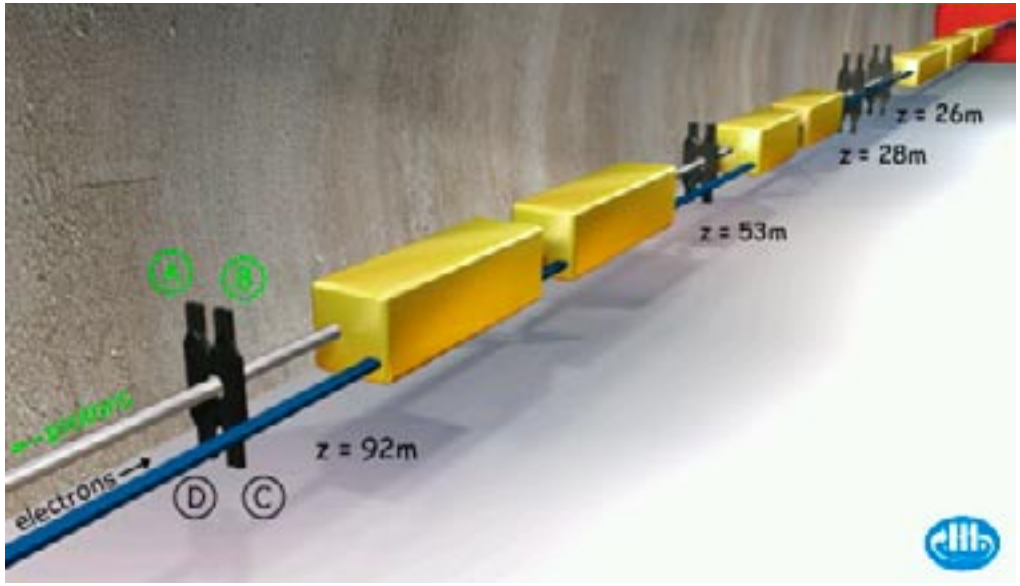
Use Forward Muon Detector and scintillators in the tunnel to tag proton dissociative events

Determine tagging efficiencies from Monte Carlo, Noise from Data

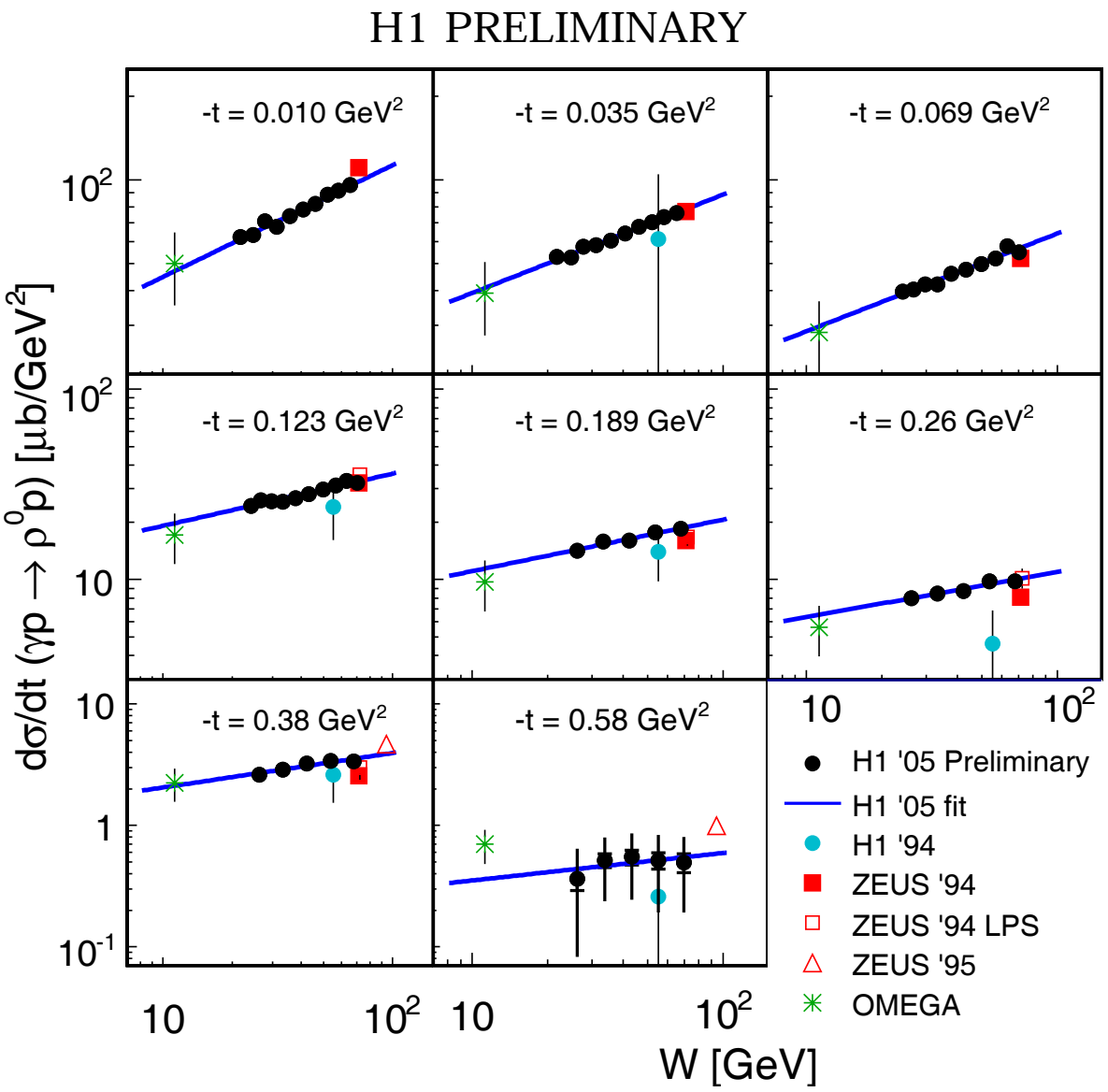
Unfold to get elastic and proton dissociative events

$\rightarrow$ Elastic cross-section





Elastic ρ^0 photoproduction



Good agreement with previous results from H1, ZEUS and OMEGA

Fit $\sigma \propto W^{(4\alpha(t)-1)}$

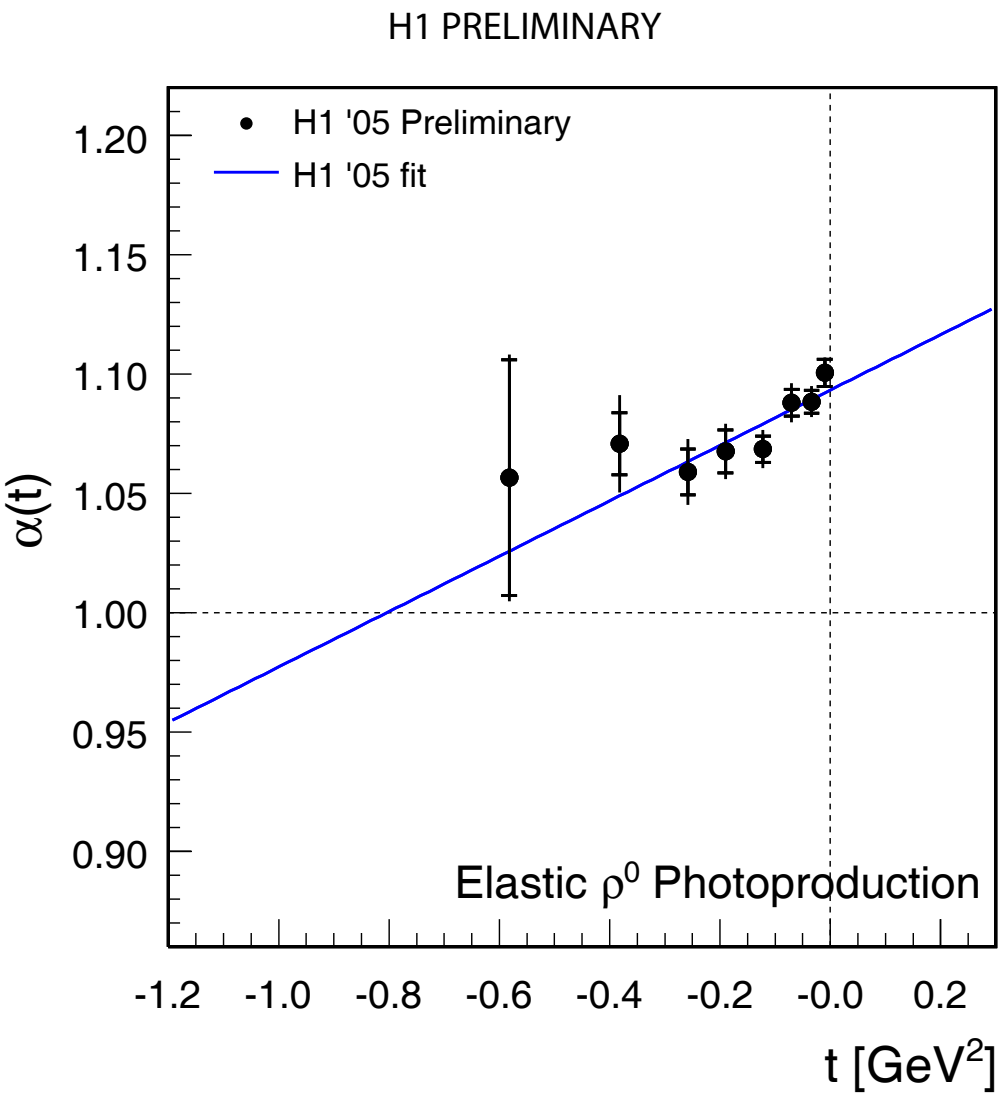
Pomeron Trajectory for ρ^0 photoproduction

Fit to the H1 data, assuming a linear Trajecory:

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

$$\alpha_{IP}(t) = (1.093 \pm 0.003\,^{+\,0.008}_{-\,0.007}) + (0.116 \pm 0.027\,^{+\,0.036}_{-\,0.046})\,\mathrm{GeV}^{-2} \cdot t$$

First Pomeron trajectory from data from a single experiment



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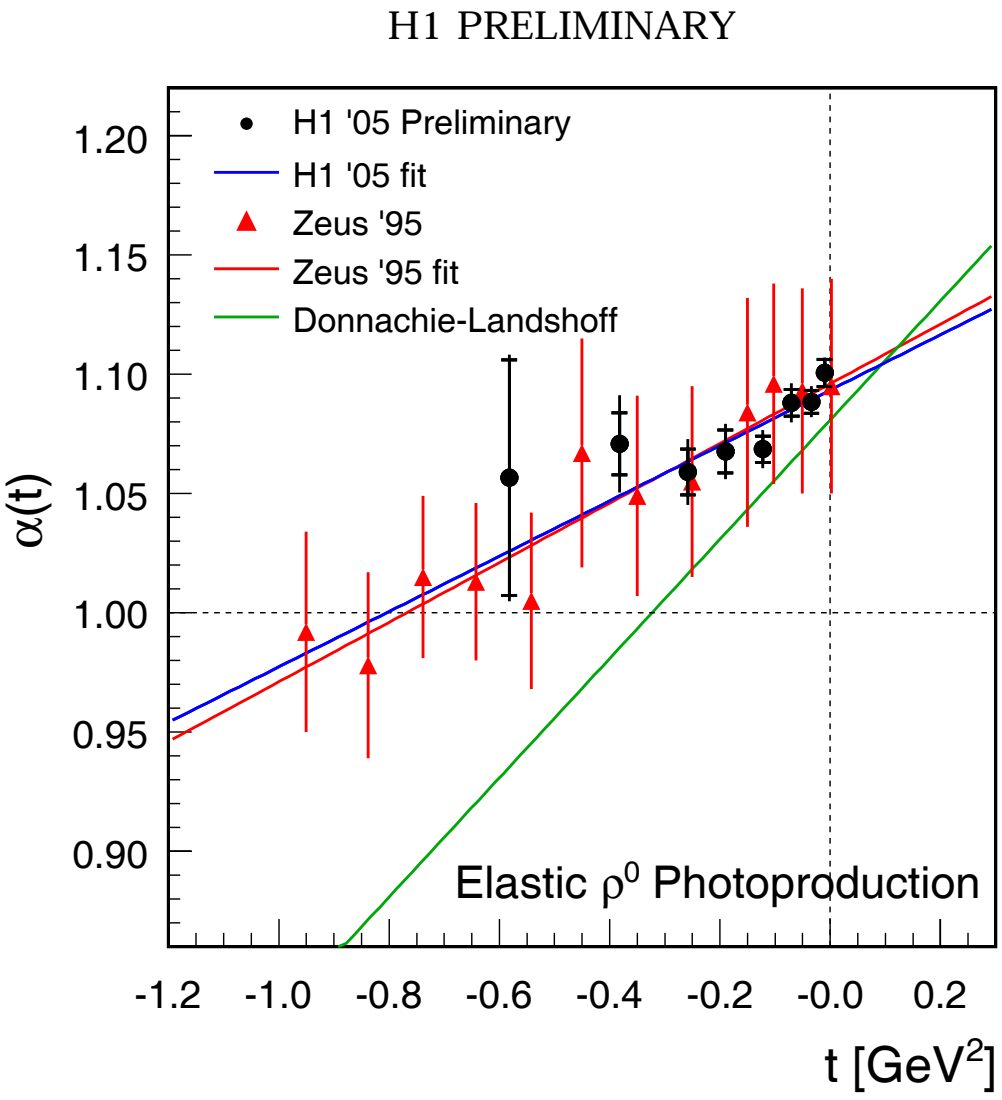
In excellent agreement with the ZEUS-OMEGA-H1 combination (errors highly correlated)

α' significantly smaller than the canonical 0.25 GeV^{-2}

(Donnachie and Landshoff, 1992)

Nonlinear trajectory?



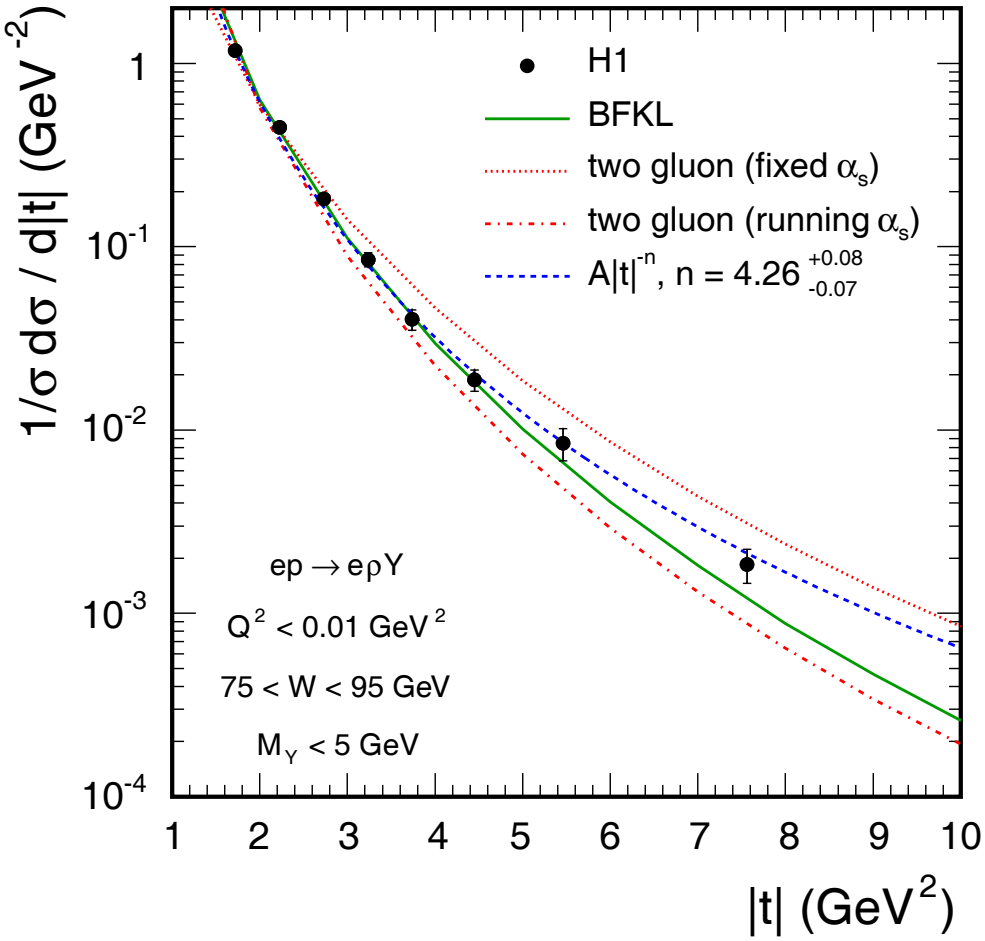
High t ρ^0 in photoproduction

$Q^2 < 0.01$ GeV^2
$75 < W < 95$ GeV
$1.5 < |t| < 20$ GeV^2
$M_Y < 5$ GeV

$\frac{d\sigma}{dt} \propto |t|^{-n}$ fits data well

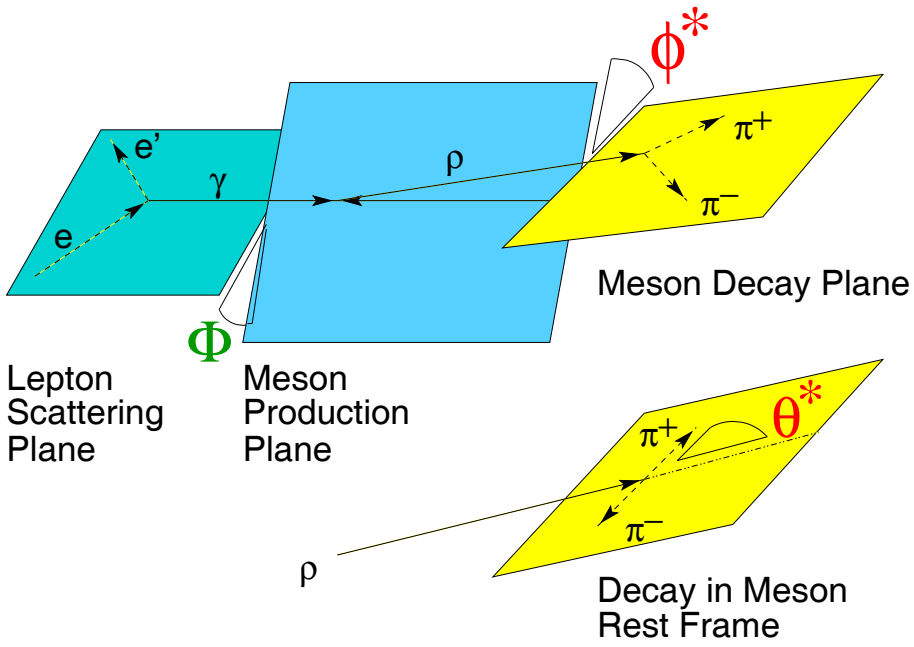
$n = 4.26 \pm 0.06\ ^{+0.06}_{-0.04}$

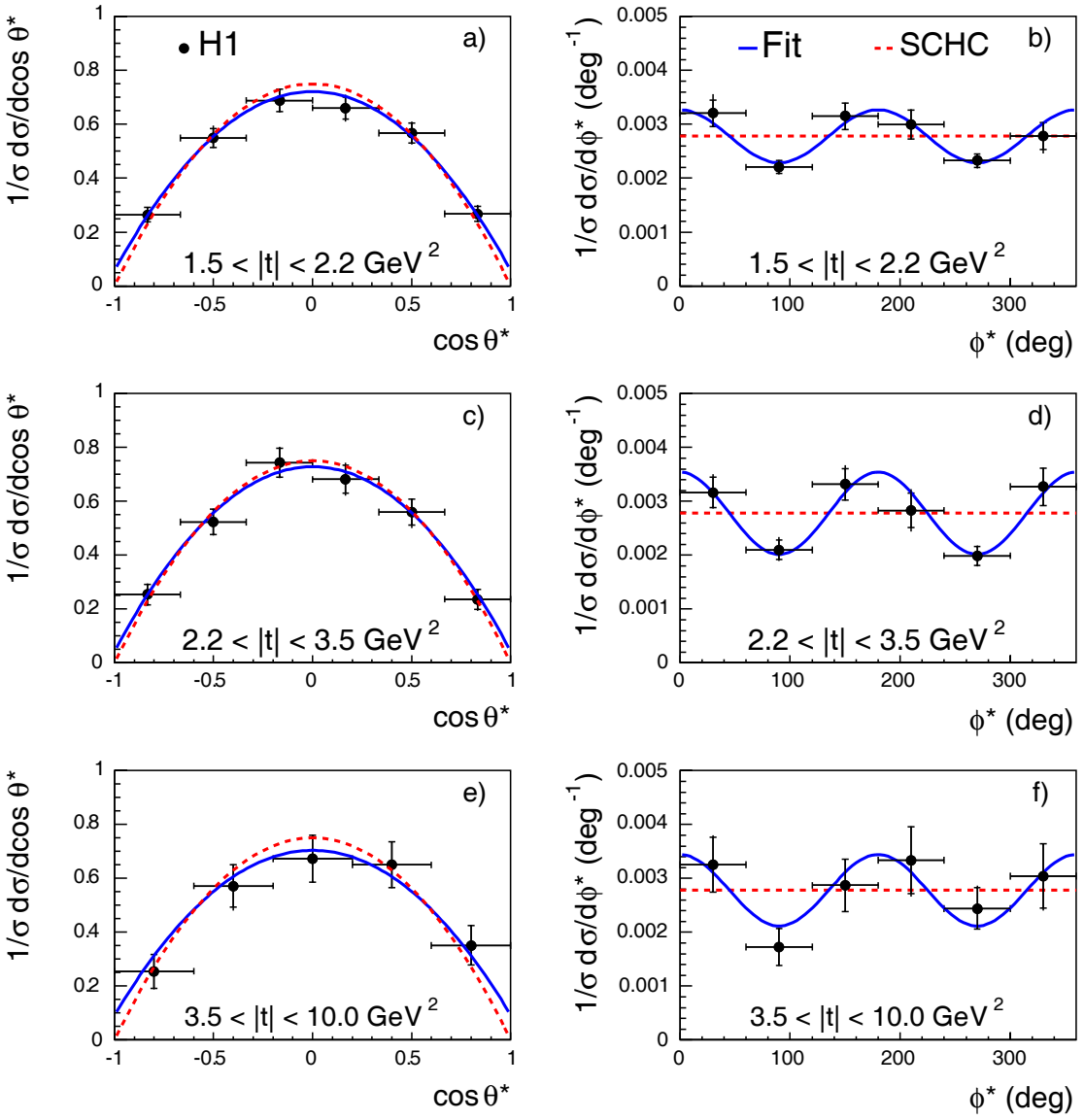
- Two gluon models don't describe data
- BFKL model gives reasonable description
  (G.G. Poludnikowski et al., JHEP 312 (2003) 002)



H1 Collab., A. Aktas et al.
Phys. Lett. B 638 (2006) 422

High t ρ^0: Angular distributions





Look for s-channel helicity NON-conservation (departure from Vector Dominance)

Photoproduction: e escapes through beampipe; only ϕ^* and θ^* accessible

High t ρ^0: Helicity Analysis

- SCHC in θ^*
- SCHC violated in ϕ^*

2-Dimensional fit:

$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\theta^* \, d\phi^*} = \frac{3}{4\pi}\left(\frac{1}{2}(1 - r^{04}_{00}) + \frac{1}{2}(3r^{04}_{00} - 1)\cos^2\theta^* - \sqrt{2}\,\mathrm{Re}(r^{04}_{10})\sin 2\theta^*\cos\phi^* - r^{04}_{1-1}\sin^2\theta^*\cos 2\phi^*\right)$$

Spin density matrix elements r:
bilinear combinations of the helicity amplitudes $M_{\lambda_\gamma,\lambda_V}$
λ_γ,λ_V : helicities (-,0,+)
of photon and vector meson

M_{++} : No Flip
M_{+0} : Single Flip
M_{+-} : Double Flip

$$r^{04}_{00} = \frac{|M_{+0}|^2}{|M_{++}|^2+|M_{+0}|^2+|M_{+-}|^2}$$

$$r^{04}_{10} = \frac{M_{++}\,M^*_{+0} - M_{+-}M^*_{+0}}{|M_{++}|^2+|M_{+0}|^2+|M_{+-}|^2}$$

$$r^{04}_{1-1} = \frac{M_{++}\,M^*_{+-} - M_{+-}M^*_{++}}{|M_{++}|^2+|M_{+0}|^2+|M_{+-}|^2}$$

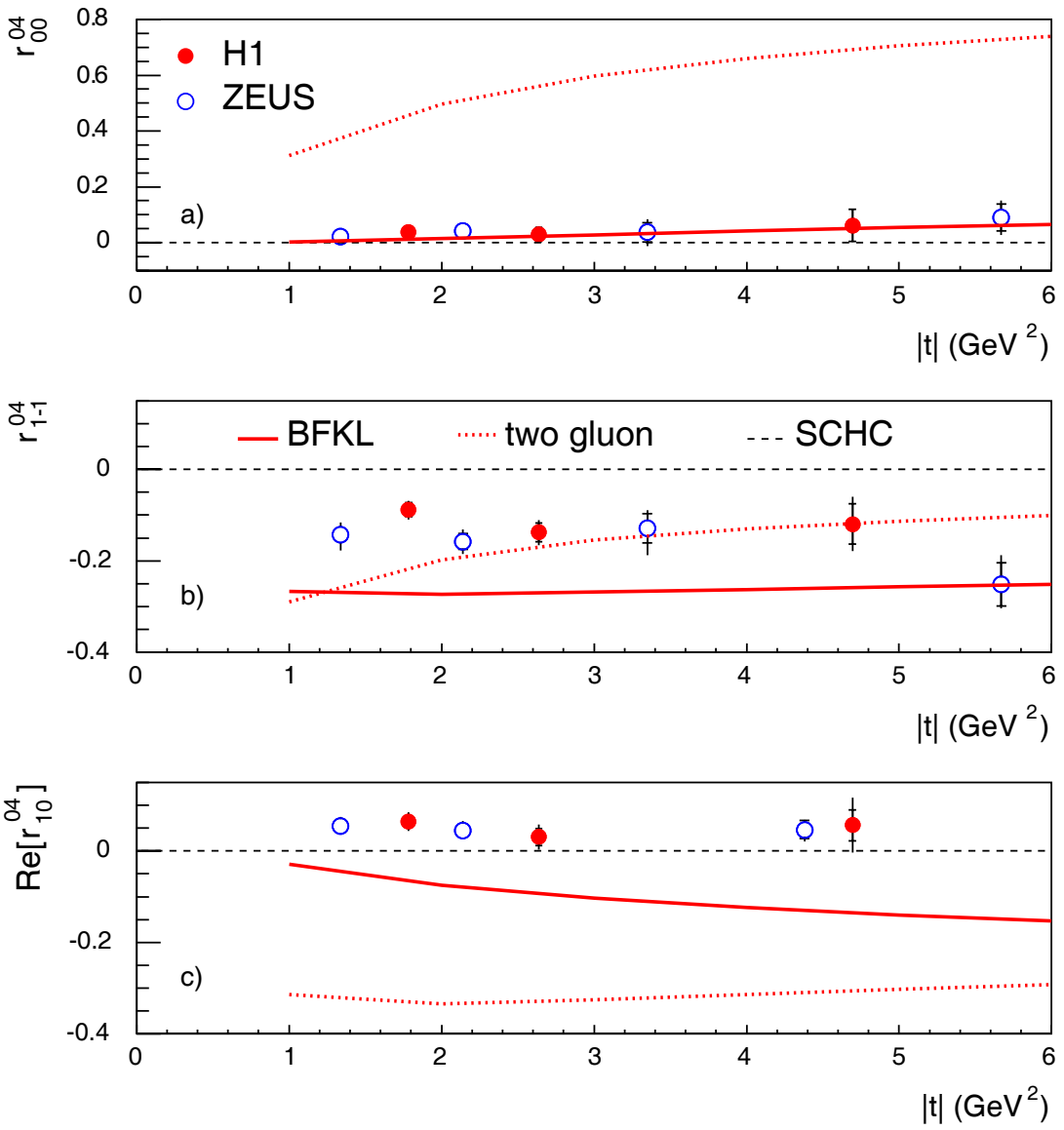
High t ρ^0: SCH-Non-Conservation

Matrix elements 0 for SCHC
Compare to 2-gluon and BFKL models

r_{00}^{04} in accordance with SCHC

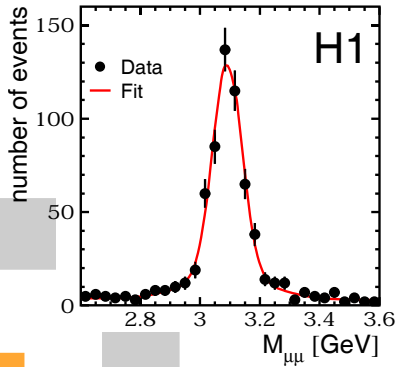
r_{1-1}^{04} and Re[r_{10}^{04}] violate SCHC

- Two gluon model fails
- BFKL based model describes r_{00}^{04}, has difficulties with r_{1-1}^{04} and fails for Re[r_{10}^{04}]

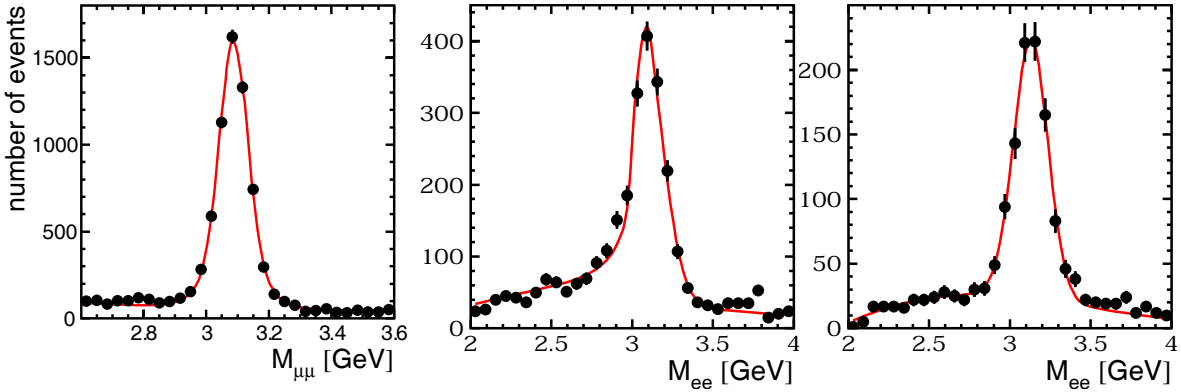


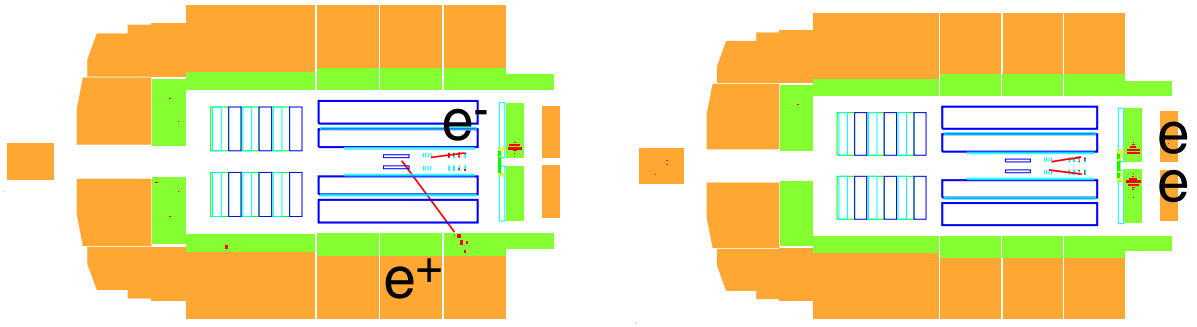
Elastic J/ψ electro- and photoproduction

Electroproduction:
$2 < Q^2 < 80$ GeV^2
$40 < W < 160$ GeV
$|t| < 1.2$ GeV^2
$J/\psi \to \mu^+\mu^-$



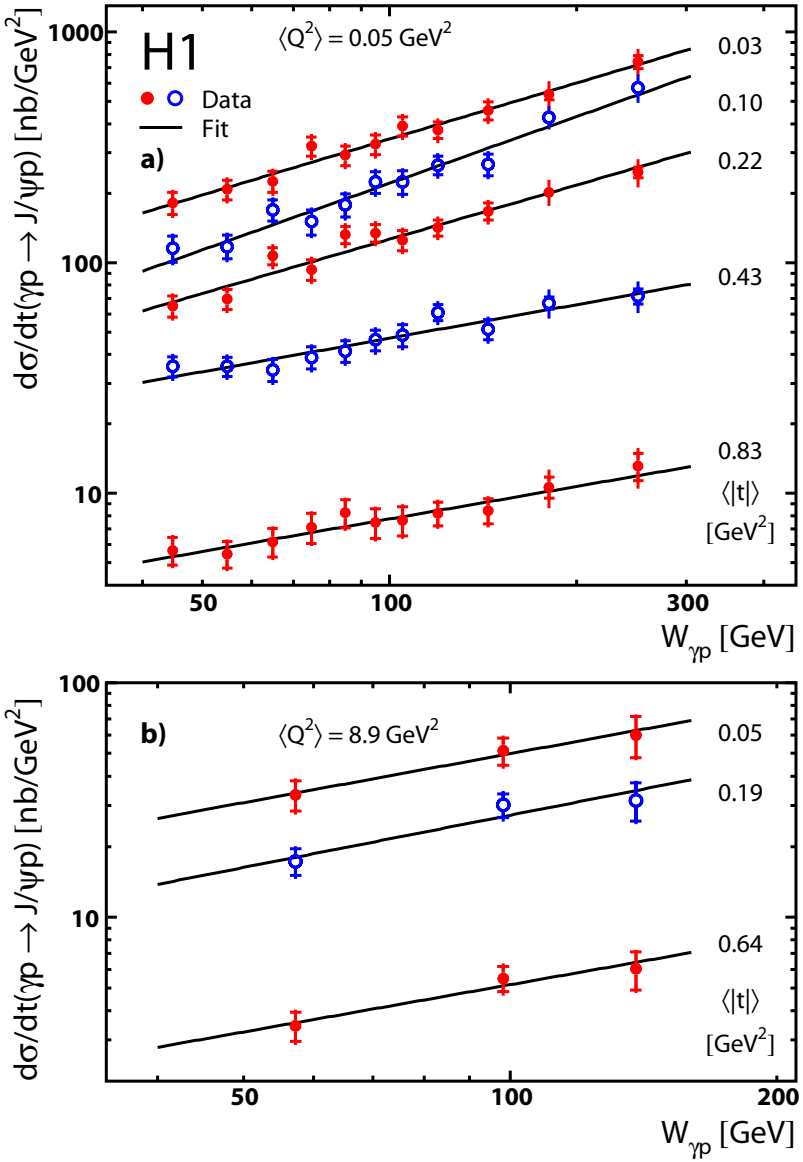
Photoproduction:
$Q^2 < 1$ GeV^2
$40 < W < 305$ GeV
$|t| < 1.2$ GeV^2
$40 < W < 160$ GeV: $J/\psi \to \mu^+\mu^-$
$135 < W < 305$ GeV: $J/\psi \to e^+e^-$





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 Collab., A. Aktas et al.
Eur. Phys. J. C46 (2006) 585

J/ψ - pomeron trajectory

- J/ψ harder than predicted by soft pomeron (γp):

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

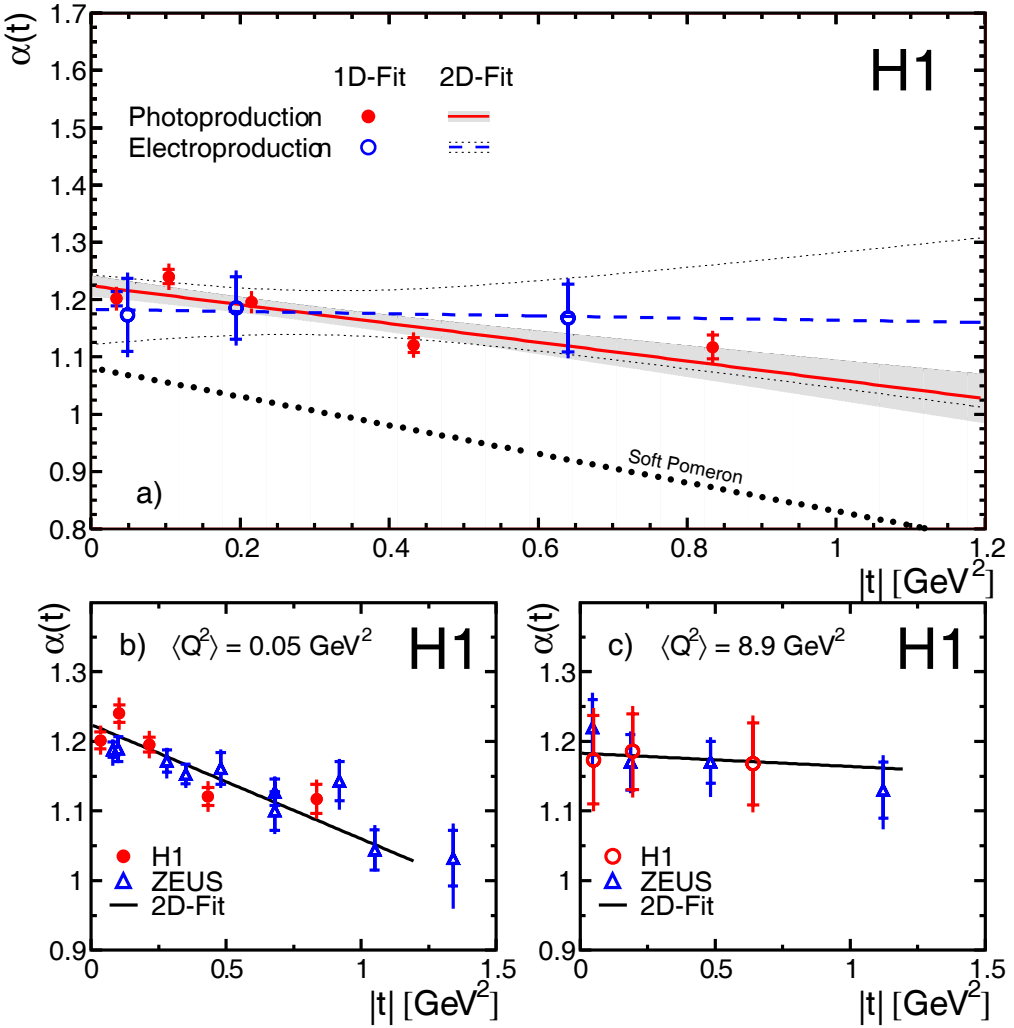
$\alpha'_P = 0.164 \pm 0.028 \pm 0.030\,\mathrm{GeV}^{-2}$

- Significant *t* dependence in photoproduction:
  4σ evidence for shrinkage,
  but also 2σ below soft pomeron

- Electroproduction: compatible with no shrinkage

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

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



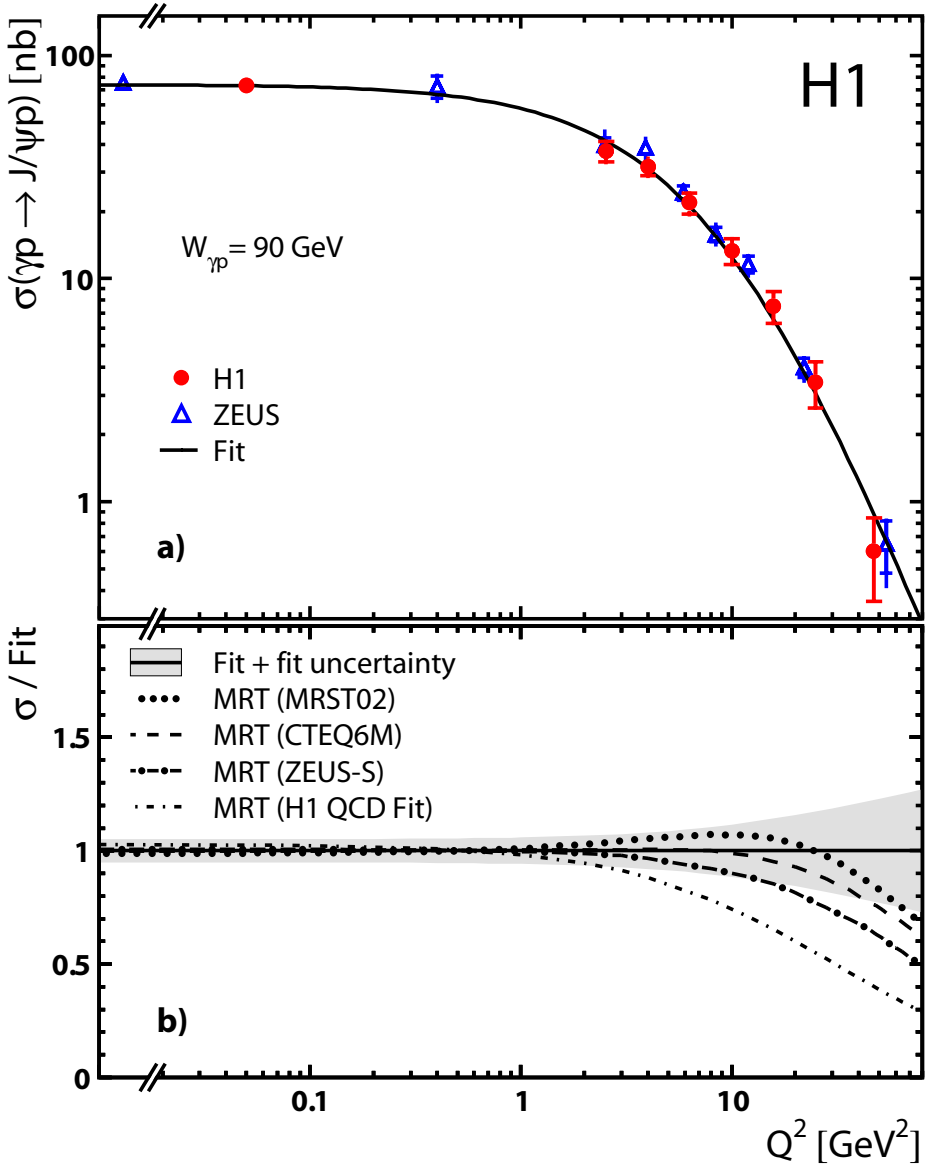
ZEUS: Nucl. Phys. B 695 (2004) 3 (DIS)
Eur.Phys.J. C 24 (2002) 345 (γp)

J/ψ - testing gluon densities?

- High J/ψ mass provides a hard scale - calculable in pQCD
- Measure cross section as a function of Q^2, W, compare to models
- Phenomenological fit $(Q^2+M^2)^{-n}$
  $n = 2.486 \pm 0.080 \pm 0.068$

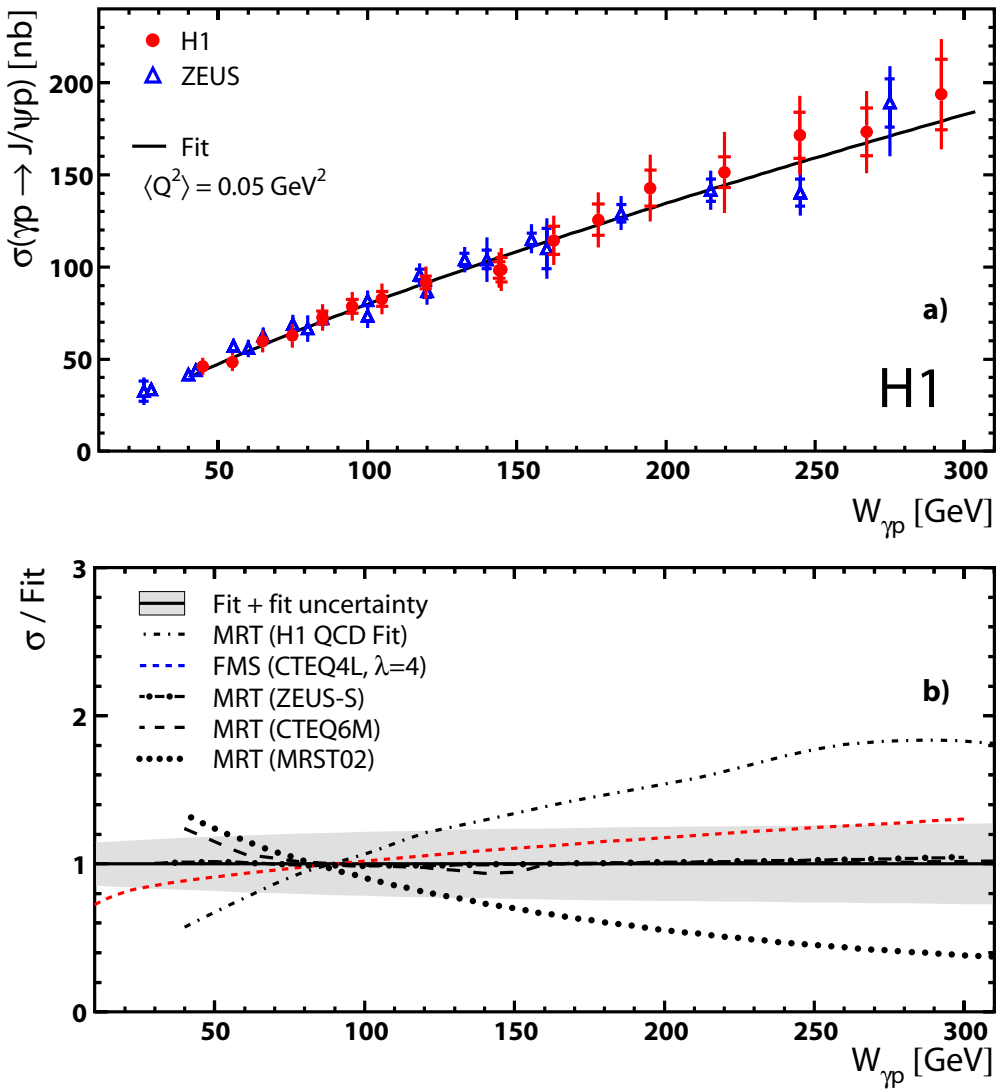
Martin, Ryskin and Teubner: pQCD model based on k_T factorisation and a parton-hadron duality ansatz (Phys.Rev.D 62 (2000) 014022)

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



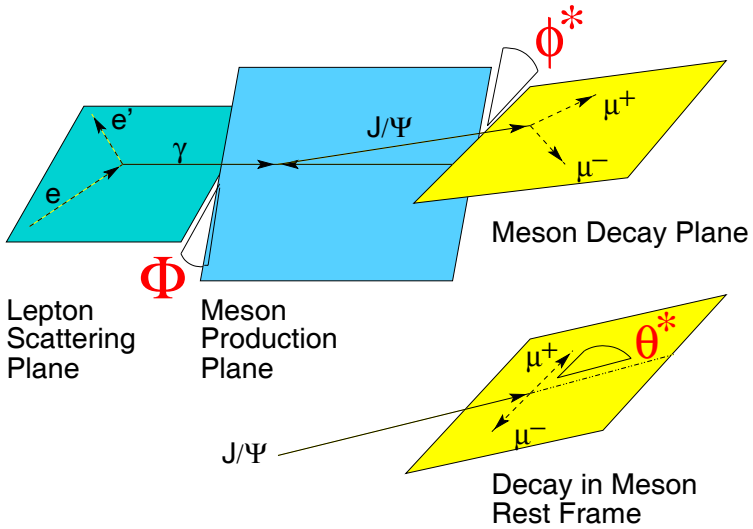
J/ψ - testing gluon densities!

- 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 into account

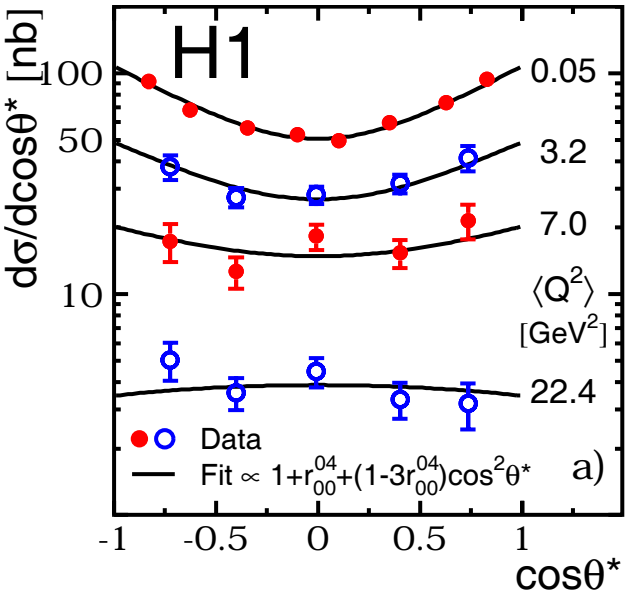


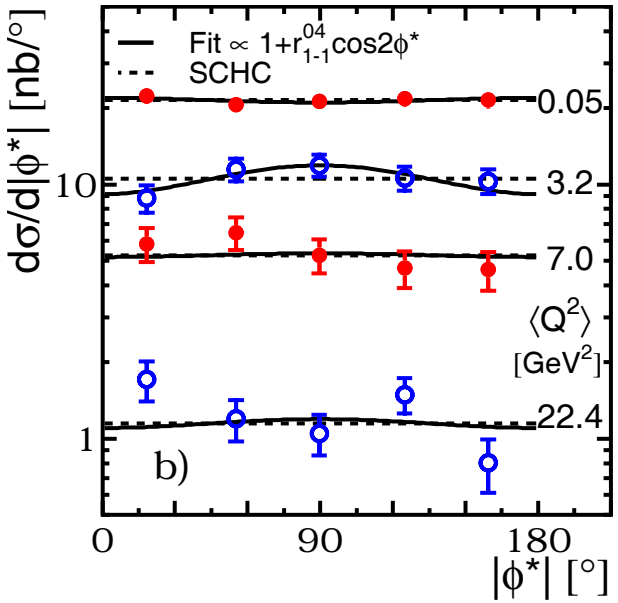
Theoretical alternative: Dipole model by Frankfurt, McDermott and Strikman (FMS)
(JHEP 0103 (2001) 045)

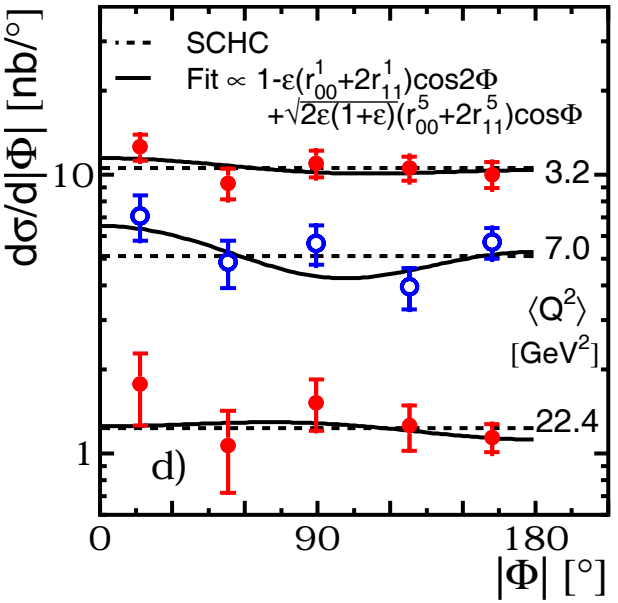
J/ψ - Helicity Analysis



- All three angles accessible in electroproduction
- Use also proton dissociative events to increase statistics





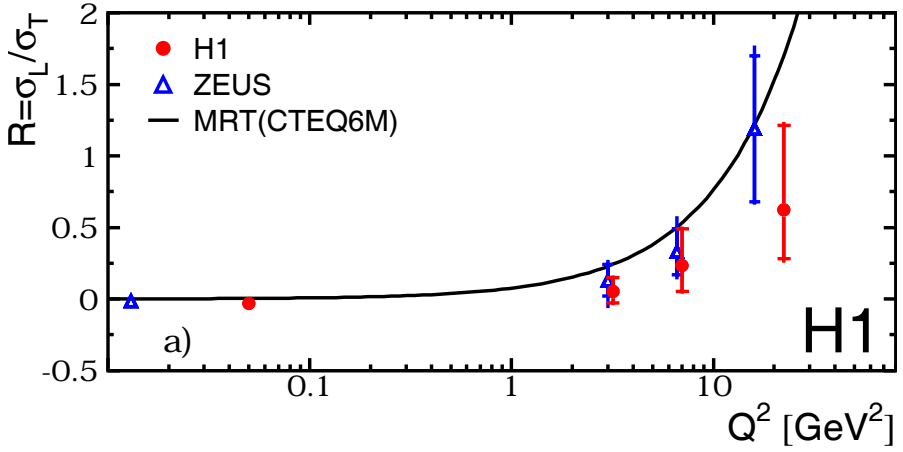


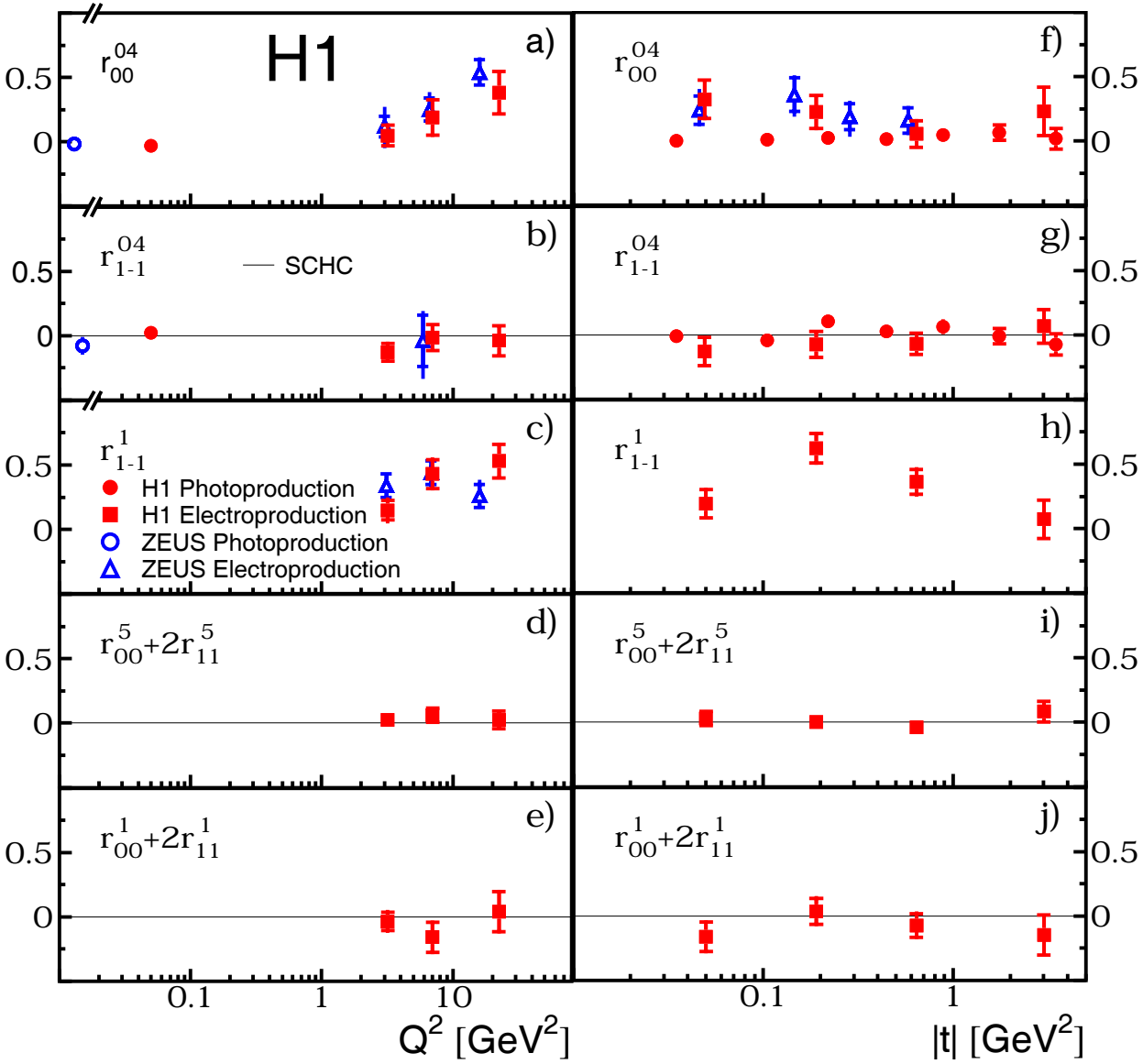
J/ψ - Helicity Analysis

The 5 measured spin-density matrix elements are in agreement with SCHC
For SCHC, the ratio

$$R = \frac{\sigma^L}{\sigma^T}$$

can be determined from r^{04}_{00}

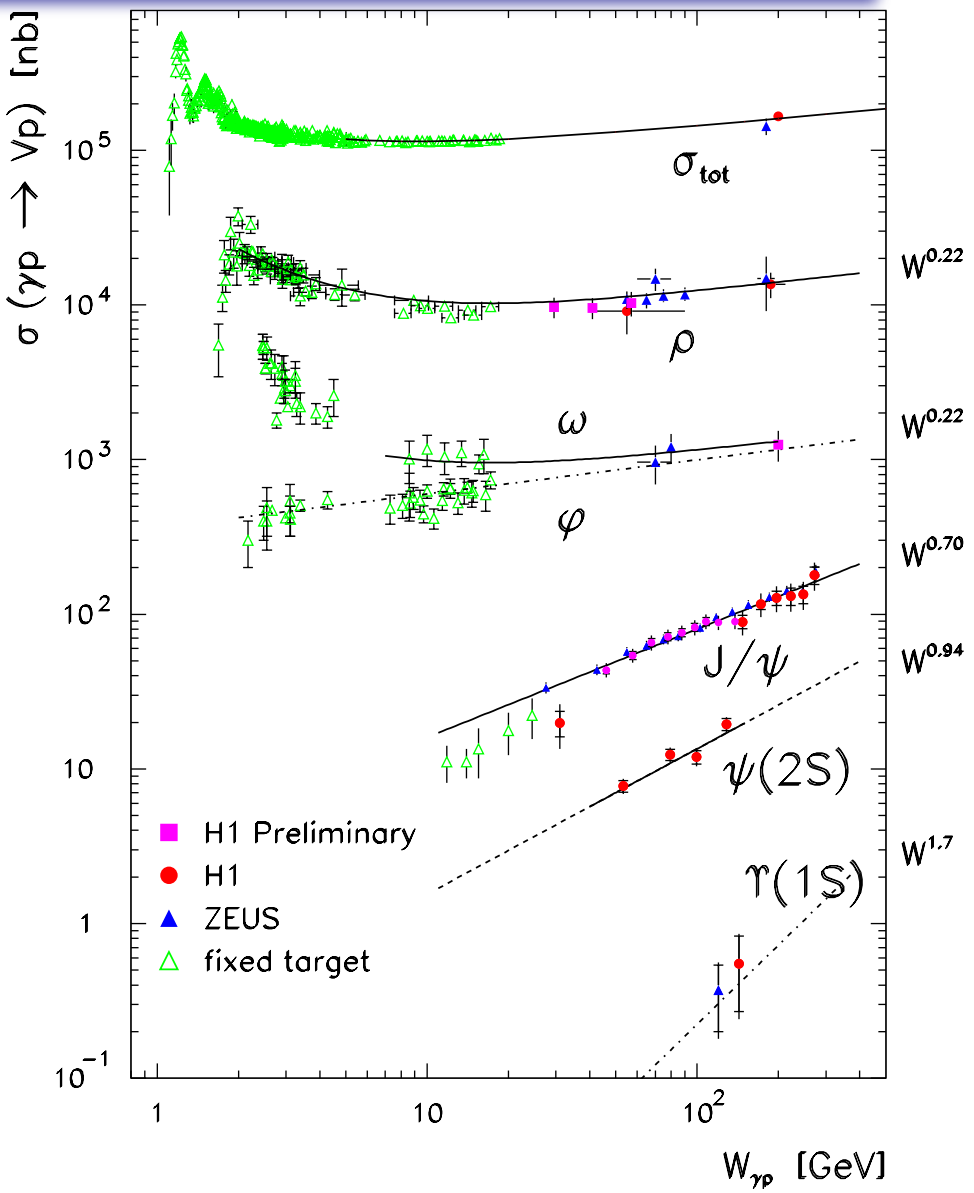




Vector Mesons at H1: Summary

- ρ^0 photoproduction at small $|t|$ not described by soft IP $\alpha' = (0.116 \pm 0.027\,^{+\,0.036}_{-\,0.046})\,\mathrm{GeV}^{-2}$
- J/Ψ production calculable in pQCD, sensitive to gluon densities and evolution
- SCHC violated for high $|t|$ ρ^0, no evidence for violation in J/ψ production

- Vector mesons are an excellent Laboratory to test various scales
- What is a "good" hard scale?



Outlook

- HERA II is running well:
  50 pb^{-1} taken by H1 in 2004
  170 pb^{-1} in 2005,
  90 pb^{-1} up to now in 2006

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

- High statistics ϕ pho-toproduction sample being analysed
- J/ψ and Υ to electrons are accessible