DVCS and vector meson production at HERA

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for the H1 and ZEUS Collaborations

Diffractive vector meson production

ρ^0 production

J/ψ production

Deeply Virtual Compton Scattering

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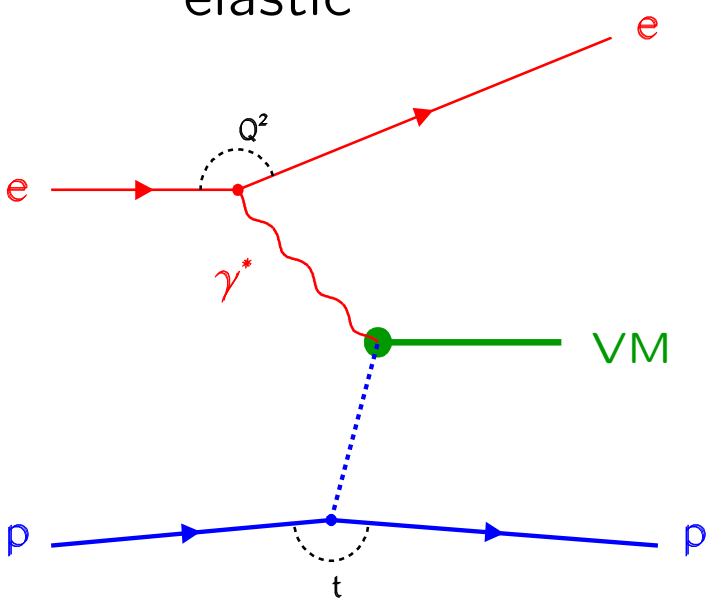
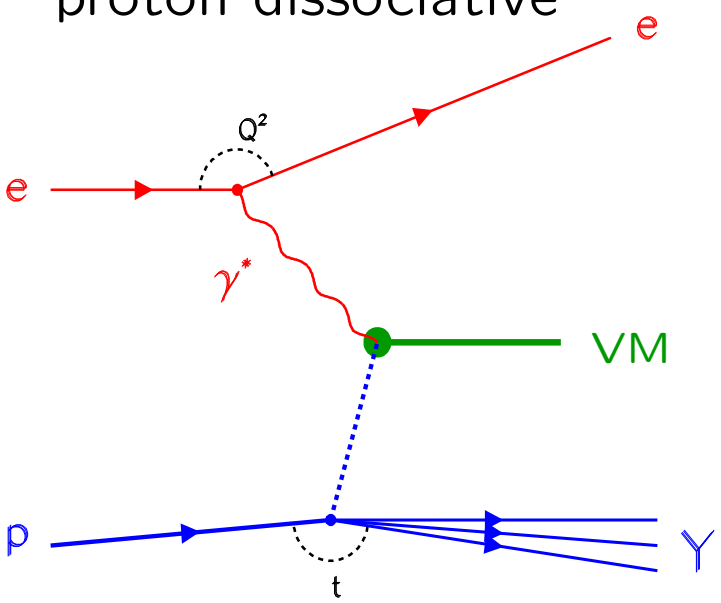
Diffractive Vector Meson Production at HERA

elastic



proton dissociative

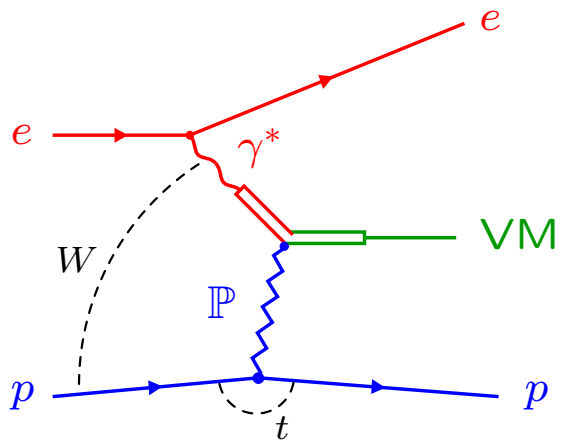


Q^2	γ^* Virtuality	$\sim 0 < Q^2 < 80\,\mathrm{GeV}^2$
W	CM Energy of $\gamma^* p$ system	$20 < W < 305\,\mathrm{GeV}$
t	(4-mom. transfer at p vertex)^2	$\sim 0 < \lvert t \rvert < 20\,\mathrm{GeV}^2$
VM	Vector Meson	$\rho^0,\ \omega,\ \phi,\ J/\psi,\ \psi',\ \Upsilon$

$\Rightarrow$ probe wide ranges of several scales: Q^2, t, M_{VM}

Expectations for Diffractive VM Production

Regge Approach



Soft Pomeron exchange

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

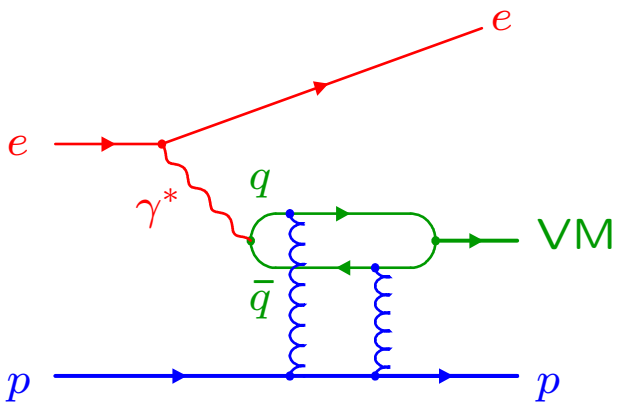
shrinkage: $b = b(W)$

slow rise $\sigma \propto W_{\gamma p}^{0.22...0.32}$

SCHC

should work for light VMs at $Q^2 \approx 0$, $t \approx 0$

pQCD Approach



exchange of ≥ 2 gluons

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

no shrinkage

steep rise due to $xg(x, Q^2)$

SCHC maybe violated

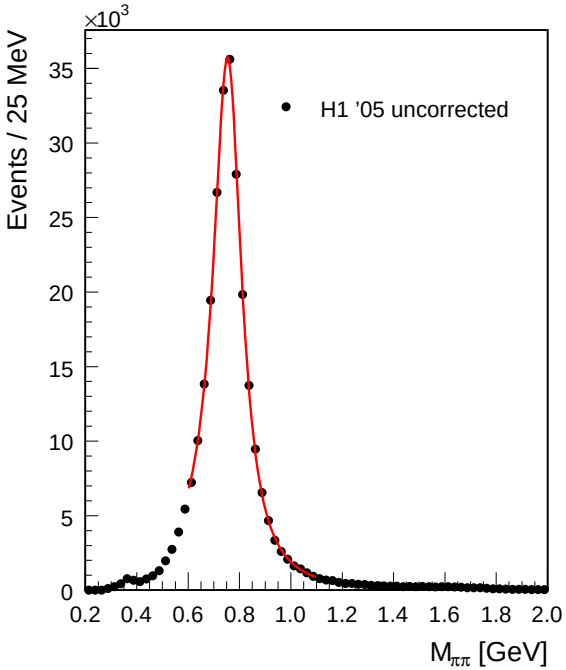
should work in presence of a hard scale

Diffractive ρ^0 Photoproduction

$Q^2 < 4\,\mathrm{GeV}^2,\ 20 < W < 90\,\mathrm{GeV}$

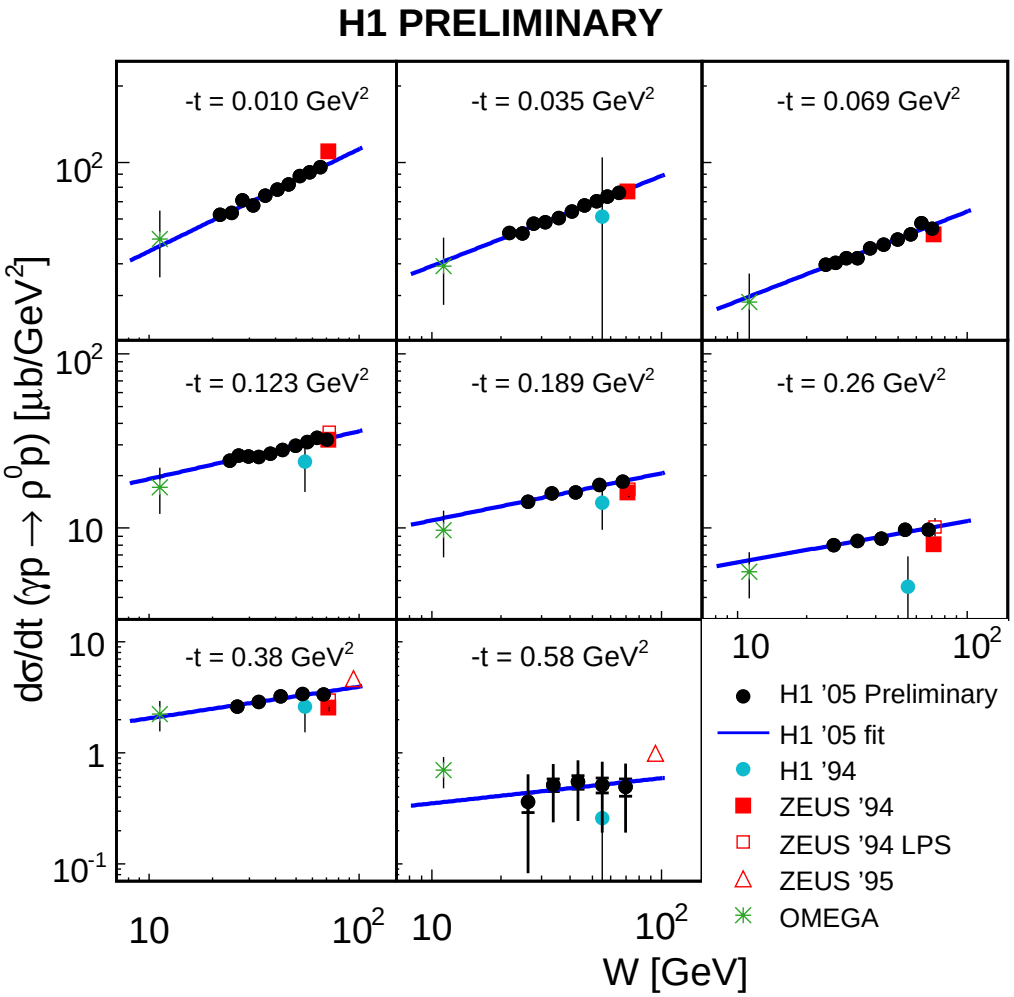
new Fast Track Trigger in HERA-2:

$\sim 250000\ \rho^0$ candidates

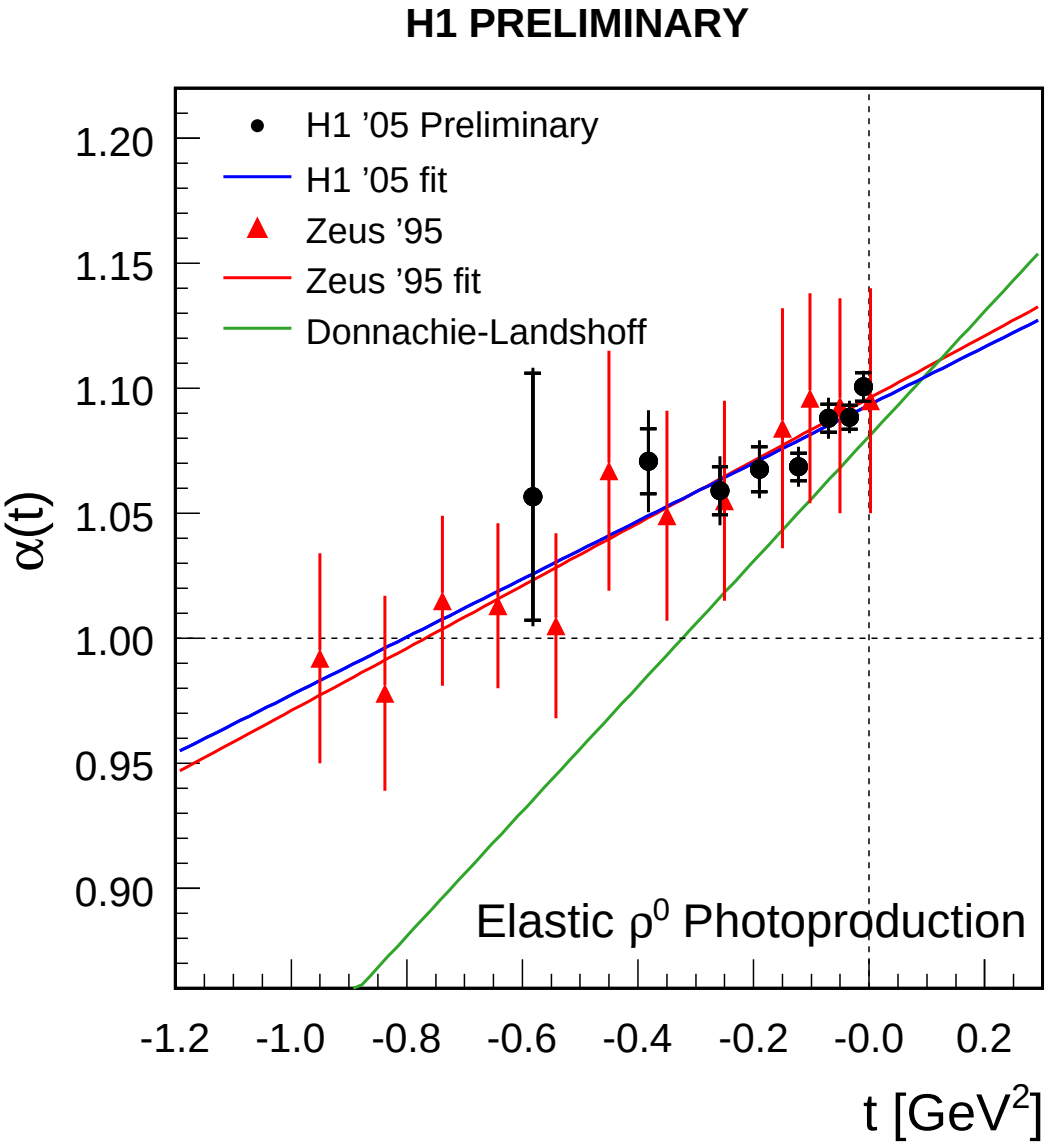


$\Rightarrow$ extract Pomeron trajectory from a single experiment

fit $\frac{\mathrm{d}\sigma(W)}{\mathrm{d}t} = \frac{\mathrm{d}\sigma(W_0)}{\mathrm{d}t}\left(\frac{W}{W_0}\right)^{4(\alpha-1)}$



Diffractive ρ^0 Photoproduction



fit single linear trajectory:

$$\alpha_{\mathbb{P}}(t) = 1.093 \pm 0.003^{+0.008}_{-0.007} + \left(0.116 \pm 0.027^{+0.036}_{-0.046}\right) \frac{t}{\mathrm{GeV}^2}$$

- good agreement with previous ZEUS result, reduced error
- significantly smaller slope than Soft Pomeron (Donnachie-Landshoff)

ρ^0 Photoproduction at Large $|t|$

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$Q^2 < 0.01\,\text{GeV}^2$

$75 < W < 95\,\text{GeV}$

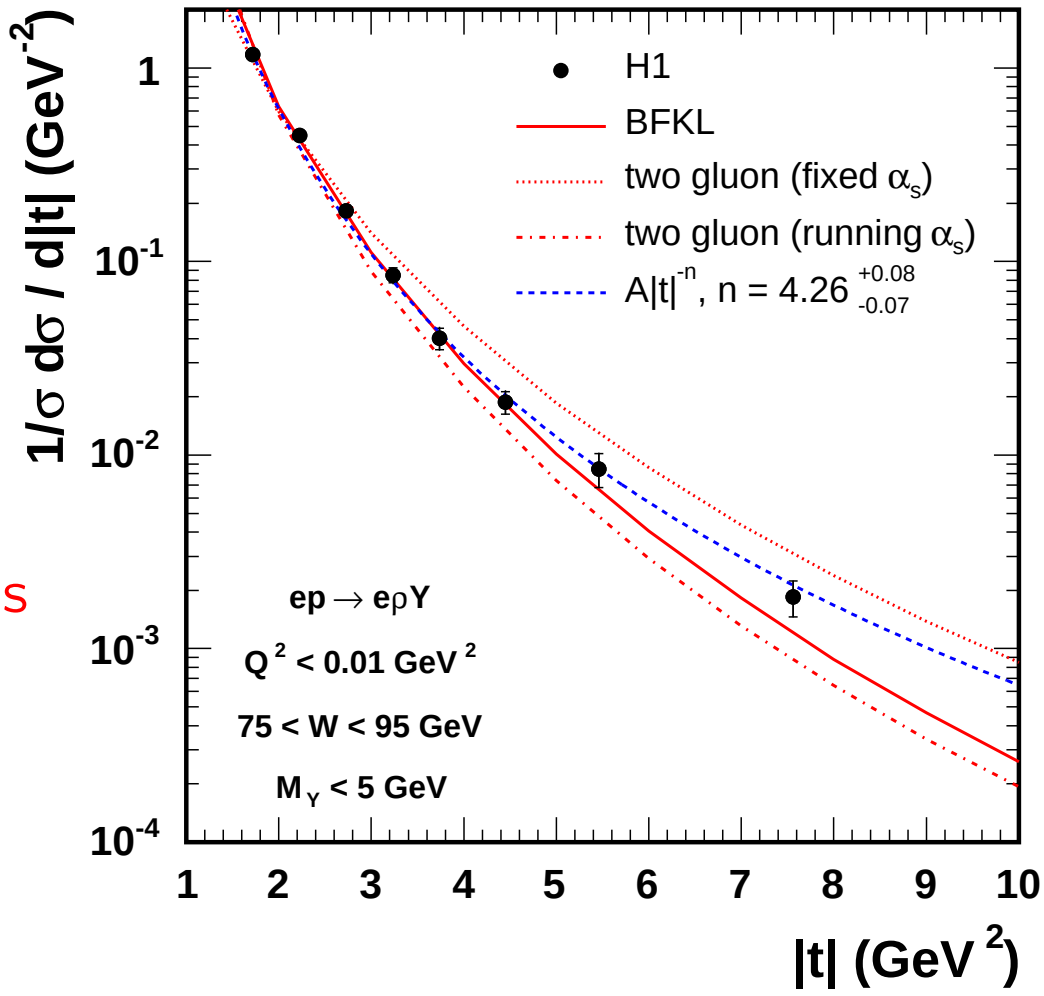
$1.5 < |t| < 10\,\text{GeV}^2$

$M_Y < 5\,\text{GeV}$

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

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

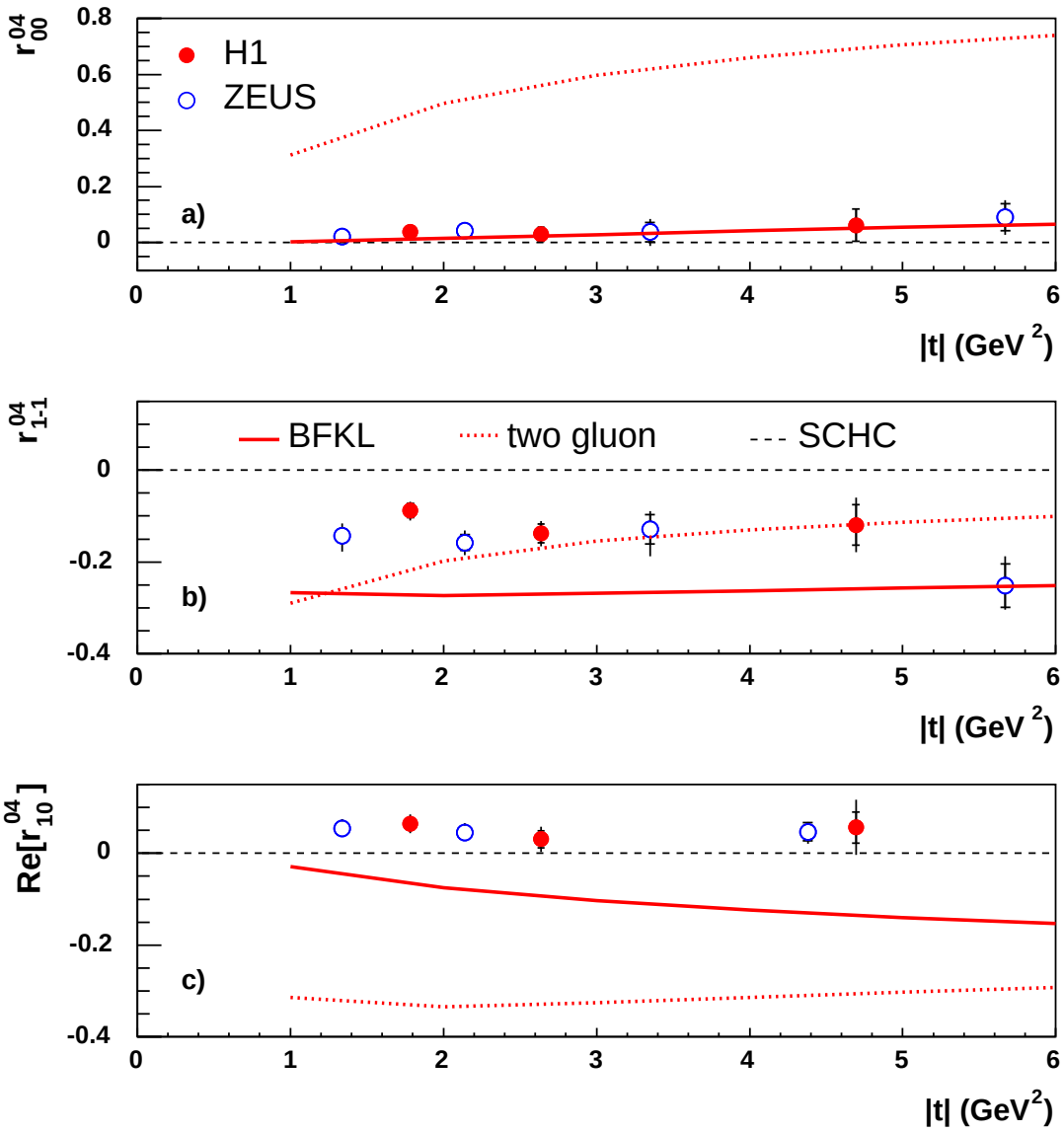
- two gluon model predictions don't describe data
- BFKL model gives reasonable description



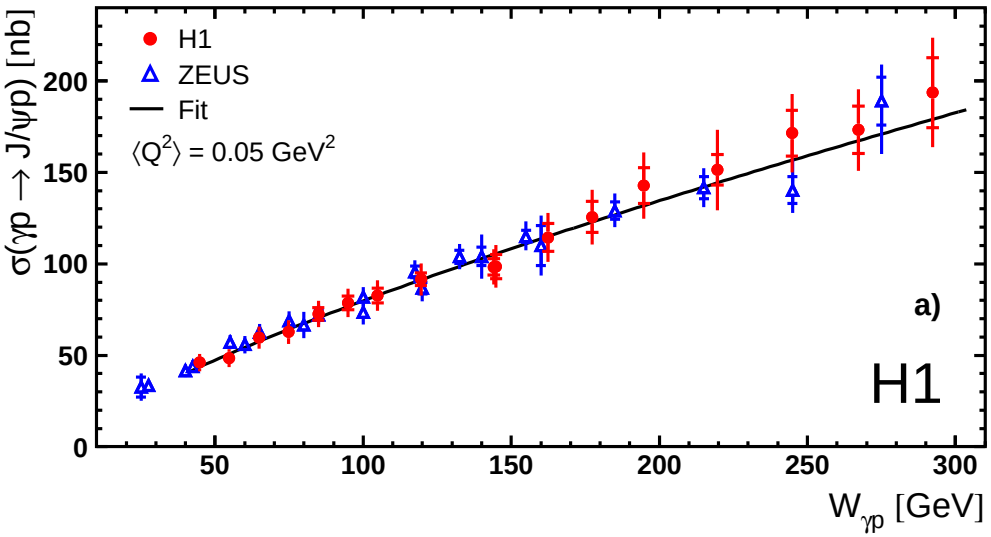
ρ^0 Photoproduction at Large $|t|$: Spin Density Matrix Elements

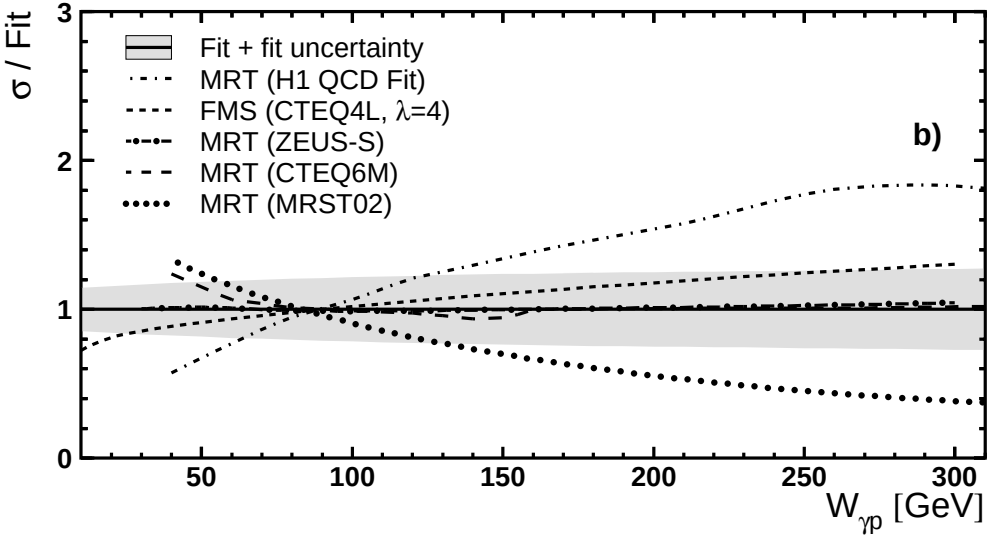
study decay angles to extract spin density matrix elements

- r^{04}_{1-1} and Re$[r^{04}_{10}]$ violate SCHC
- two gluon model fails
- BFKL model cannot describe r^{04}_{1-1} and Re$[r^{04}_{10}]$



Elastic J/ψ Production





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photoproduction:

$Q^2 < 1\,\mathrm{GeV}^2$

$40 < W < 305\,\mathrm{GeV}$

$|t| < 1.2\,\mathrm{GeV}^2$

$\sigma \propto W^{\delta}$ fits data well

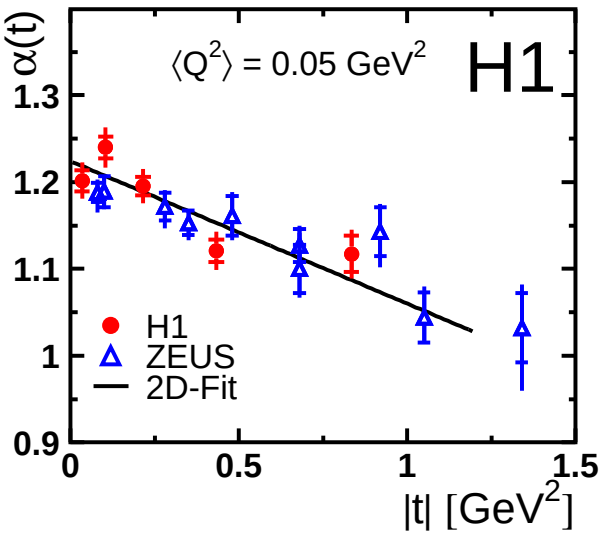
$\delta = 0.75 \pm 0.03 \pm 0.03$

MRT* model is very sensitive to the shape of the gluon at low x

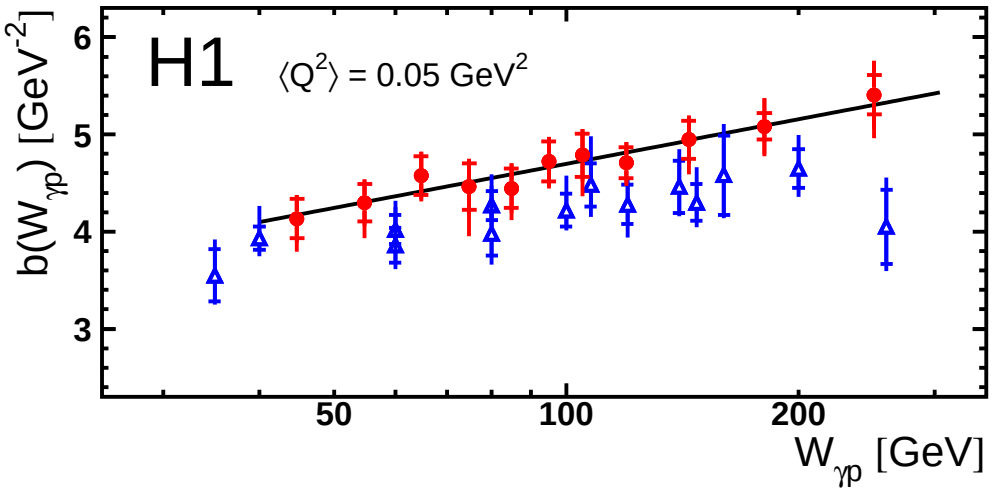
* using generalized pdfs (GPDs)

Elastic J/ψ Production

Pomeron tractory



shrinkage



photoproduction:

$\alpha_{\mathbb{P}}(t) = 1.224 \pm 0.010 \pm 0.012 +$
$(0.164 \pm 0.028 \pm 0.030)\,\mathrm{GeV}^{-2} \cdot t$

electroproduction $(2 < Q^2 < 80\,\mathrm{GeV}^2)$
is compatible

harder than Soft Pomeron (DL)

photoproduction: yes

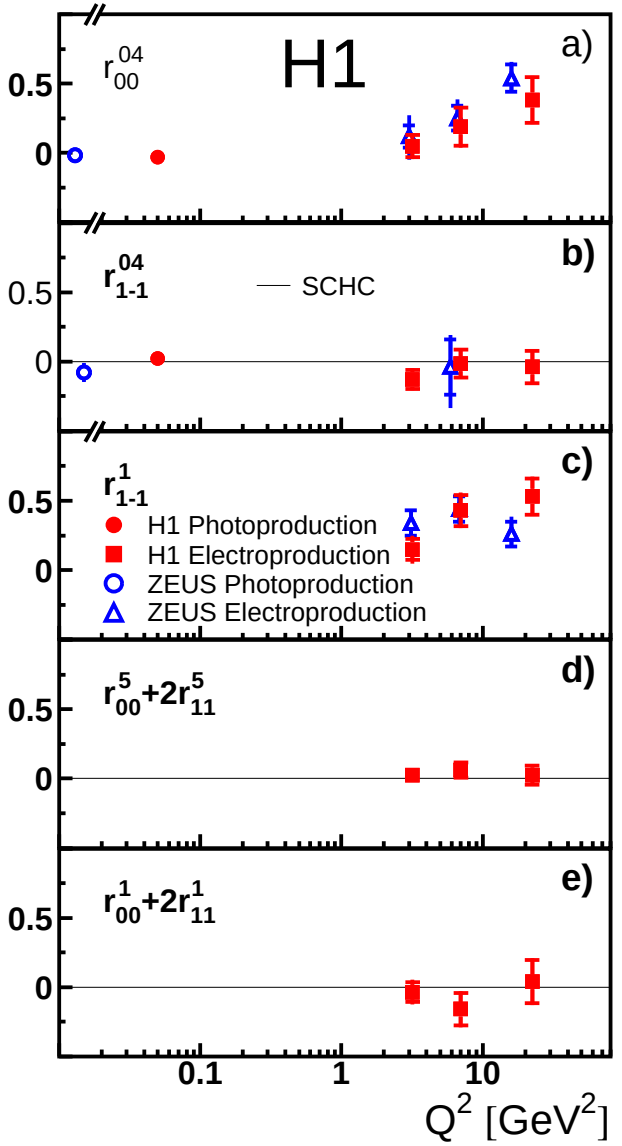
electroproduction: ?

Elastic J/ψ Prod.: Spin Density Matrix Elements

spin density matrix elements
extracted from production
and decay angles

good agreement with ZEUS results

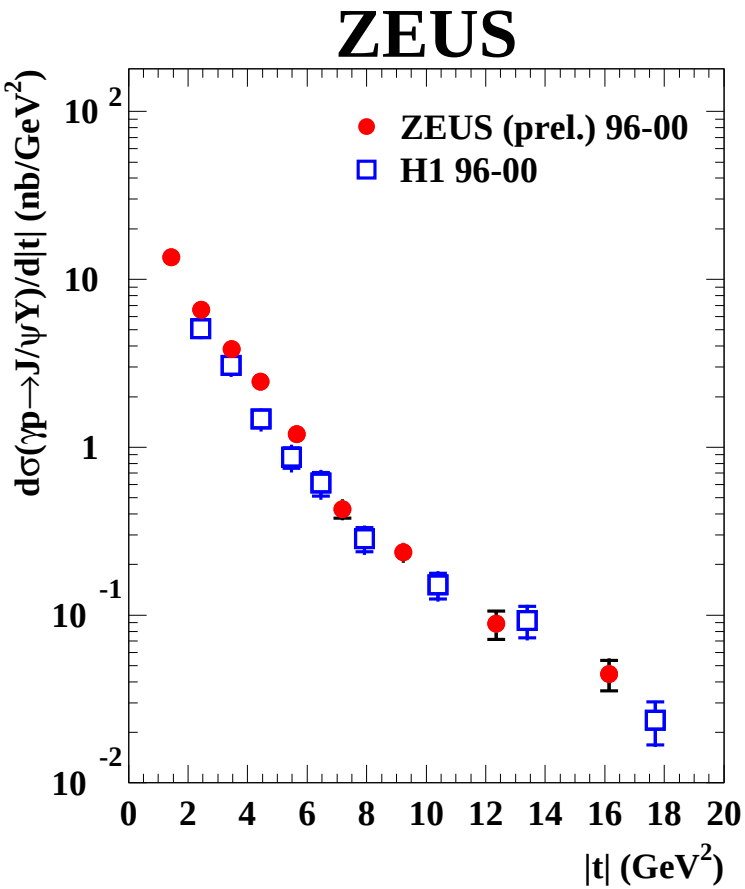
no evidence for SCHC violation

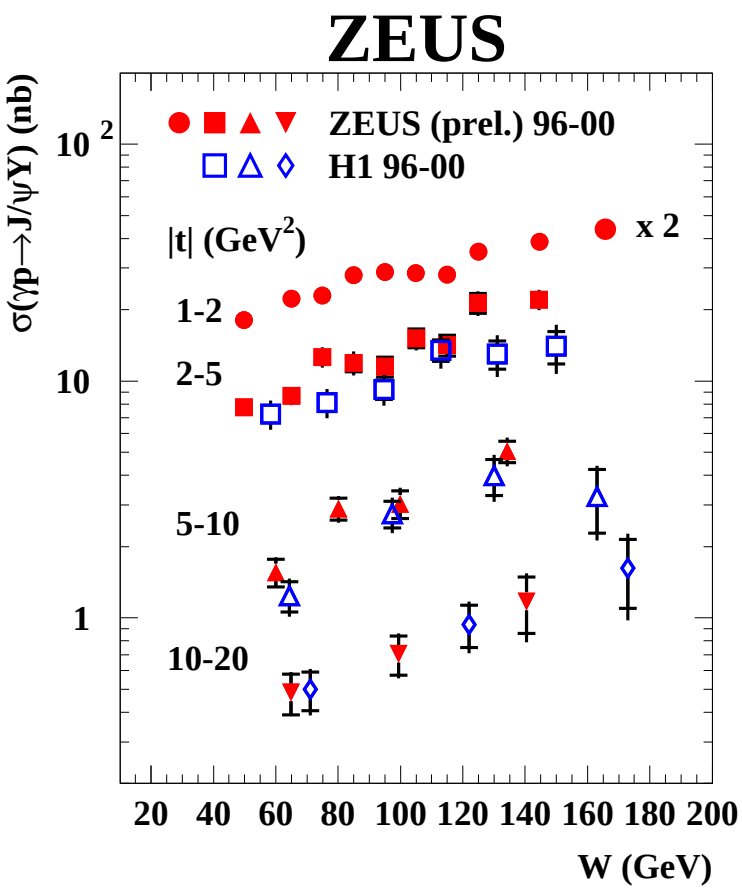


J/ψ Photoproduction at Large $|t|$

$50 < W < 150\,\text{GeV},\ M_Y < 30\,\text{GeV},\ 1 < |t| < 20\,\text{GeV}^2,\ z < 0.95$

ZEUS data above H1 at low $|t|$, agreement at high $|t|$

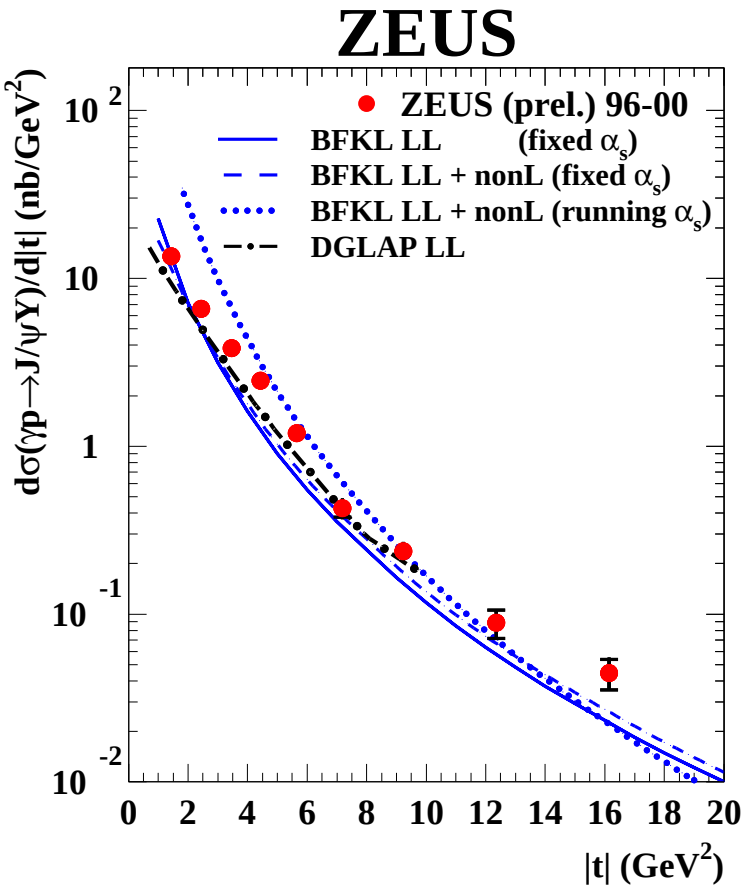


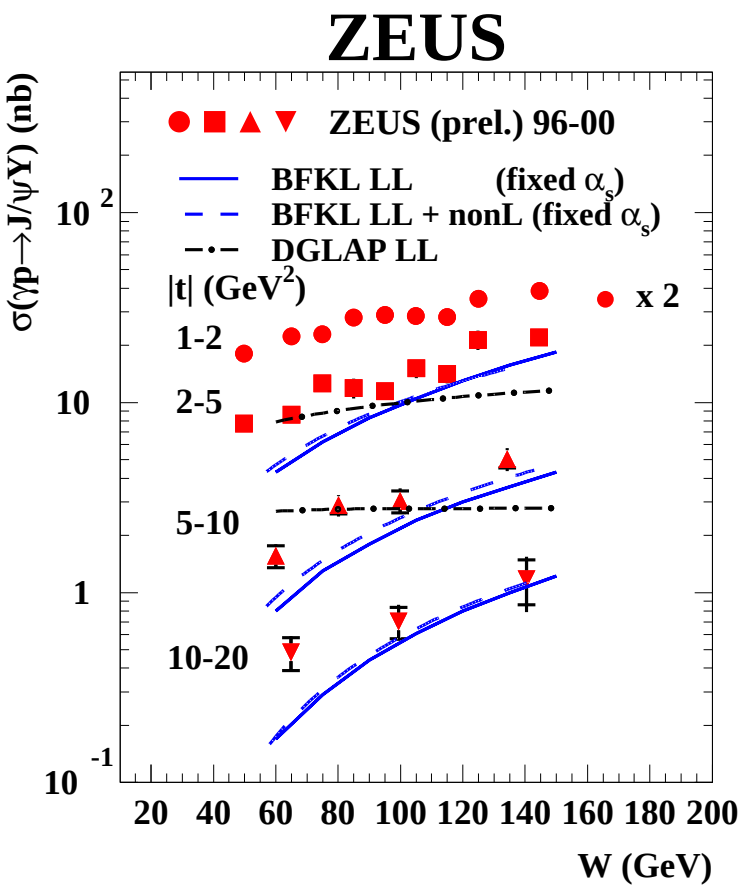


J/ψ Photoproduction at Large $|t|$

DGLAP and BFKL with fixed α_s describe $|t|$ dependence

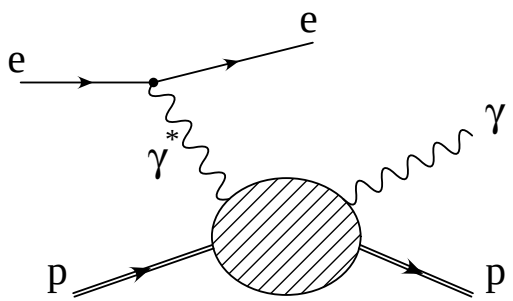
BFKL reproduces rise with W, DGLAP does not



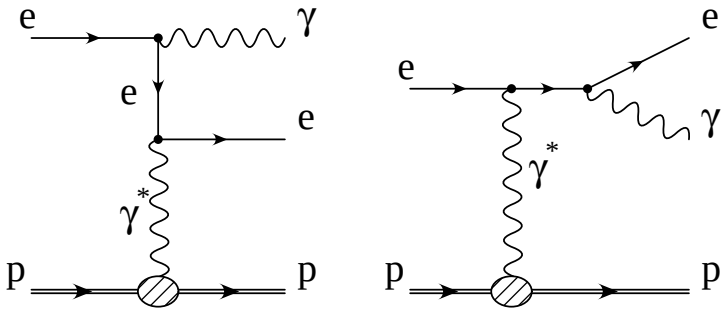


Deeply Virtual Compton Scattering

DVCS



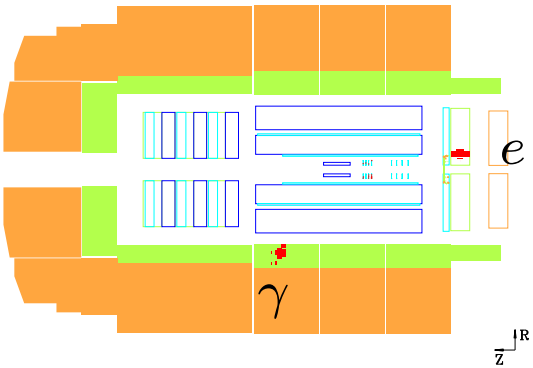
Bethe-Heitler



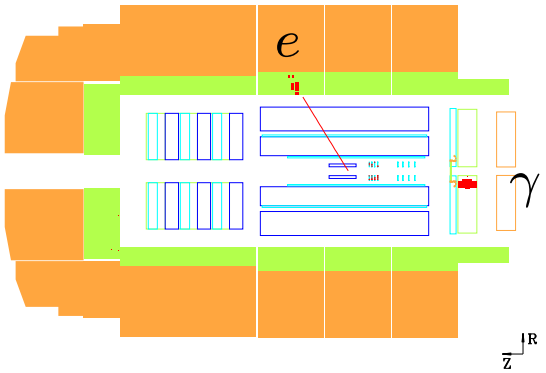
DVCS and Bethe-Heitler have same final state

$\Rightarrow$ interference term vanishes due to integration over azimuth

$\Rightarrow$ use Bethe-Heitler to control detector response

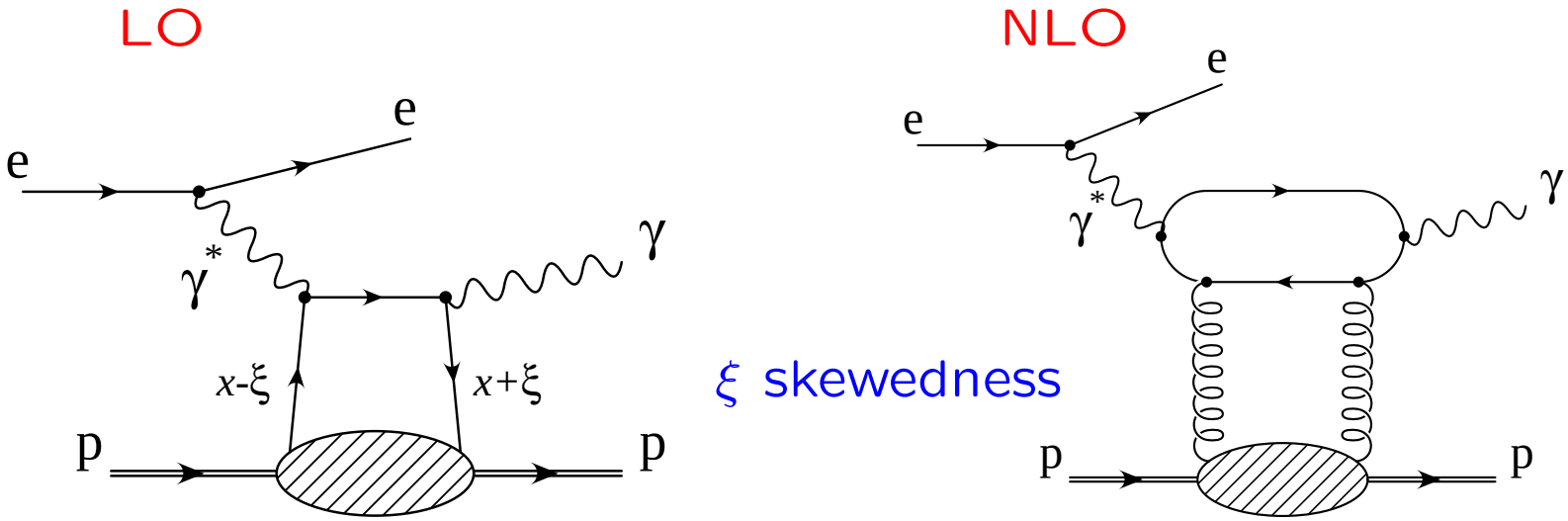


DVCS+Bethe-Heitler



Bethe-Heitler

DVCS predictions



QCD predictions:

- new formalism to describe proton dynamics: GPDs $= f(x, \xi, t; \mu^2)$
- access to transverse momentum of partons, correlations

Color Dipole Model:

- photon fluctuates into a $q\bar{q}$ pair
- color dipole interacts with proton
- GBW saturation model with DGLAP evolution (BGBK) applied

DVCS results

HERA-2: $6.5 < Q^2 < 80\,\mathrm{GeV}^2$

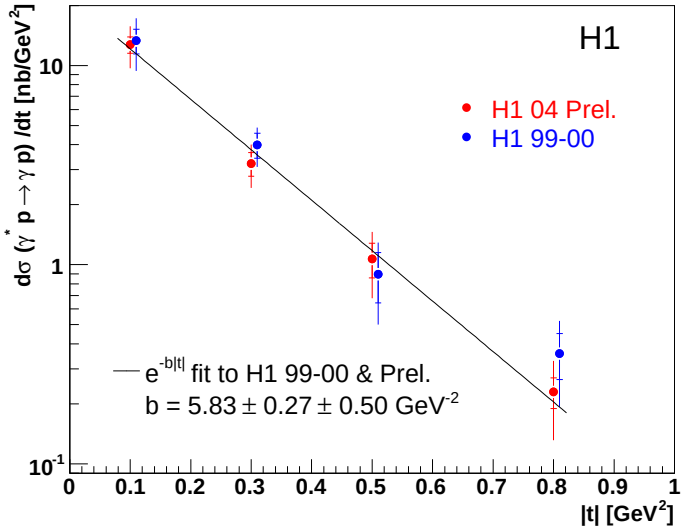
$30 < W < 140\,\mathrm{GeV},\ |t| < 1\,\mathrm{GeV}^2$

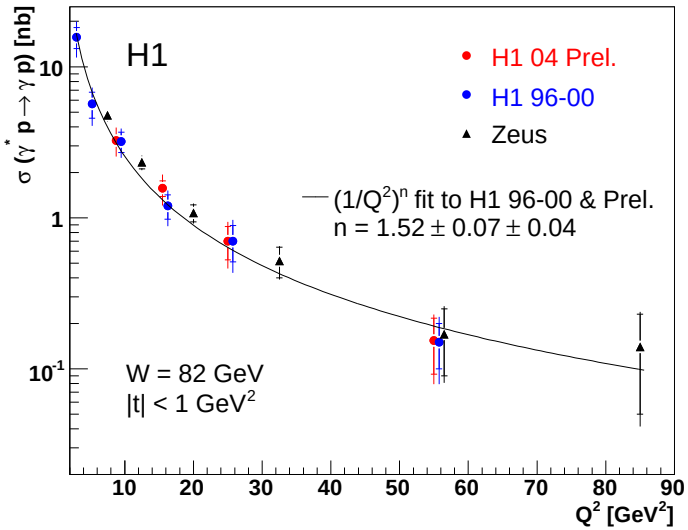
good agreement with HERA-1

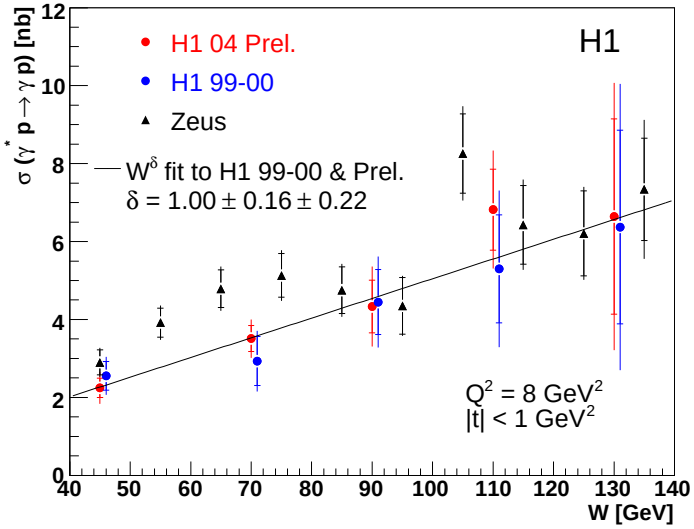
statistical errors reduced

fit W^δ: $\delta = 1.00 \pm 0.16 \pm 0.22$

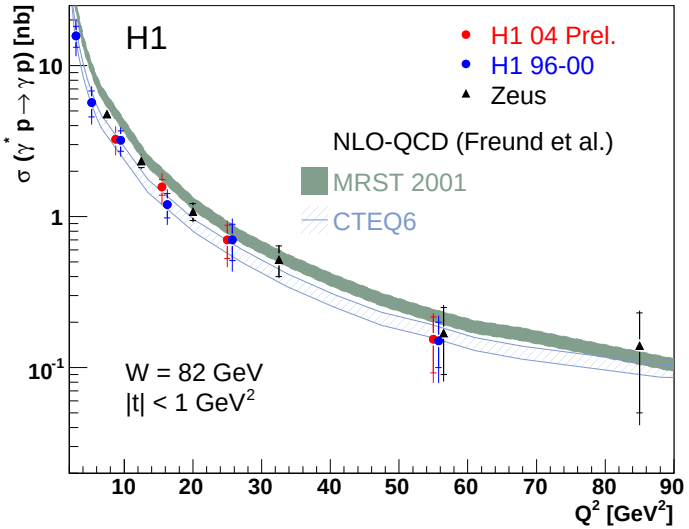
more data soon! $\rightarrow$ study e^+ vs. e^-

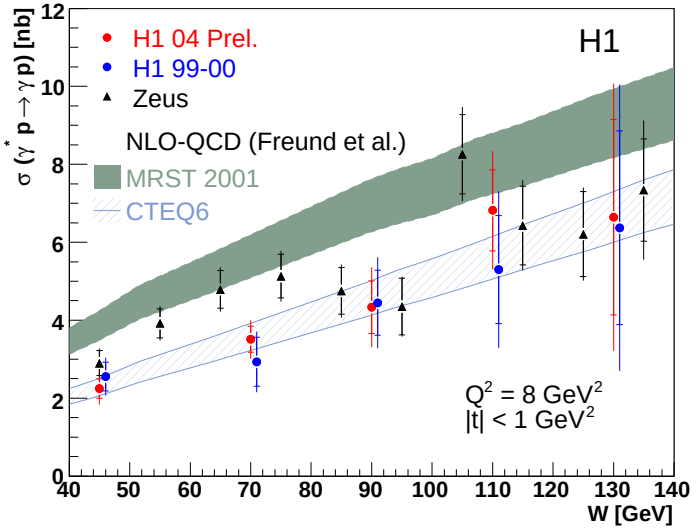






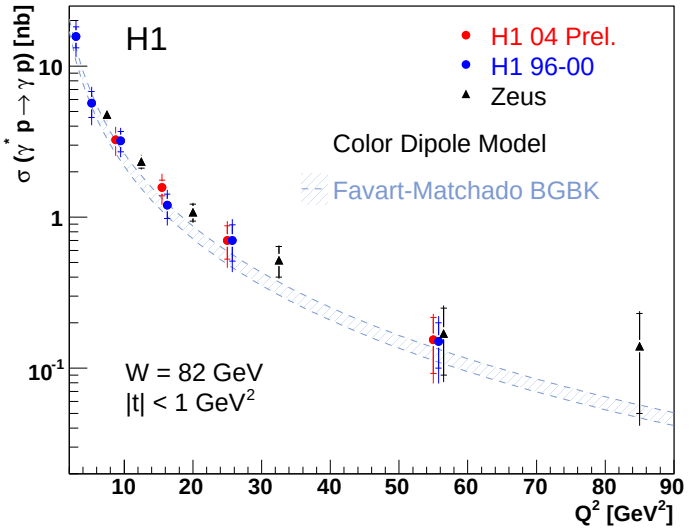
DVCS comparison to predictions

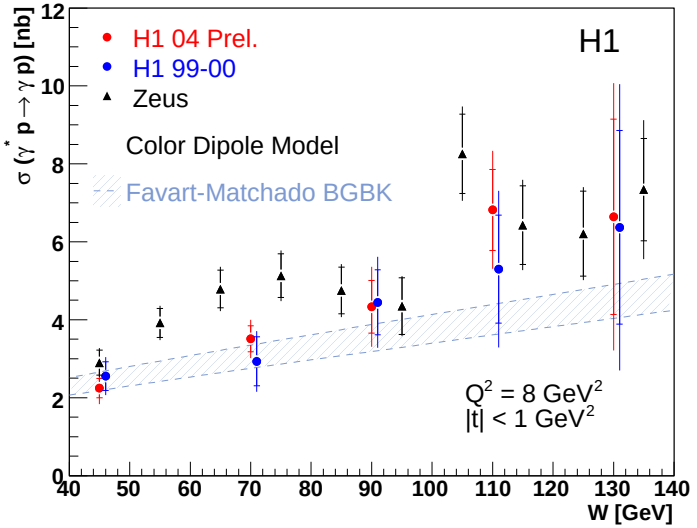




NLO QCD OK ✓

sensitive to GPDs





Color Dipole Model OK ✓

different W dep.?

Conclusions

Diffractive Vector Meson Production:

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

Deeply Virtual Compton Scattering:

- QCD and Color Dipole Model can describe the data
- QCD is sensitive to gluon density (generalized parton density)

more analyses with HERA-2 data to come!