Deeply Virtual Compton Scattering and Diffractive High *t* Photons at H1

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On behalf of the H1 Collaboration

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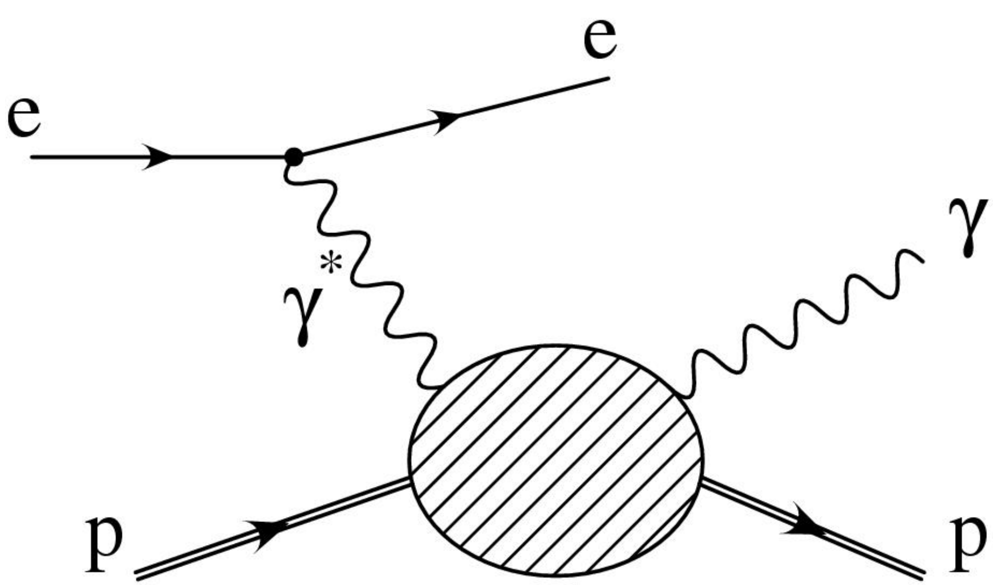
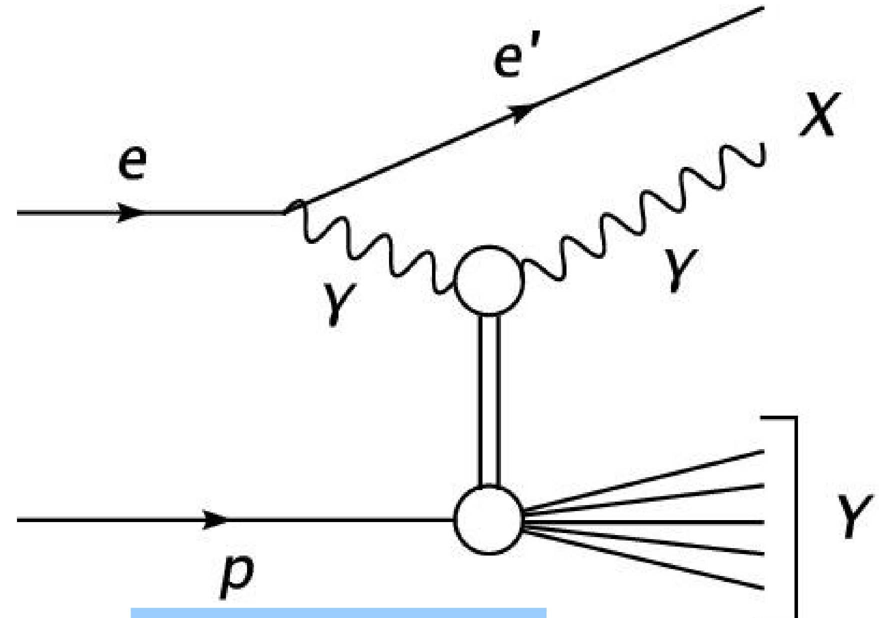
Introduction



DVCS

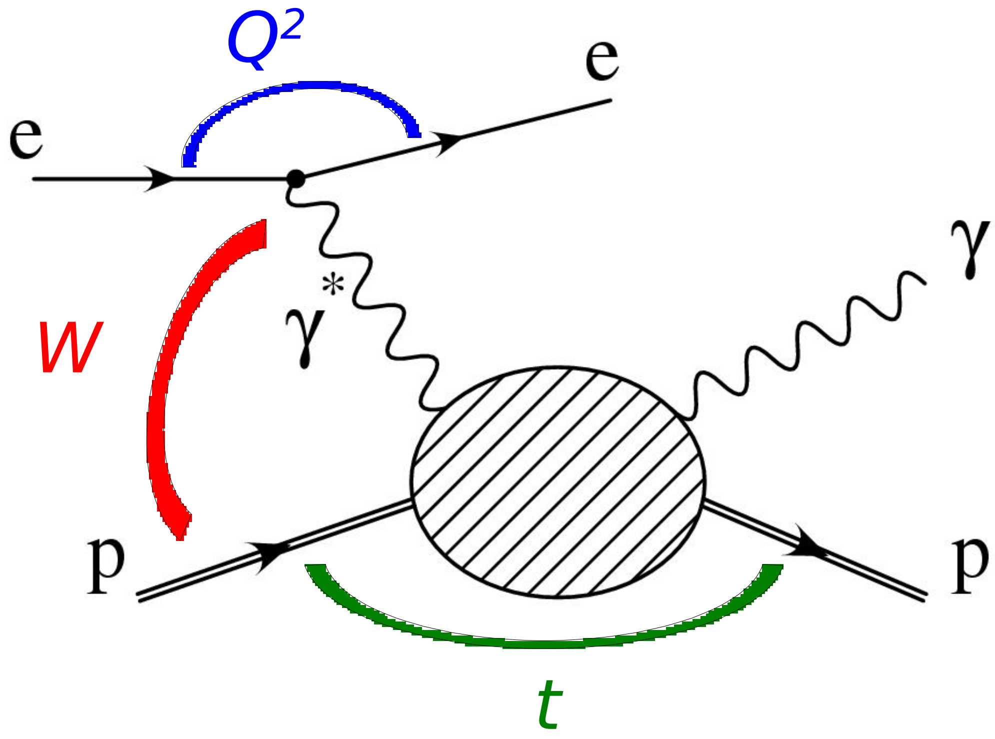


High *t* Photons

- Two similar final states in different kinematic regimes
- DVCS: $e p \rightarrow e \gamma p$ at high Q^2, low t
- High *t* photons: $e p \rightarrow e \gamma Y$ at low Q^2, high t

DVCS at HERA

$$ep \rightarrow e\gamma p$$

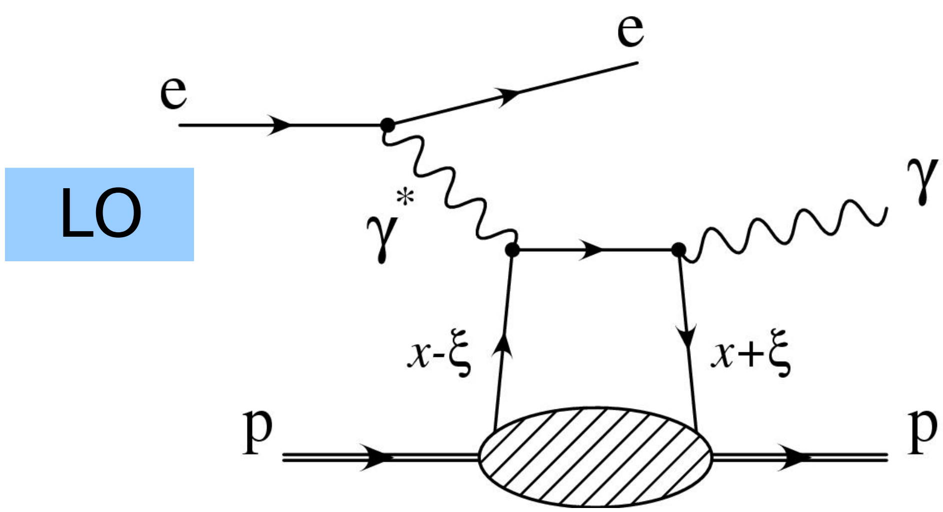


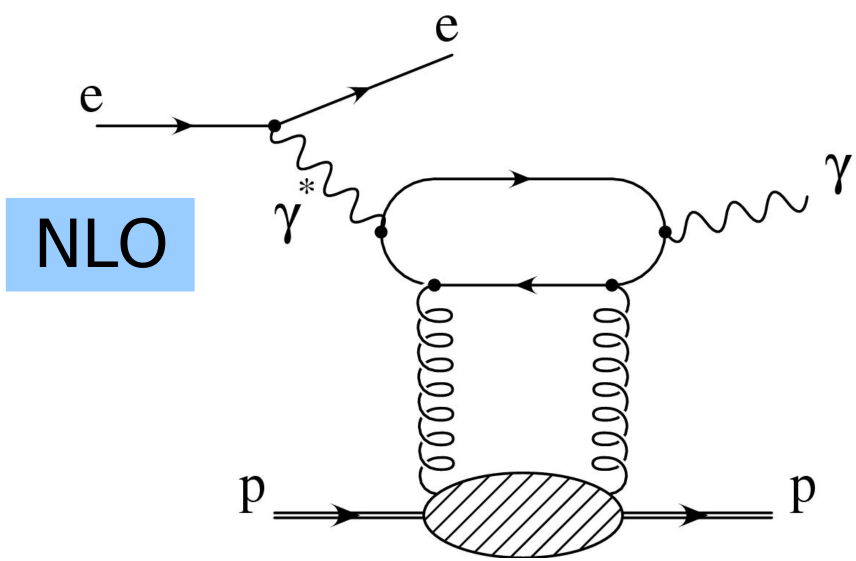
- Clean experimental signature
- Diffractive process calculable in pQCD
- No uncertainty from a VM wavefunction
- Sensitive to Generalised Parton Distributions (GPDs)

Q^2 = virtuality of exchanged photon
W = $\gamma^* p$ centre of mass energy
t = (four-momentum transfer)^2 at proton vertex

QCD Predictions

$Q^2 >> 1 GeV^2$
$-t << Q^2$ $\Rightarrow$ Factorise DVCS amplitude into hard scattering part (fully calculable in pQCD)+ non-perturbative part describing internal dynamics of proton





- Skewednesss ξ: Emitted and absorbed partons carry different long. momentum fractions
- Need to use GPDs to describe DVCS: GPD=$f(x,\xi,t;\mu^2)$
- GPDs encode transverse distribution of partons + correlation between partons in long. and trans. planes

QCD Predictions II: GPDs

4 Types of GPD for *q* and *g*:

	Proton Helicity Conserved	Allow Proton Helicity Flip
Unpolarised	$H^{q,g}(x,\xi,t;\mu^2)$	$E^{q,g}(x,\xi,t;\mu^2)$
Polarised	$\widetilde{H}^{q,g}(x,\xi,t;\mu^2)$	$\widetilde{E}^{q,g}(x,\xi,t;\mu^2)$

At low *x*, DVCS mainly sensitive to $H^g(x,\xi,t;\mu)$

NLO leading twist calc: A. Freund, M. McDermott Eur. Phys. J. C23 (2002) 651

DGLAP region ($|x| > \xi$):

$$H^{q,g}(x,\xi,t;\mu) \xrightarrow[\xi\to 0]{t\to 0} q(x), g(x)$$

$$\widetilde{H}^{q,g}(x,\xi,t;\mu) \xrightarrow[\xi\to 0]{t\to 0} \Delta q(x), \Delta g(x)$$

ERBL Region ($|x|<\xi$):

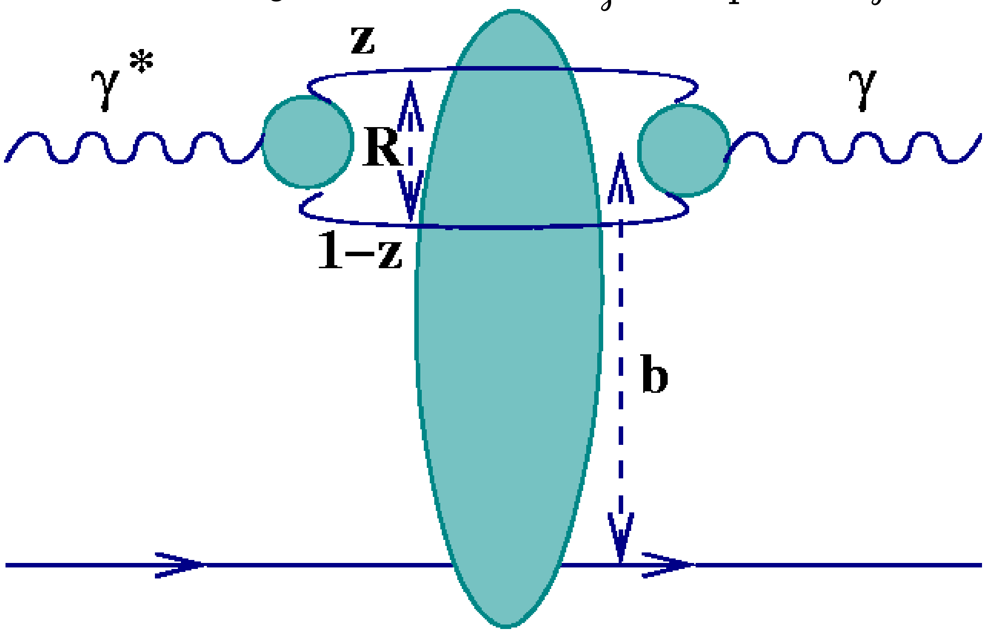
Simple analytic functions for quark singlet and gluon dists.

- Input PDFs: MRST2001 and CTEQ6 at starting scale
- *t* dependence: parametrised as $\exp(-b|t|)$
- ξ and Q^2 dependence: generate dynamically using evolution equations

Colour Dipole Model

- Proton rest frame: three time-factorised subprocesses
  - γ^* fluctuates into $q\bar{q} + q\bar{q}g + \ldots$
  - Colour dipole interacts with proton
  - $q\bar{q}$ pair annihilates into real γ
- Photon wavefunction ($\Psi_{\gamma^*}^{\text{in}}, \Psi_{\gamma}^{\text{out}}$) calculable
- σ_{dipole}:model dependent

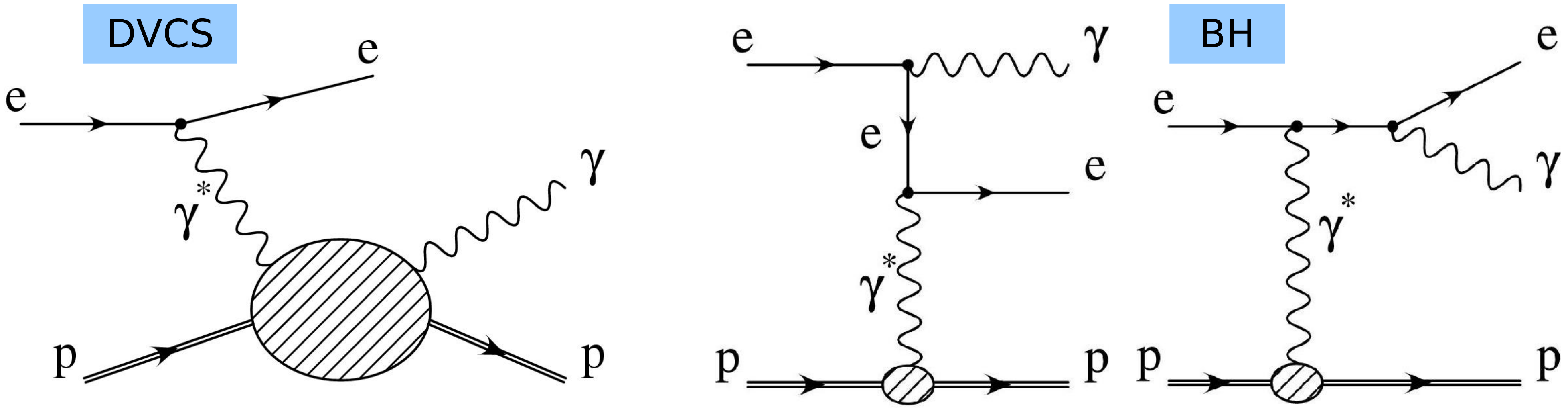
$$A = \int d^2R \, dz \, \Psi_{\gamma^*}^{\text{in}} \sigma_{\text{dipole}} \Psi_{\gamma}^{\text{out}}$$



GBW Saturation Model with DGLAP evolution (BGBK) applied to DVCS

K. Golec-Biernat, M. Wüsthoff, Phys. Rev. D 60 (1999) 114023
L. Favart, M.V.T. Machado Eur. Phys. J. C29, (2003) 365

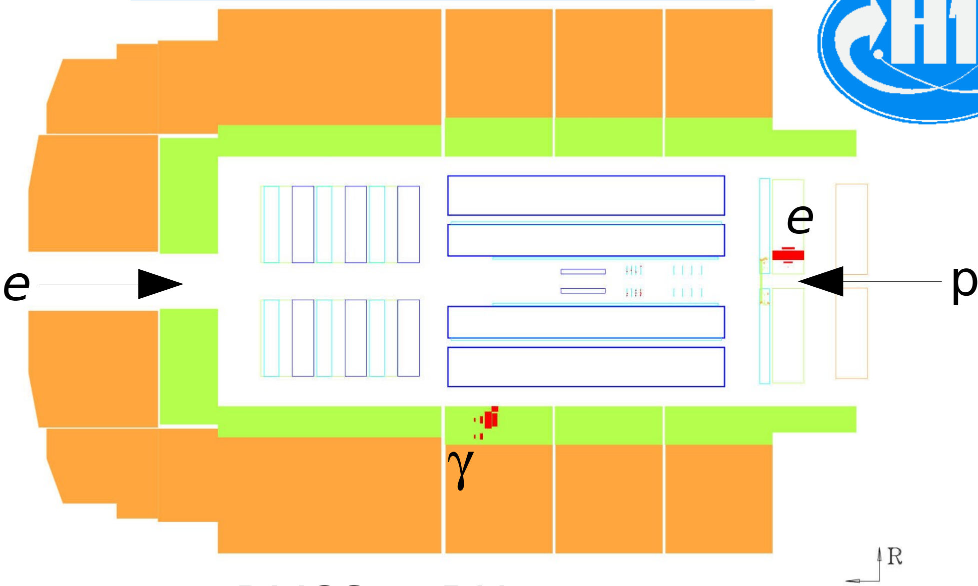
Bethe-Heitler Background



- Interference from Bethe-Heitler process
- Purely EM process – fully calculable using elastic proton form factors
  - precise knowledge of background
  - use BH to study detector response
- Interference term vanishes when integrating over azimuthal angle ⇒ make subtraction

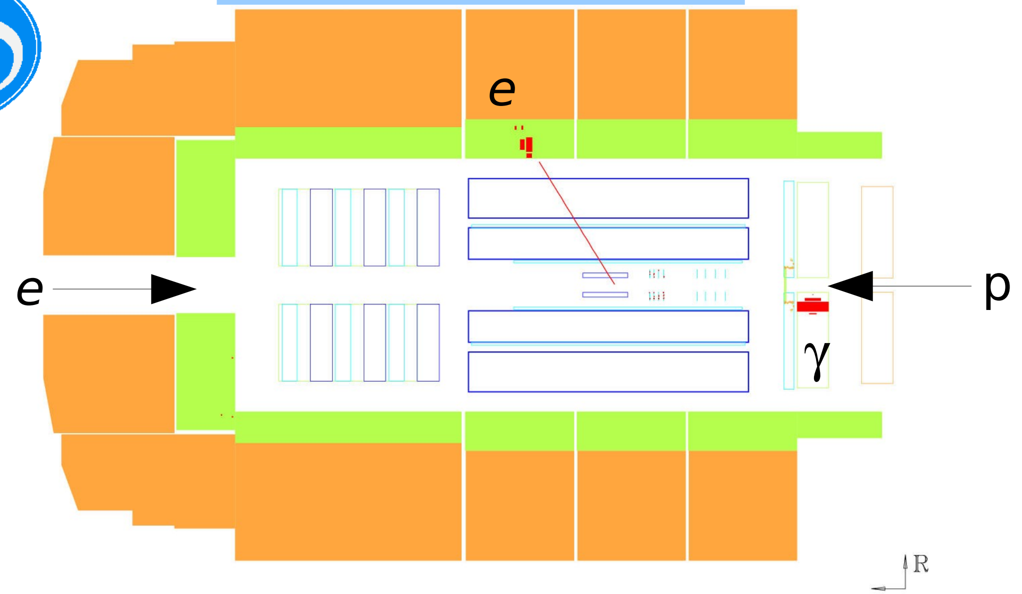
Data Selection

DVCS enriched sample



DVCS + BH events

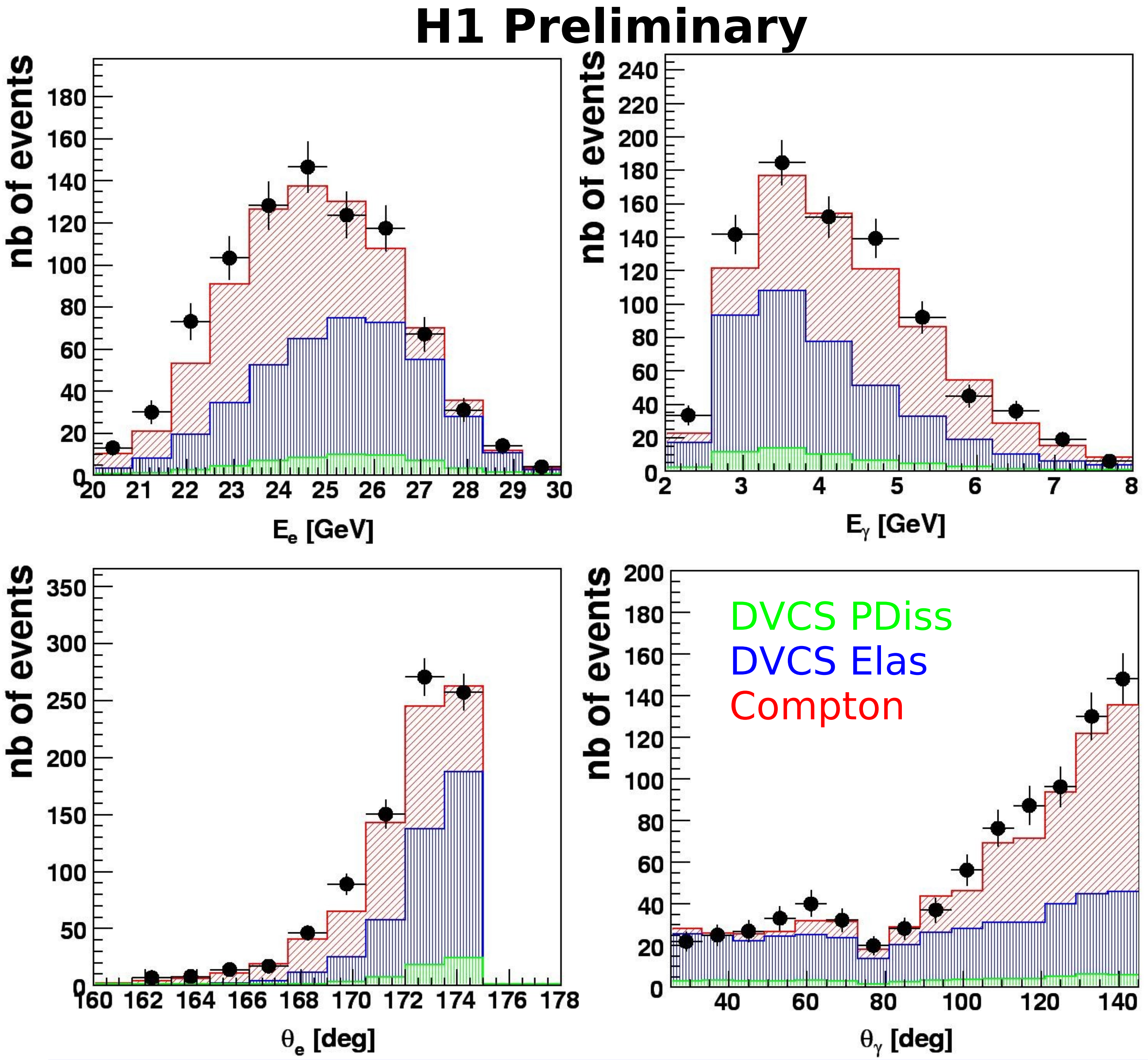
BH Control Sample



Dominated by BH

- 39.7 pb^{-1} 2004 Prelim. data (cf. 46.5 pb^{-1} H1 1999-2000)
  - first HERA II DVCS measurement
- Particle in SpaCal: E_1>15 GeV
- Particle in LAr: $p_{T\,2}$>2 GeV
- (Anti-)Tracking cuts for (photon) electron
- Elastic Event: No cluster with E>0.5 GeV, fwd. det. veto

Control Plots



H1 Prelim. 2004
L = 39.7 pb^{-1}

MC Simulation:

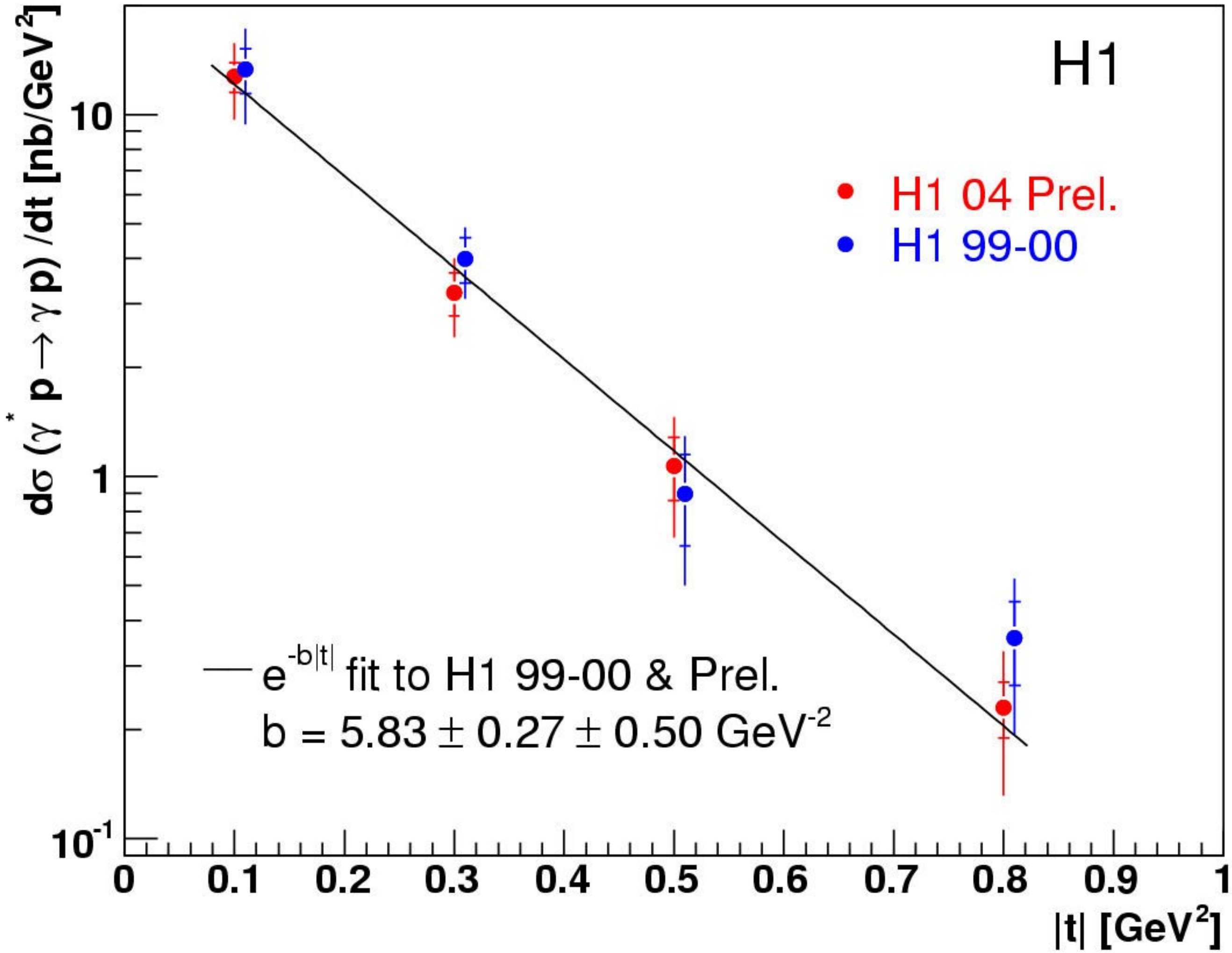
- MILOU for DVCS elastic + inelastic (NLO QCD cross section + radiative corrections)
- COMPTON2.2 for BH elastic + inelastic

Cross Section Measurement

H1 Prelim. 2004

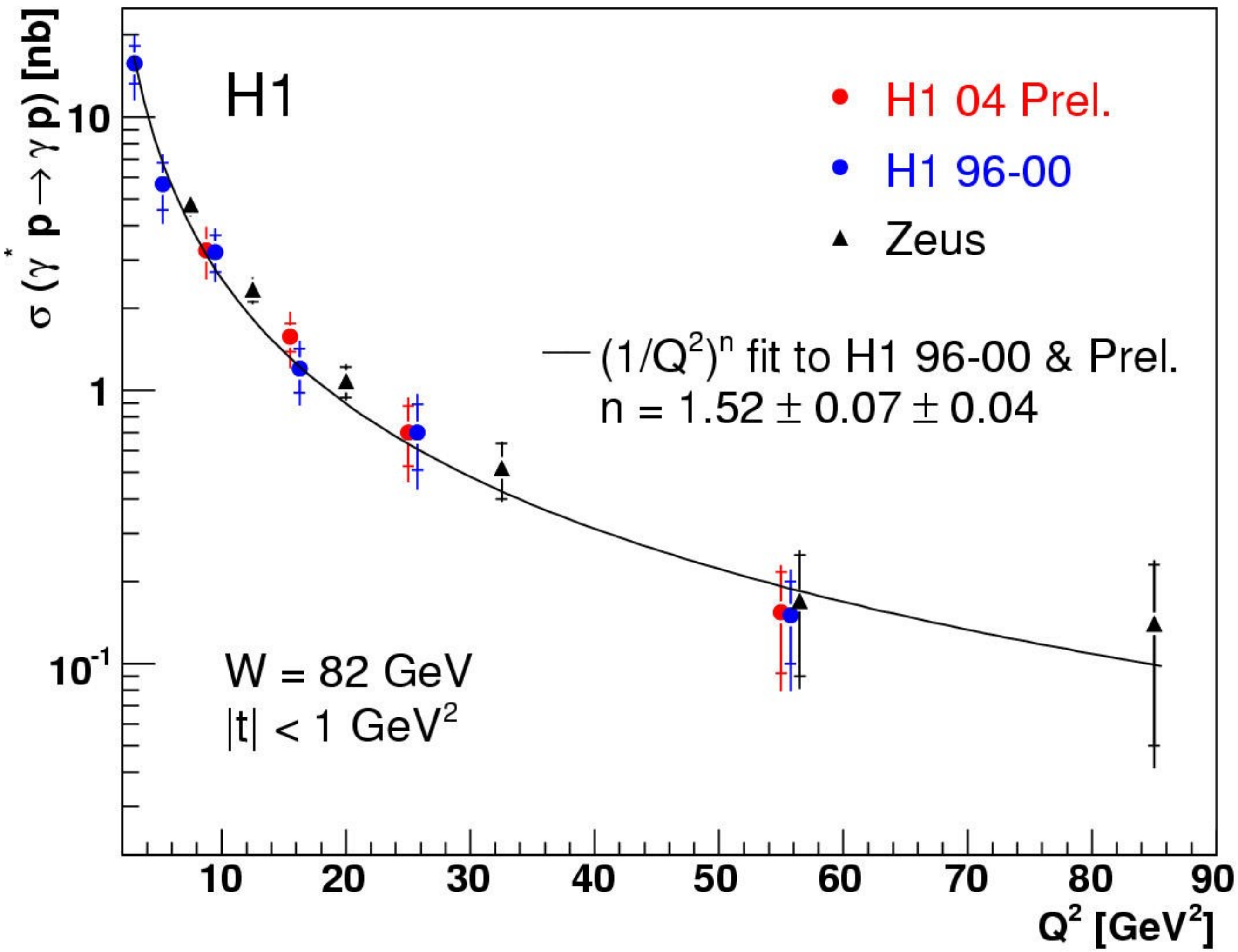
- Kinematic range: $6.5<Q^2<80$ GeV^2
  $30<W<140$ GeV
  $|t|<1$ GeV^2
- Extraction of cross section:
  - bin-by-bin subtraction of background (MC expectations for elas. + inelas. BH and inelas. DVCS)
  - correct for acceptance, trigger efficiency and radiative corrections
  - photon flux factor
- Main systematic uncertainties:
  - Proton dissociation background subtraction: 8-14%
  - Acceptance correction: 2-6%
  - Electron, photon angle: 4-6%
  - Energy scale: 2-5%
- Total systematic error: ~20%

t Dependence



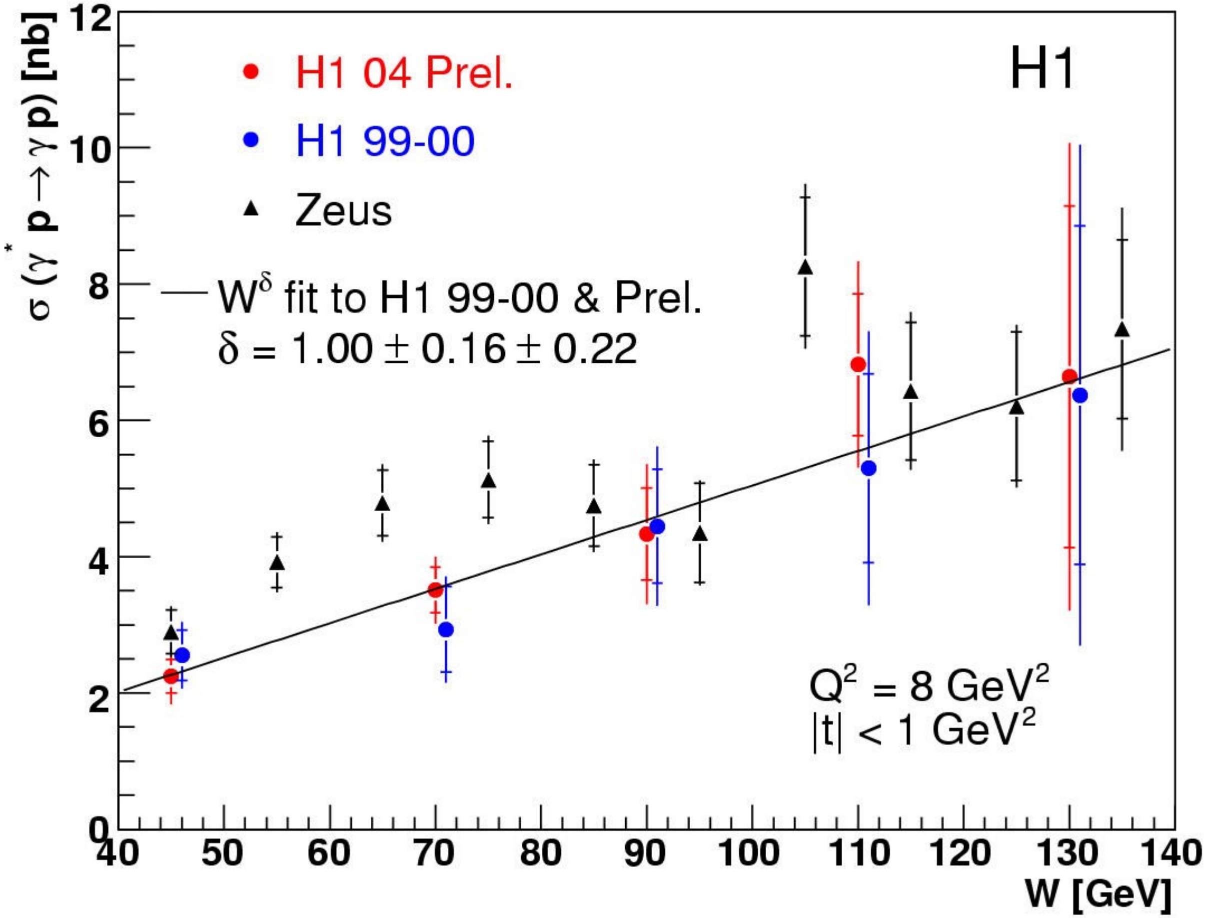
- Good agreement between two H1 data sets
- Combined fit to H1 99-00 and H1 04 Prel. data: $\frac{d\sigma}{dt} \propto \exp(-bt)$
- Statistical error on b reduced

Q^2 Dependence



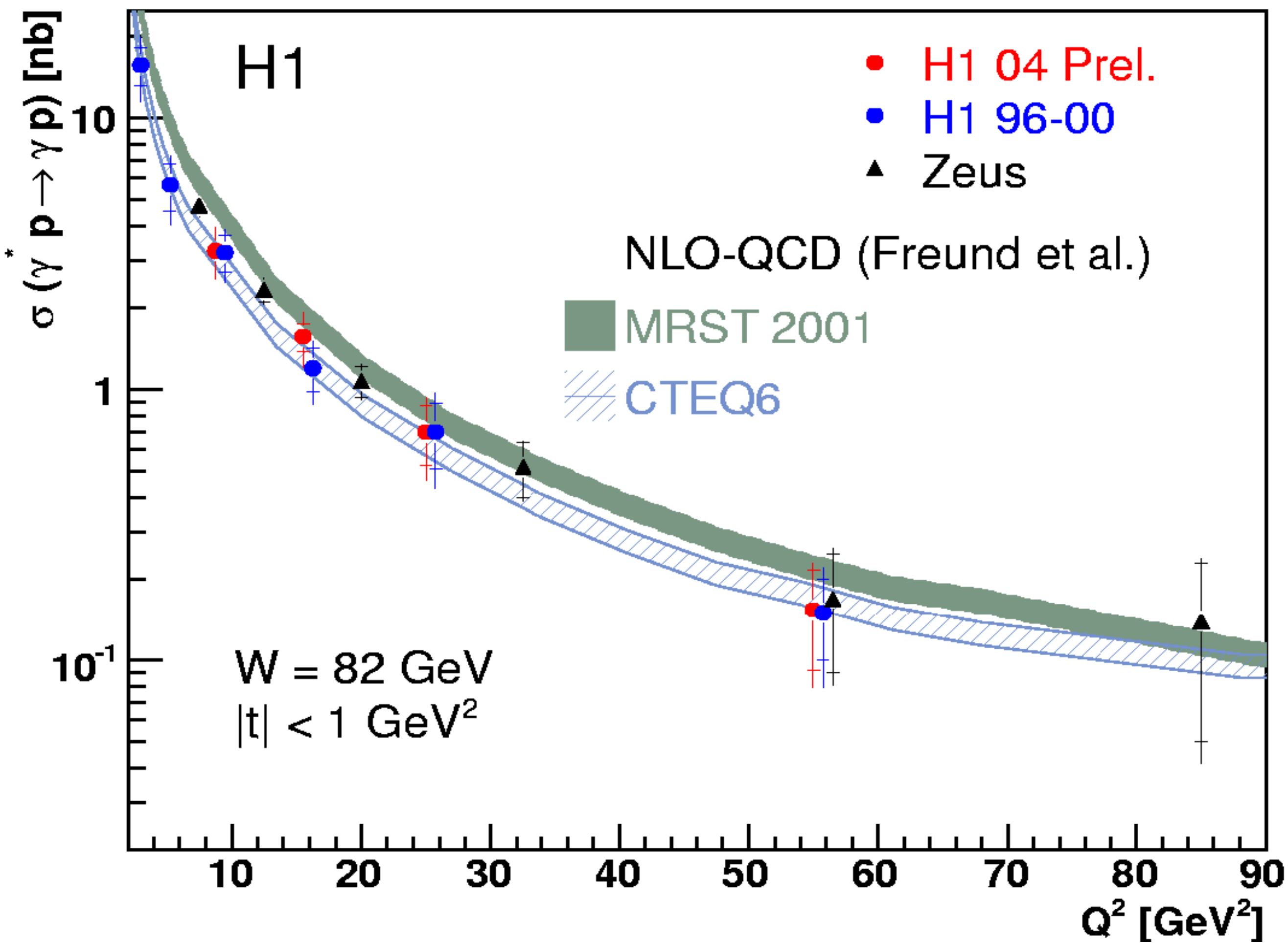
- Good agreement between H1 and ZEUS data sets
- Combined fit to H1 99-00 and H1 04 Prel. data: $\sigma(Q^2) \propto \left(\frac{1}{Q^2}\right)^n$
- Statistical error on *n* reduced

W Dependence



- Good agreement between H1 measurements, however ZEUS measurement higher at W~70 GeV
- Combined fit to H1 99-00 and H1 04 Prelim. data: $\sigma(W) \propto W^{\delta}$
- δ=1 indicates presence of hard scale cf. J/Ψ(δ=0.75±0.03±0.03) ⇒DVCS even harder

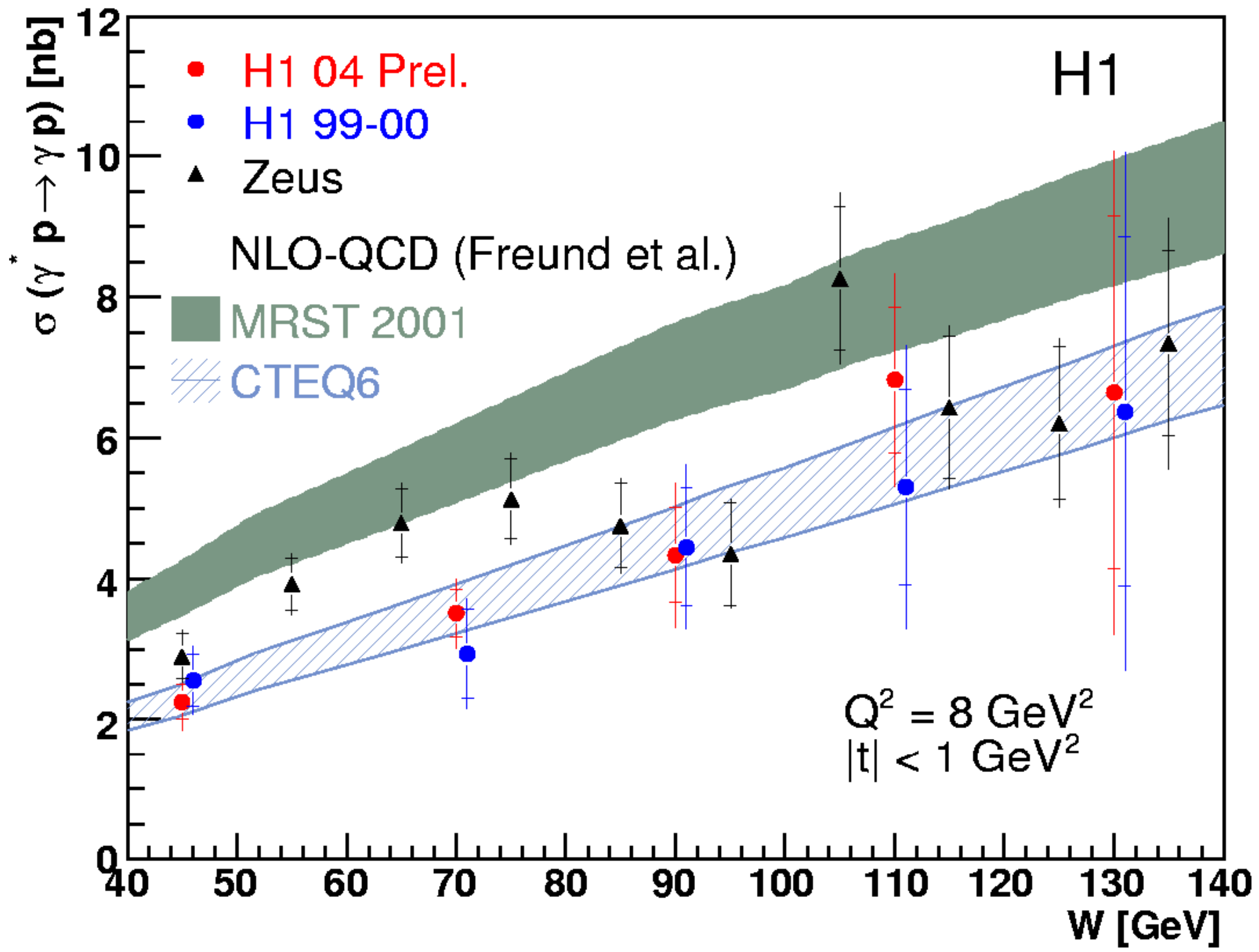
Q^2 Dependence: NLO Predictions



- Curve width includes error on *b* slope -reduced due to *b* measurement
- *b* kept constant with Q^2
- Sensitivity to PDF inputs to GPDs
- No intrinsic skewing in calculation

- Good description by NLO QCD

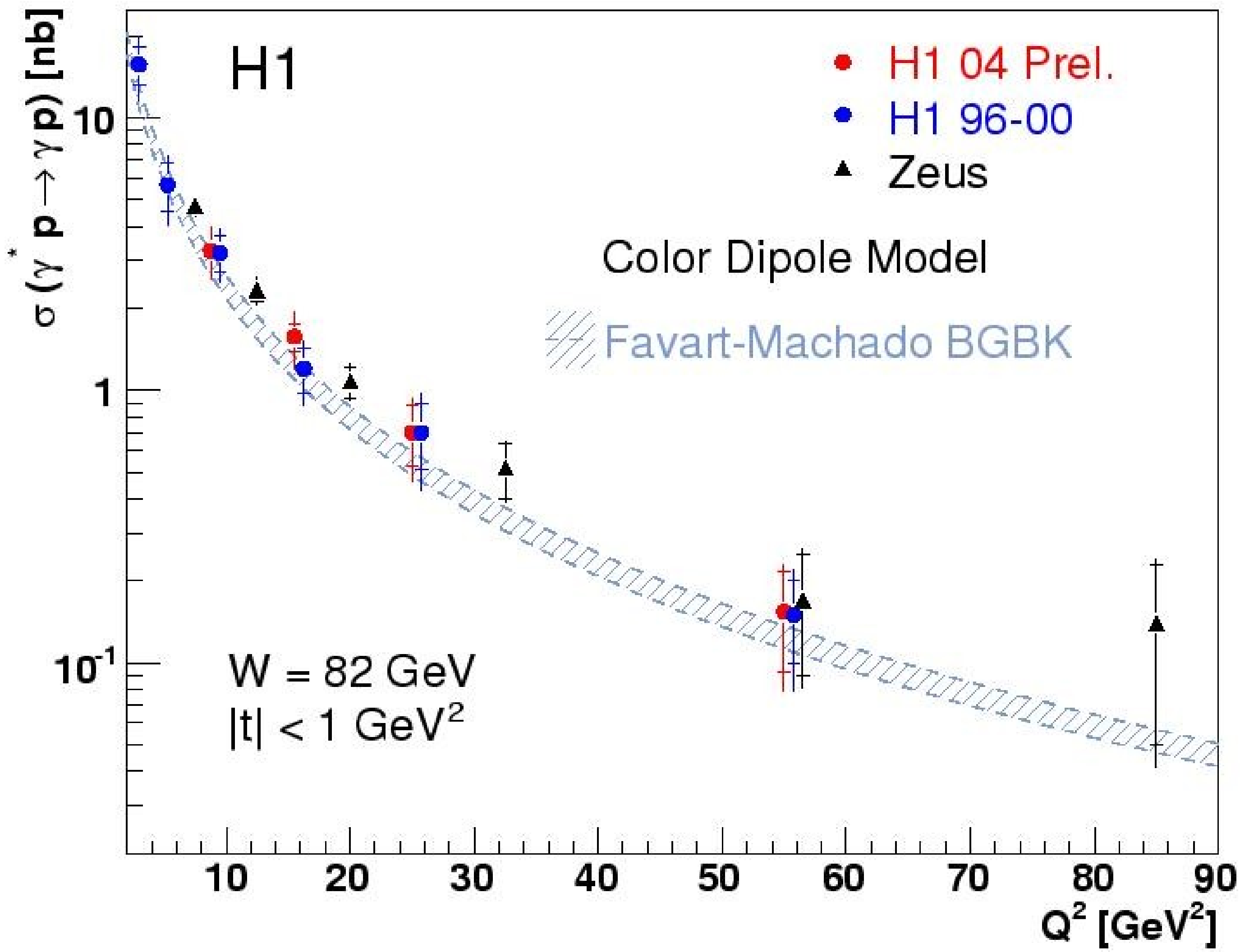
W Dependence: NLO Predictions



- Sensitivity to PDF inputs to GPDs
- Predictions reflect relative sizes of singlet and gluon in input PDFs
- No intrinsic skewing in calculation

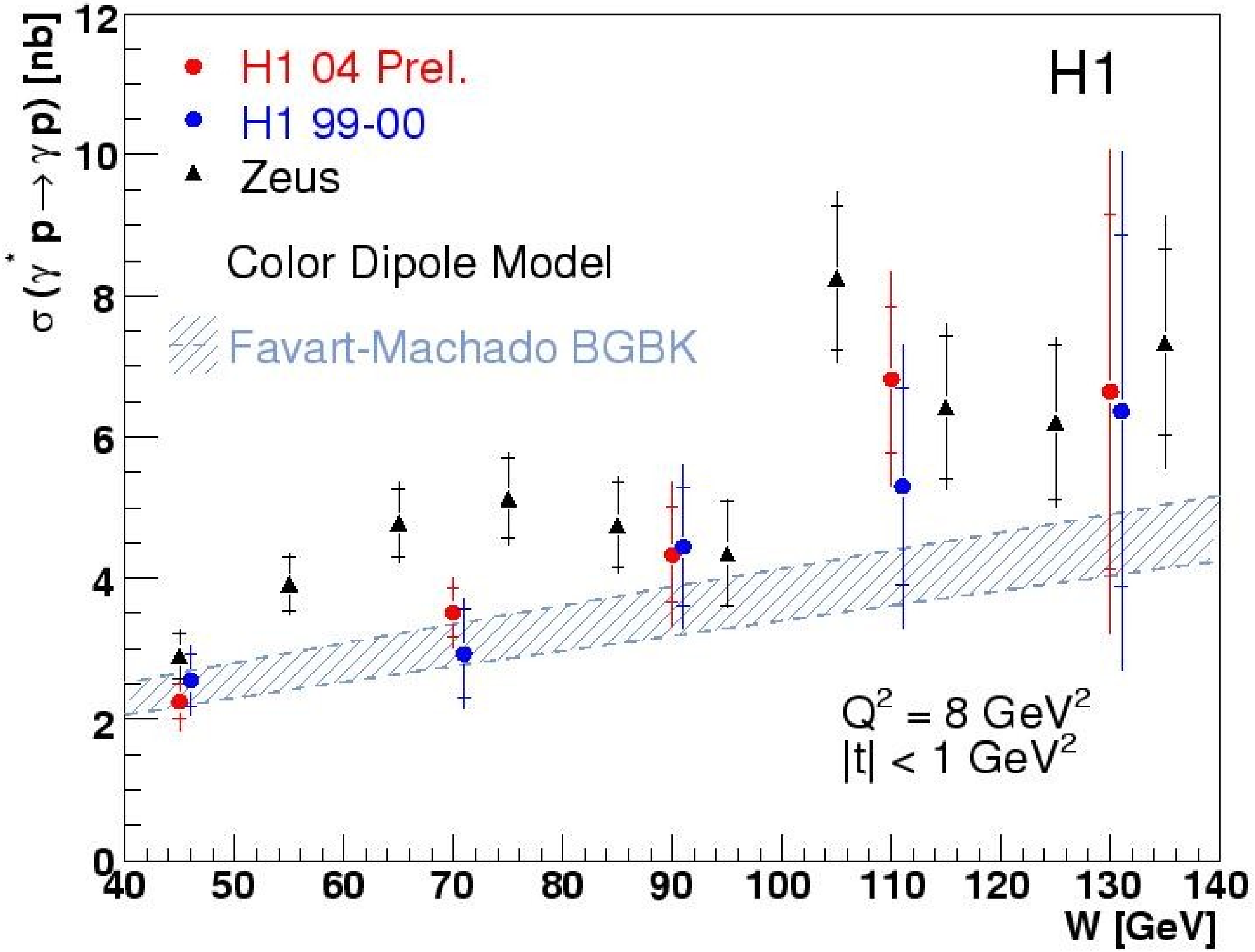
- Good description by NLO QCD

Q^2 Dependence: Dipole Model



– Reasonable description by FM model (GBW saturation model with DGLAP evolution)

W Dependence: Dipole Model

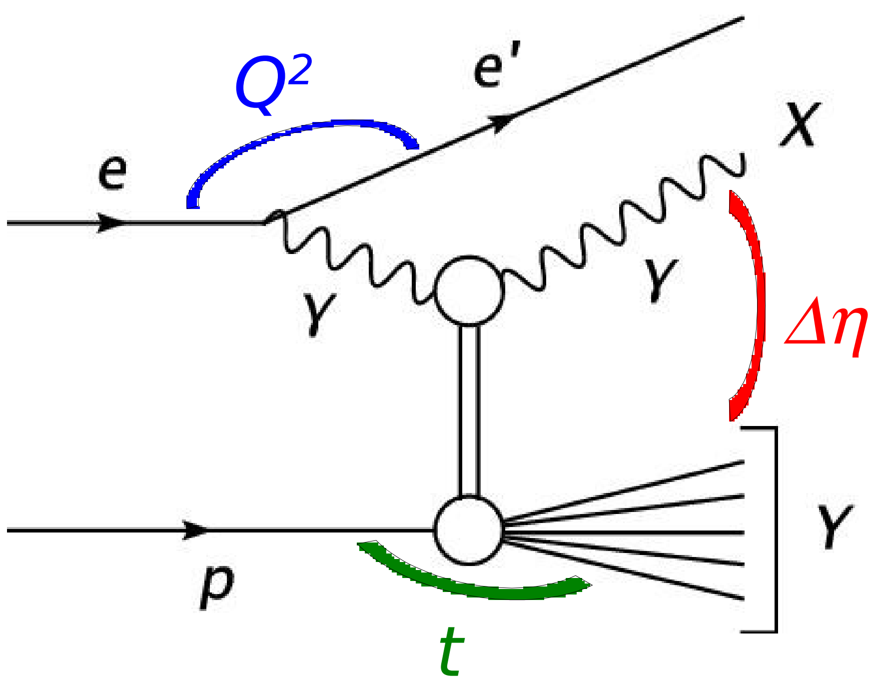


- Shallower *W* dependence from model?

– Reasonable description by FM model (GBW saturation model with DGLAP evolution)

Diffractive High t Photons

$$ep \to e\gamma Y$$



- Also clean process with no VM wavefunction uncertainty
- Access large rapidity gaps
- Photoproduction $\Rightarrow$ only hard scale from large t
- Complementary to DVCS
- LLA BFKL calculation included in HERWIG MC generator

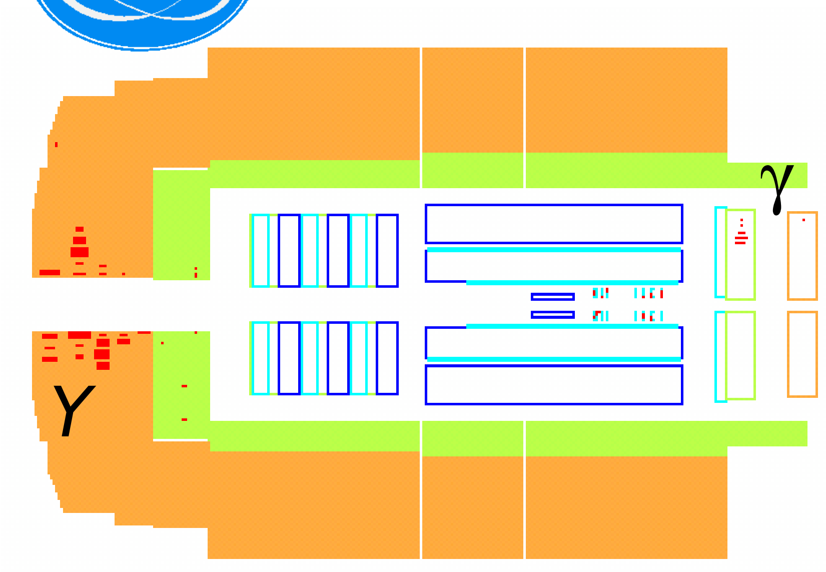
B. Cox, J. Forshaw J. Phys. G26(2000) 702

Kinematics: $t \simeq -(p_T^{\gamma})^2$

$$x_{IP} = \frac{q.(P-Y)}{q.P} \simeq \frac{(E+P_z)_\gamma}{2E_p} \simeq \frac{(p_T^{\gamma})^2}{W^2}$$

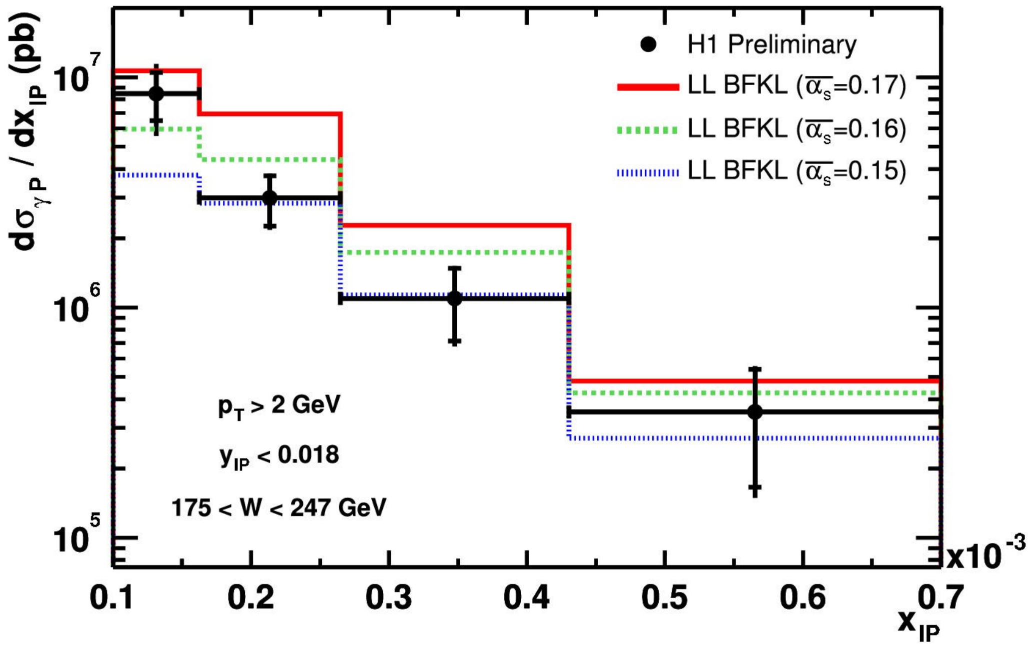
$$y_{IP} = \frac{P.(q-X)}{q.P} \simeq \frac{\sum_Y (E-P_z)}{2E_\gamma^{\text{in}}} \sim e^{-\Delta\eta}$$

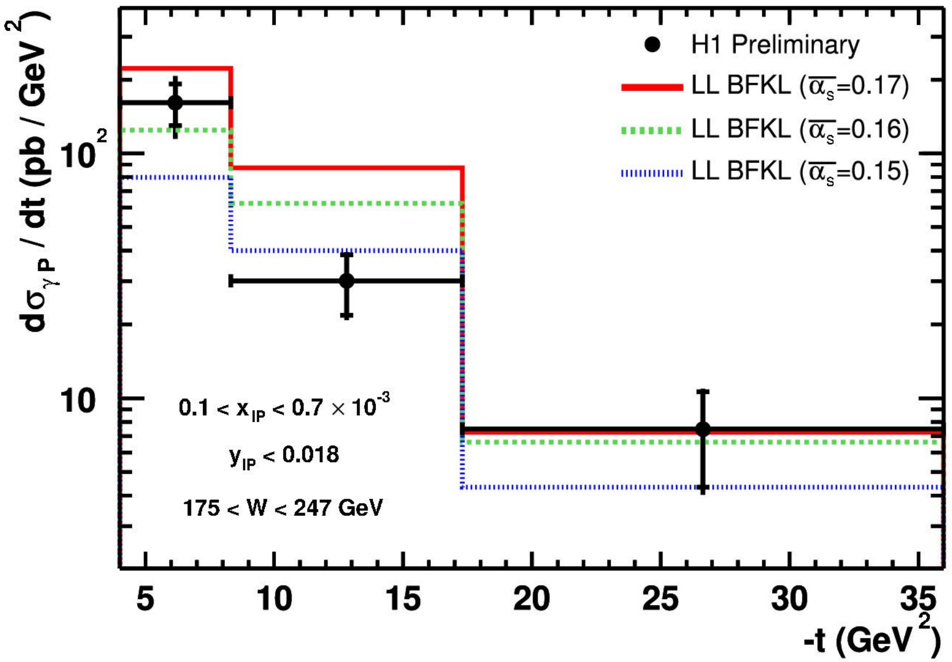
Data Selection



- 48 pb^{-1} 1999-2000 data
- Tagged photoproduction:
  Q^2<0.01 GeV^2
  175<W<247 GeV
- Photons: p_T>2 GeV, E>8 GeV
- Rapidity gap: y_{IP} < 0.018, $\Delta\eta$>2
- Backgrounds:
  - Inclusive diffractive photoproduction <9% subtracted
  - Diffractive ω production negligible ($\pi^0\gamma$ and $\pi^+\pi^-\pi^0$ decay modes)

High t Photons: x_{IP} and t





- Steep rise with small x_{IP}
- Reasonable description by BFKL LLA prediction with $\overline{\alpha_s}$=0.15−0.17 (cf. $\overline{\alpha_s}$=0.17 for high t J/ψ production)
- Normalisation uncertainty within LLA
- Could be important higher order effects

Conclusions

- First HERA II measurement of DVCS
  - cross sections versus Q^2, W and t
- Preliminary results in agreement with previous DVCS measurements
- Statistical errors on Q^2, W and t slope fits decreased
  - improvement in t slope fit constrains theory normalisation
- Good description of data by NLO QCD predictions based on GPDs
  - sensitive to PDF inputs, but do not measure GPDs
- Reasonable description by Colour Dipole predictions
- High t photon production reasonably described by LLA BFKL prediction