

DVCS and High t Photons at HERA

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On behalf of the



and



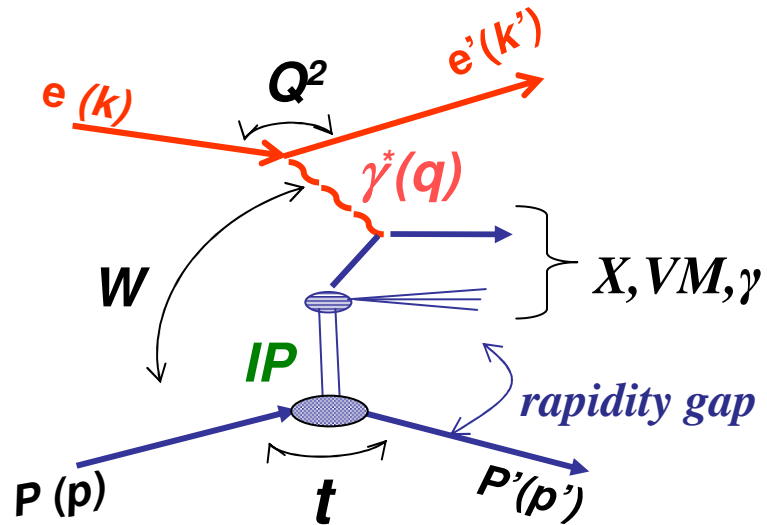
collaborations

DIFFRACTION 2008
International Workshop on Diffraction in High-Energy Physics

La Londe-les-Maures, France
September 9 - 14, 2008

DVCS at HERA

Diffractive DIS



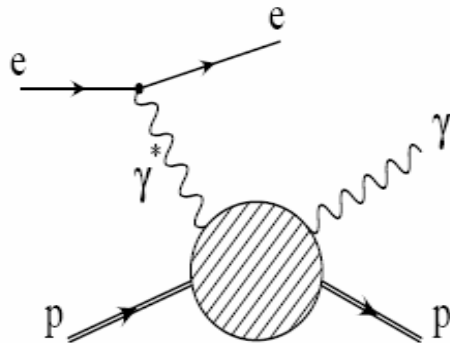
Kinematics variables

$$Q^2 = -q^2 = -(k - k')^2 \approx 4E_e E'_e \sin^2 \frac{\theta}{2}$$

$$W^2 = (k + p)^2$$

$$t = (p - p')^2$$

DVCS $\gamma^* p \rightarrow \gamma p$



- ✓ Very clean and simple final state
- ✓ Fully calculable in QCD
- ✓ Gives access to GPDs
- ✓ no uncertainty due to VM wave function

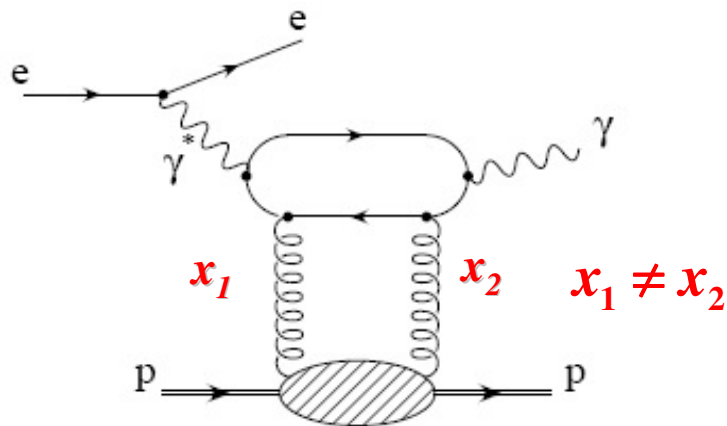
$$t = (p - p')^2 = -\frac{p_T^2}{x_L} = -(p_{T,e} + p_{T,\gamma})^2$$

$$x_L = \frac{p'_L}{p}$$

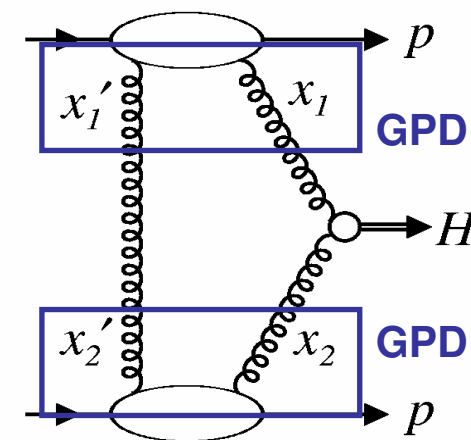
Why DVCS?

Inclusive DIS: allow the extraction of proton **PDFs** which are a crucial input to pQCD calculations. But PDFs do not provide a complete picture of the partonic structure of nucleons (correlations between partons, their transverse motion).

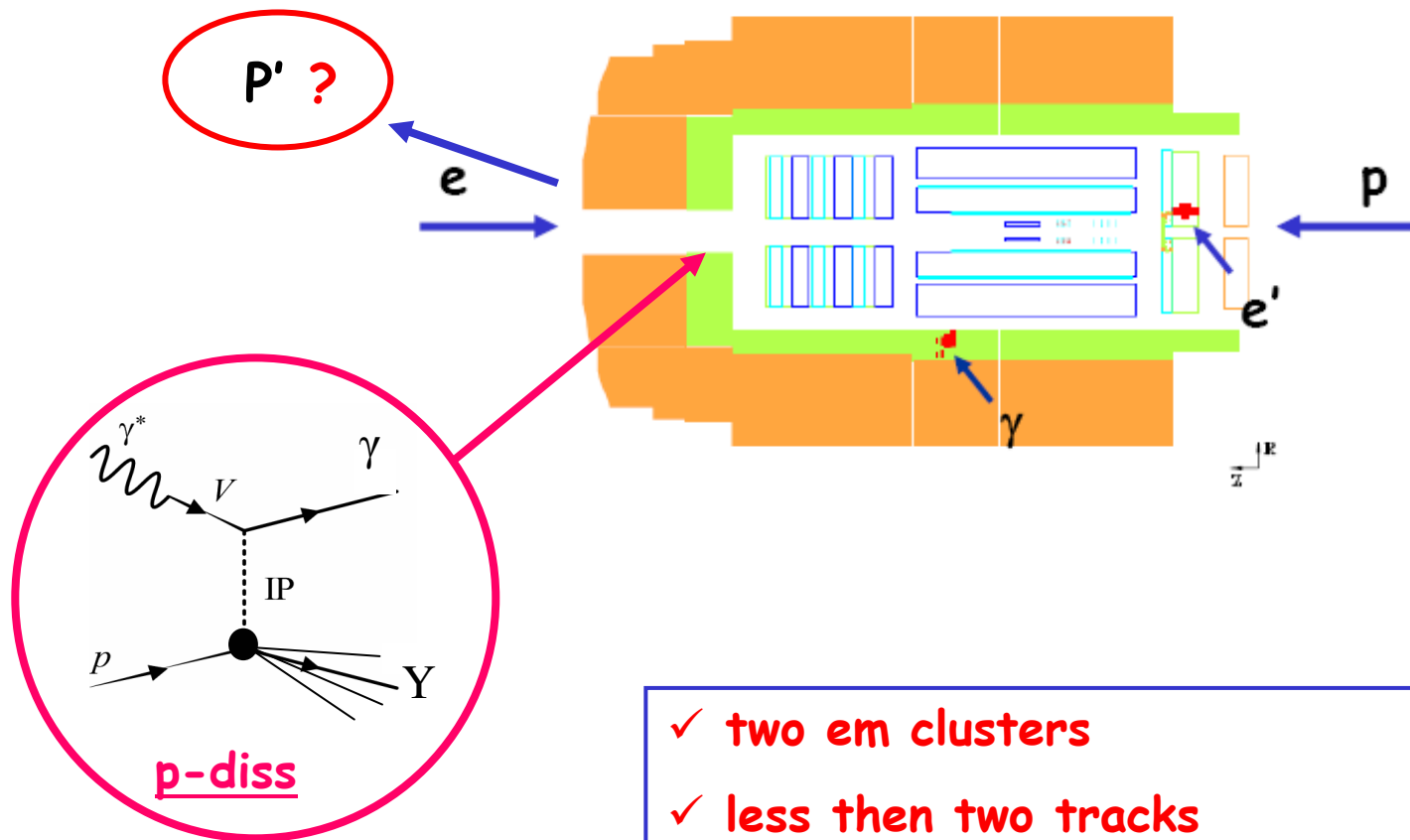
DVCS: provide additional information on the proton structure (correlation between two partons which differ by longitudinal (x_1, x_2) - **skewing** - and transverse momentum at given Q^2) via **GPDs**.



GPDs are important for the exclusive diffractive Higgs production:

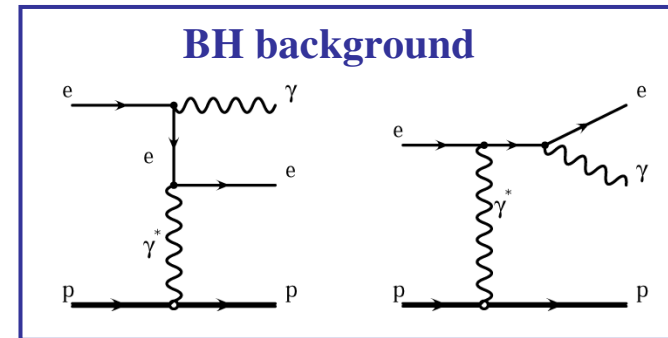
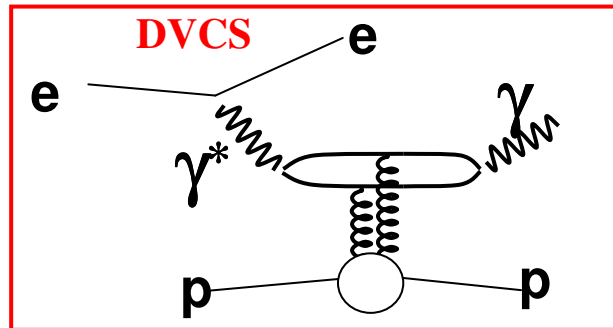


How we measure DVCS?

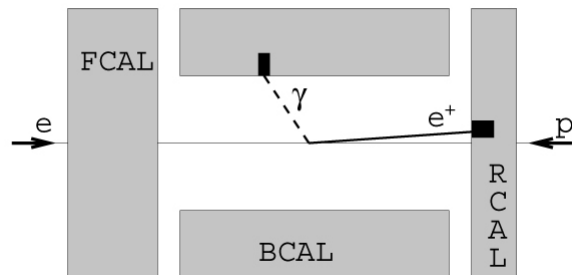


- ✓ two em clusters
- ✓ less than two tracks
- ✓ well definite tracks acceptance
- ✓ nothing more!

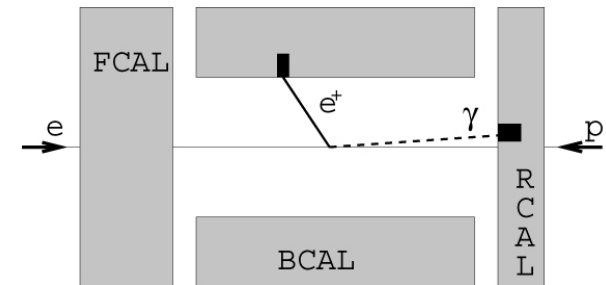
How we measure DVCS?



(Real photon emitted from the electron)



γ Sample: no tracks matching to the forward candidate
(DVCS+BH)

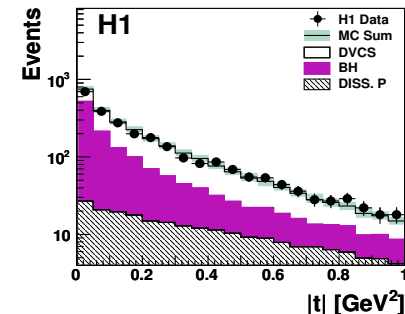
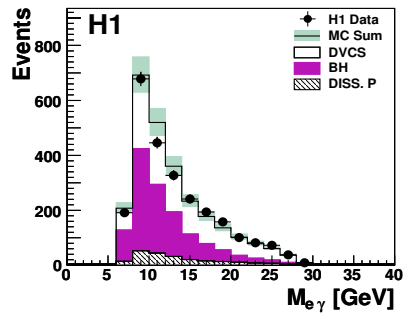
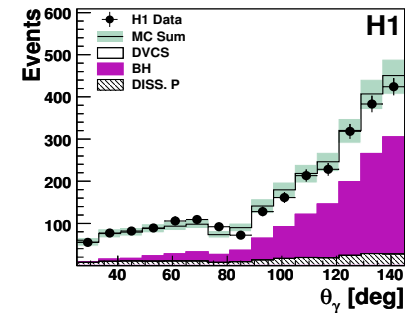
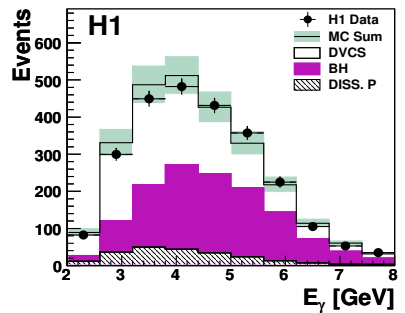
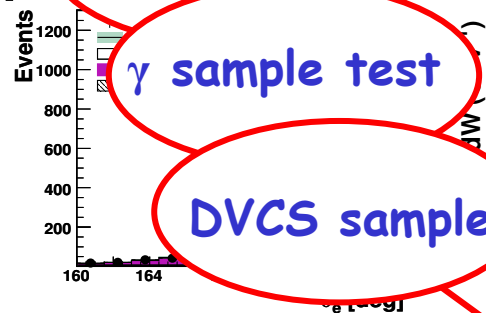
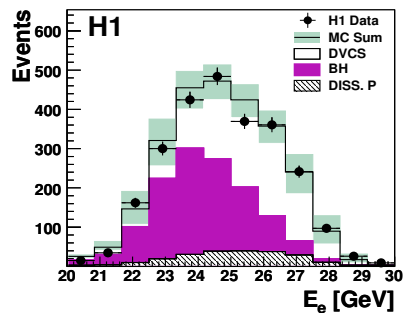


e^+ Sample: a track match to the forward candidate
(BH+ Dilepton+ J/Ψ)

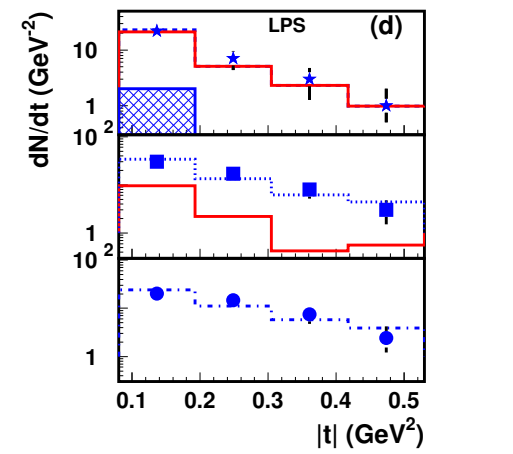
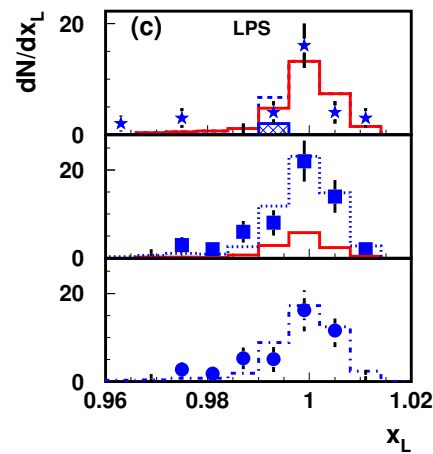
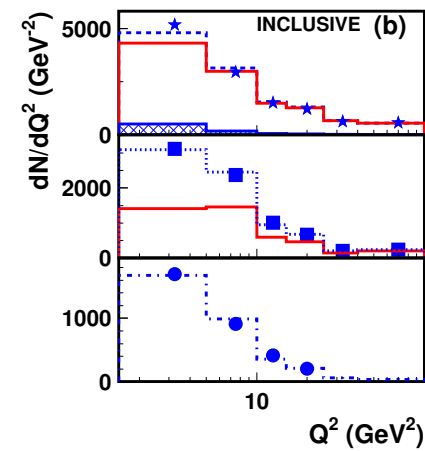
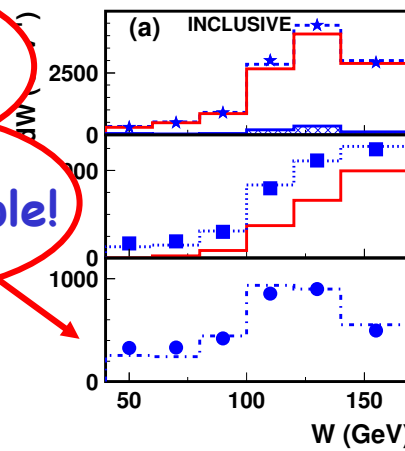
e^- Sample: a negative track match to the forward candidate (Dilepton+ J/Ψ)

distributions

H1



ZEUS



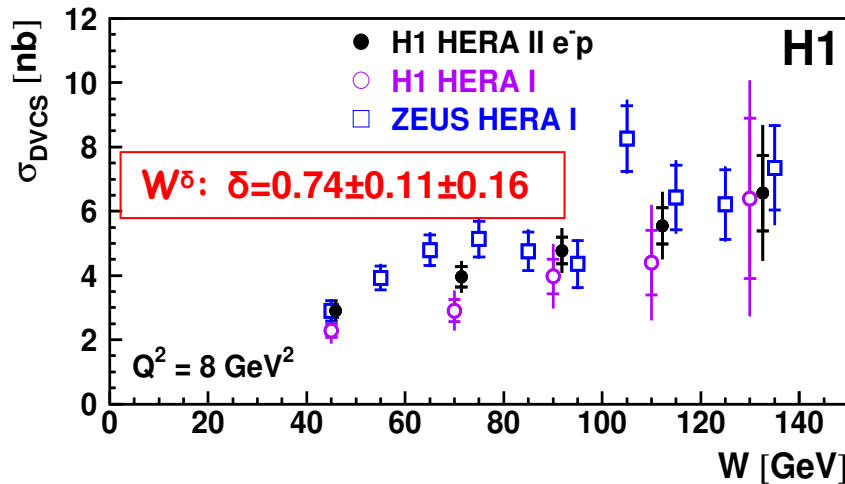
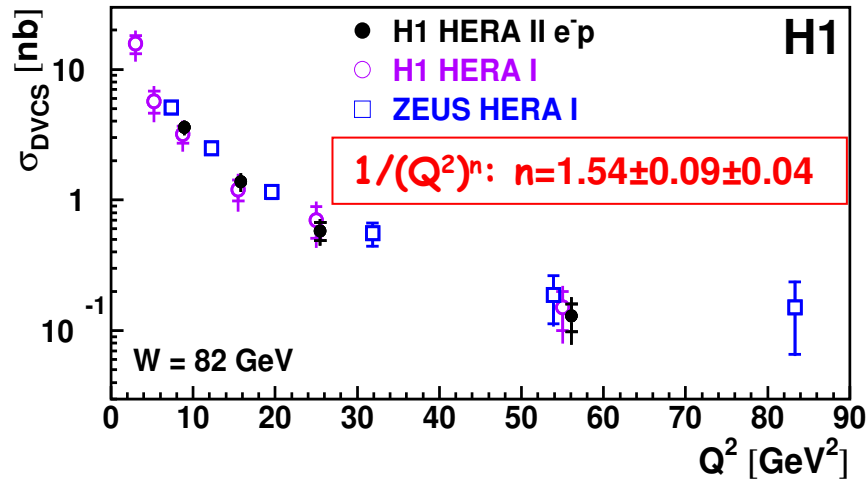
- ★ ZEUS (e-sample)
- ZEUS (γ -sample)
- ZEUS (γ -sample after BH and p-diss sub.)
- ⊠ e^+e^-+J/ψ
- BH+ e^+e^-+J/ψ
- BH
- ⋯ BH+FFS (DVCS)
- ⋯ FFS (DVCS)

P-diss bg estimate: $16 \pm 5\%$

P-diss bg estimate: $17.5 \pm 1.3^{+3.7}_{-3.2} \%$

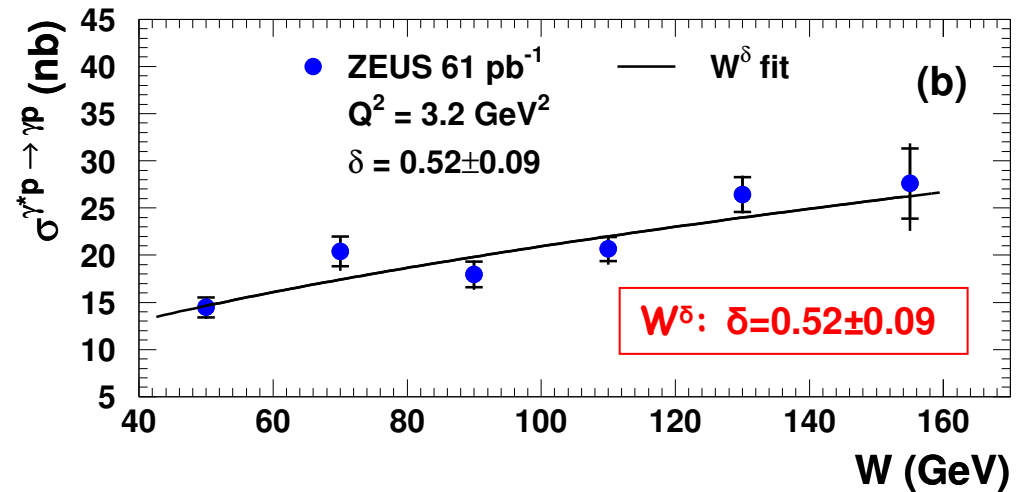
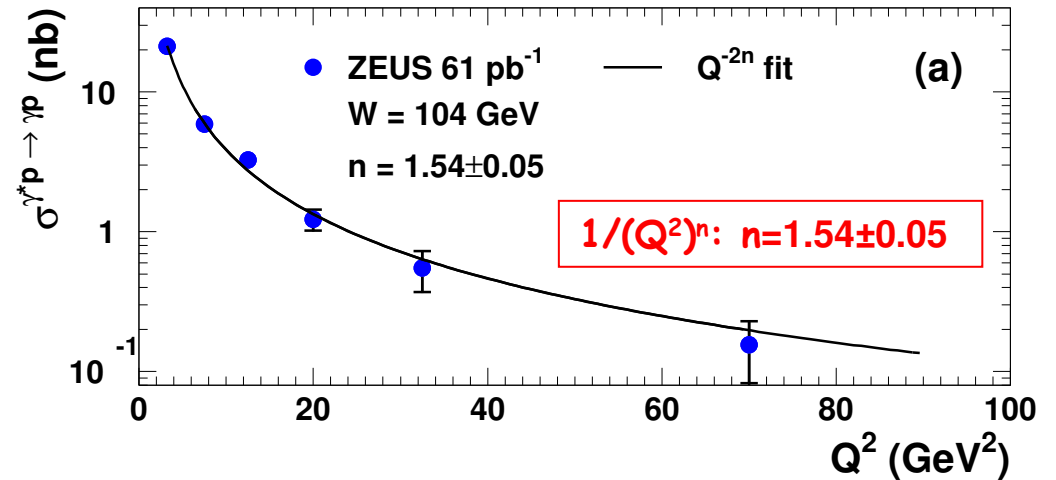
Cross sections

H1



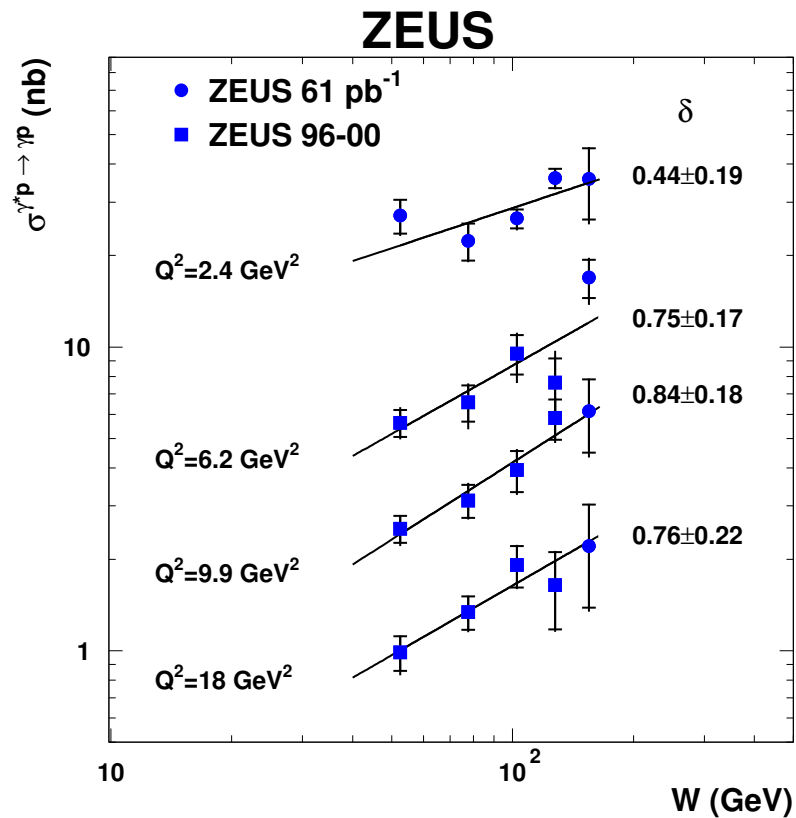
- ✓ H1: 145pb⁻¹ 0506(e⁻)
- ✓ $6.5 < Q^2 < 140 \text{ GeV}^2$; $30 < W < 140 \text{ GeV}$

ZEUS

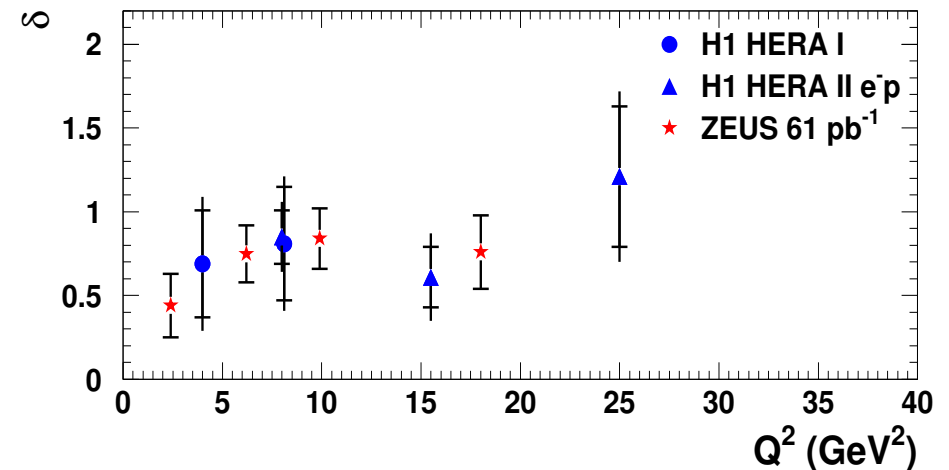
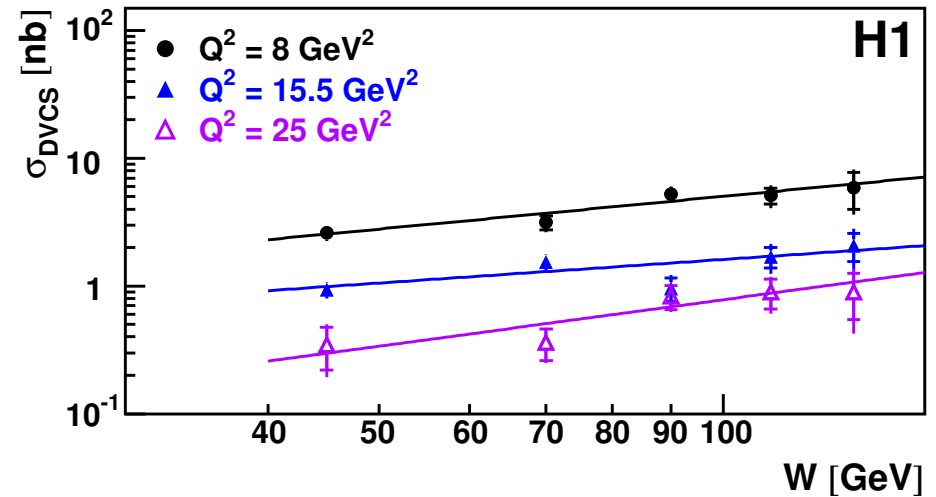


- ✓ ZEUS: 61pb⁻¹ 9900(e⁺)
- ✓ $1.5 < Q^2 < 100 \text{ GeV}^2$; $40 < W < 170 \text{ GeV}$

DVCS energy dependence



$$\sigma(W) \propto W^\delta$$

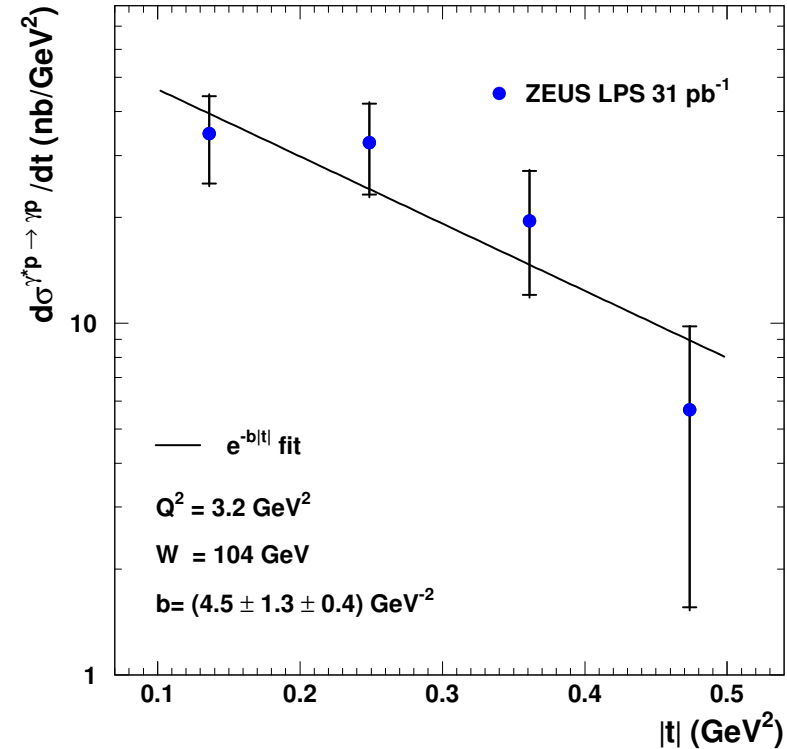
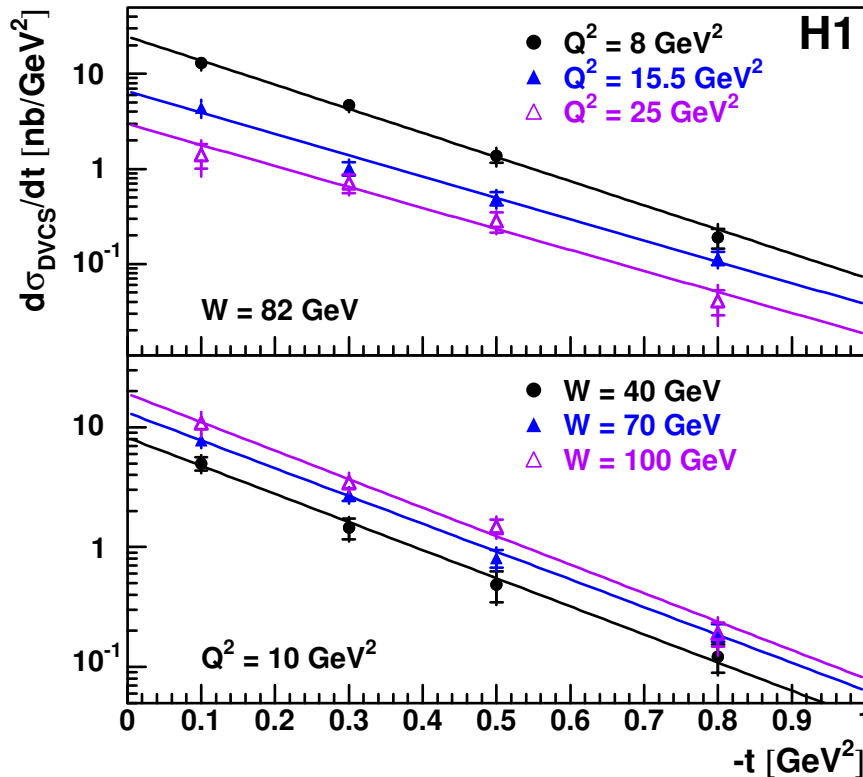


DVCS shows hard W dependence (even at low Q^2)

DVCS + dependence

$$\frac{d\sigma}{dt} \propto e^{-b|t|}$$

ZEUS



H1 Global fit:

$$b = 5.45 \pm 0.19 \pm 0.34 \text{ GeV}^{-2}$$

$$W = 82 \text{ GeV}$$

$$Q^2 = 8 \text{ GeV}^2$$

First direct measurement of t !!!

(LPS 2000 data)

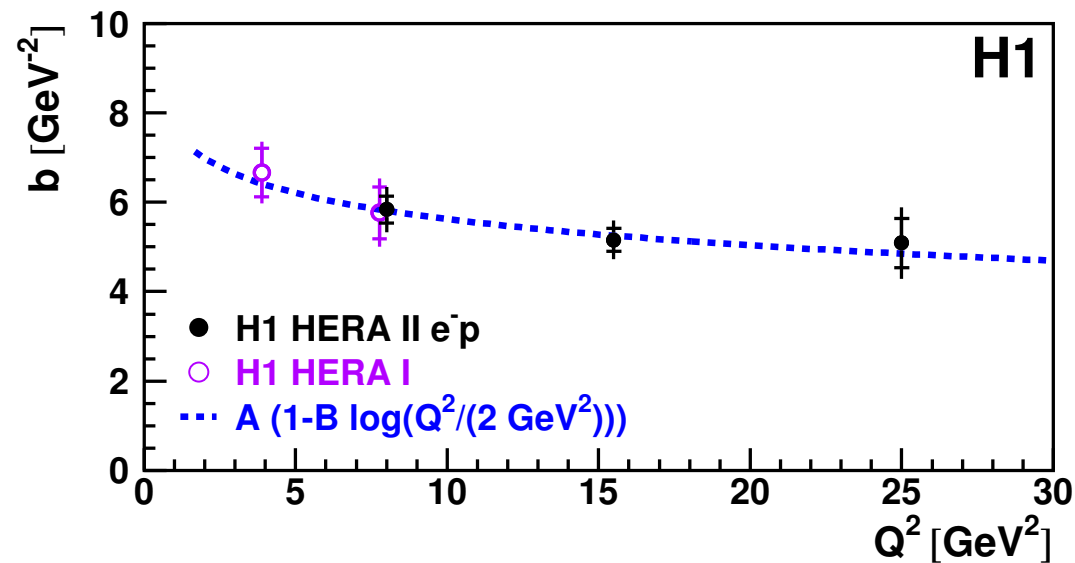
$$b = 4.5 \pm 1.3 \pm 0.4 \text{ GeV}^{-2}$$

$$W = 104 \text{ GeV}$$

$$Q^2 = 3.2 \text{ GeV}^2$$

$$t = (p - p')^2 = -\frac{p_T^2}{x_I} = -(p_{T,e} + p_{T,\gamma})^2$$

DVCS + dependence/cont

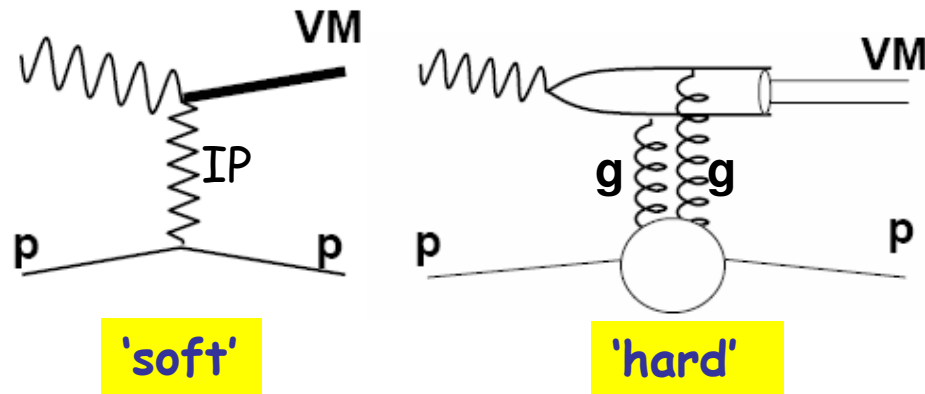


W and Q^2 \dagger -dependence

- no W dependence
- Q^2 dependence: $B(Q^2)=A[1-B \log(Q^2/2)]$

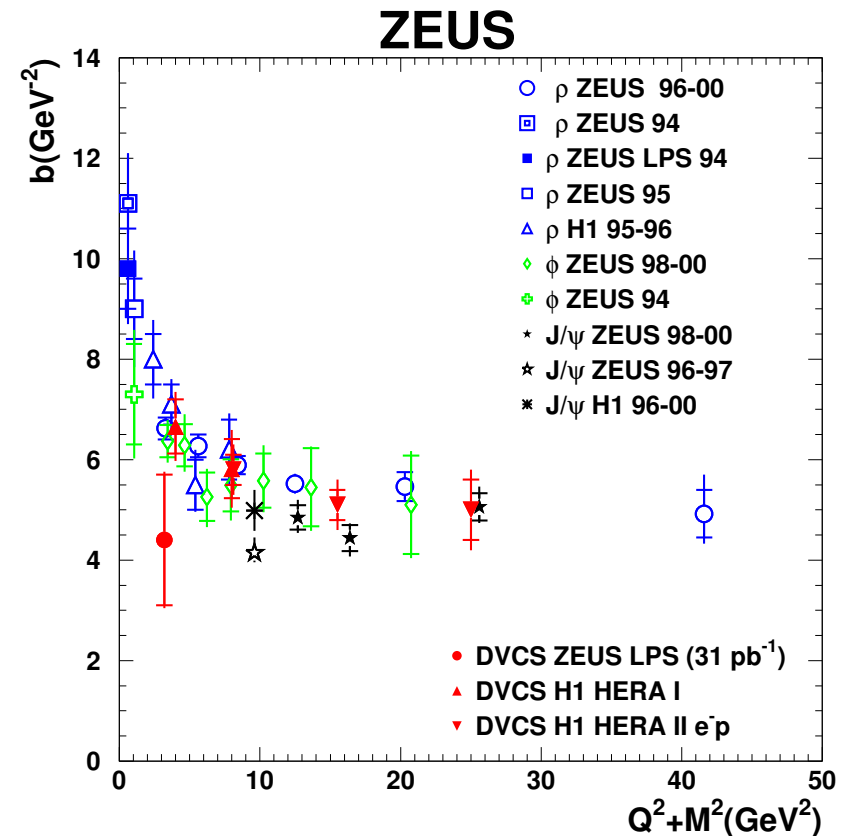
$$A=6.98\pm0.54 \text{ GeV}^{-2} \quad B=0.12\pm0.03$$

DVCS and hard diffraction expectations

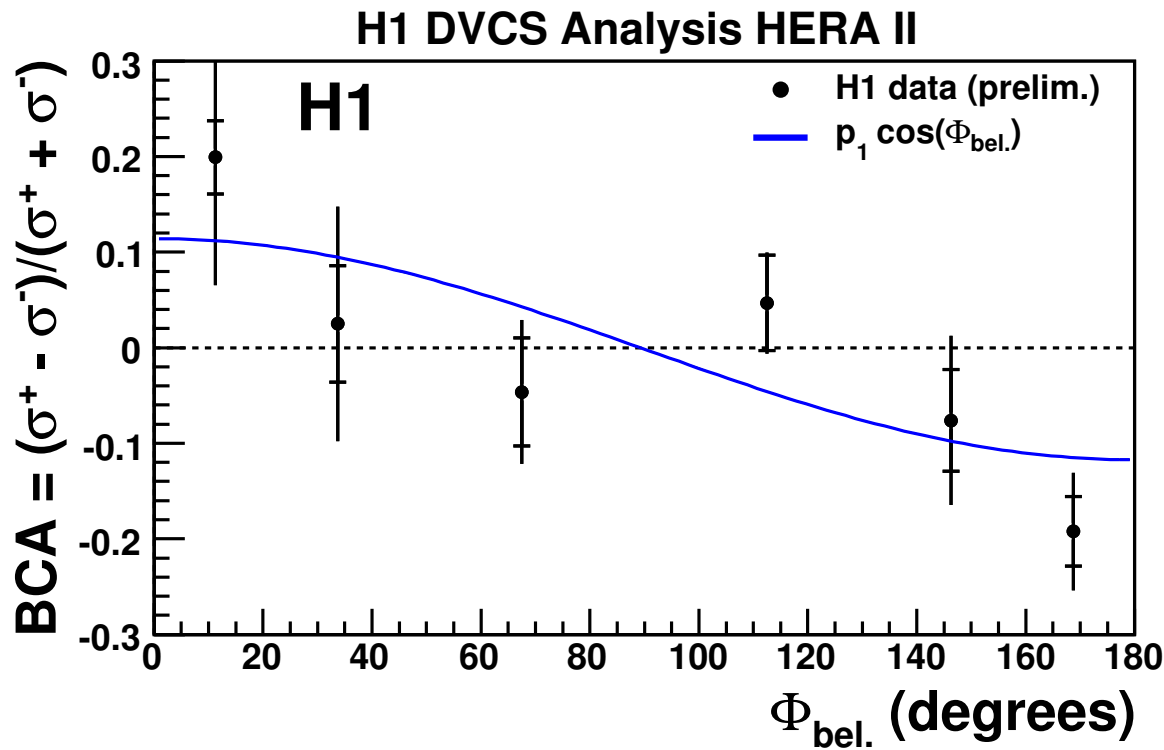


VM&DVCS:

- Universal behavior with scale $Q^2 + M^2$
- b characterize the size of interaction, expect b decreases with $Q^2 + M^2$ from $\sim 10 \text{ GeV}^{-2}$ (soft proc) to $\sim 5 \text{ GeV}^{-2}$ (hard proc)
- in term of transverse extension of partons in the proton (mainly sea quark and gluons at low x_{bj}) higher is the scale and lower radius: from $\sim 0.8 \text{ fm}$ to $\sim 0.6 \text{ fm}$



Beam charge asymmetry (BCA)



**First
measurement!!!**

146 pb⁻¹ (e⁺)

145 pb⁻¹ (e⁻)

$Q^2 = 10 \text{ GeV}^2$

$0.05 < t < 1 \text{ GeV}^2$

$$BCA = \frac{\left(\frac{d\sigma^+}{d\phi} - \frac{d\sigma^-}{d\phi} \right)}{\left(\frac{d\sigma^+}{d\phi} + \frac{d\sigma^-}{d\phi} \right)}$$

The interference term of DVCS/BH cross section is proportional, in the leading twist approximation, to the cos of the azimuthal angle of the photon.

Fit $\sim A \cos \Phi$

$A = 0.17 \pm 0.03 \pm 0.05$

DVCS and GPDs

Test Q^2 dependence of GPDs by correcting the cross section for the Q^2 dependence from the propagator and from $b(Q^2)$

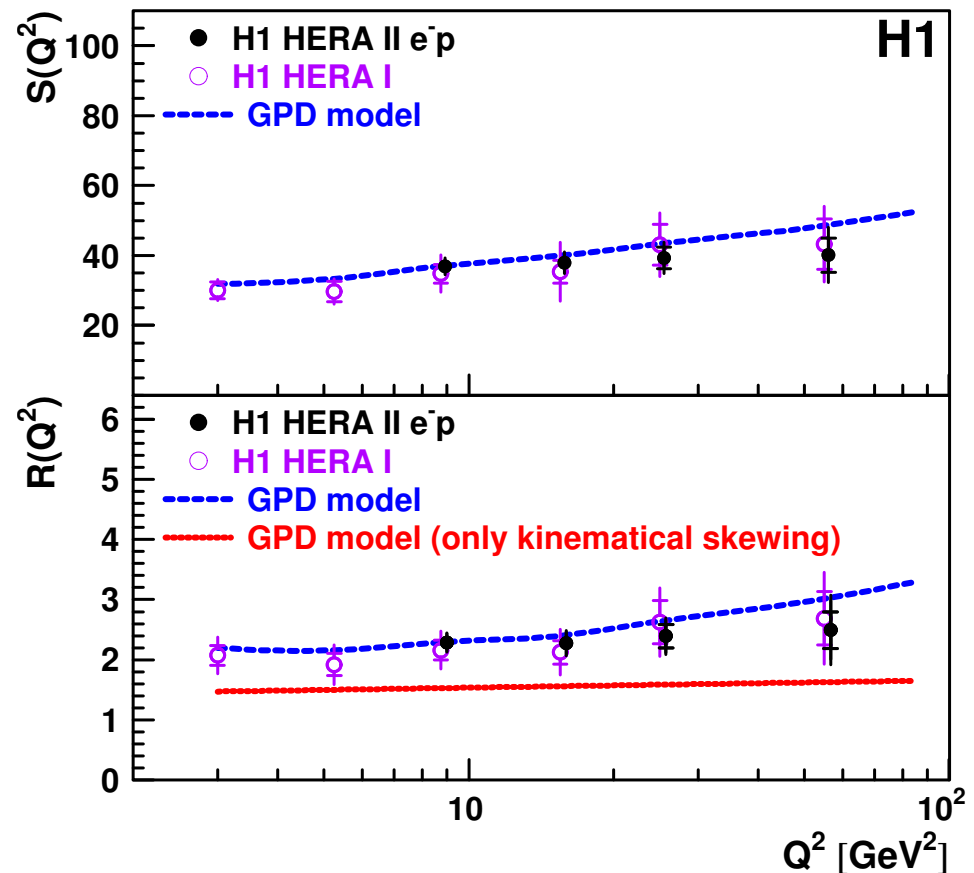
$$\sigma_{DVCS}(Q^2, W) \equiv \frac{[\text{Im}A(\gamma^* p \rightarrow \gamma p)_{t=0} Q^2, W](1 + \rho^2)}{16\pi b(Q^2, W)}$$

$$S = \sqrt{\frac{\sigma_{DVCS} Q^4 b(Q^2)}{(1 + \rho^2)}}$$

(Q^2 evolution of GPDs)

Magnitude of the skewing effect in DVCS → **factor 2**

$$R = \frac{\text{Im} A(\gamma^* p \rightarrow \gamma p)_{t=0}}{\text{Im} A(\gamma^* p \rightarrow \gamma^* p)_{t=0}} = \frac{4\sqrt{\pi\sigma_{DVCS} b(Q^2)}}{\sigma_T(\gamma^* p \rightarrow X) \sqrt{(1 + \rho^2)}}$$



DVCS (geometric scaling)

DVCS interpretation with the dipole approach in the saturation regime

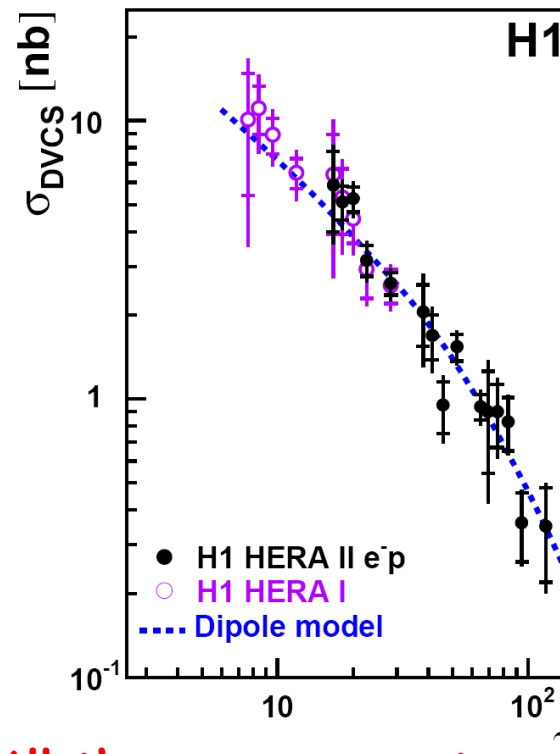
The cross sec can be described as a function of a single variable τ (geometrical scaling):

$$\sigma_{DVCS}(x, Q^2) = \sigma_{DVCS}(\tau)$$

$$\tau = \frac{Q^2}{Q_s^2(x)}$$

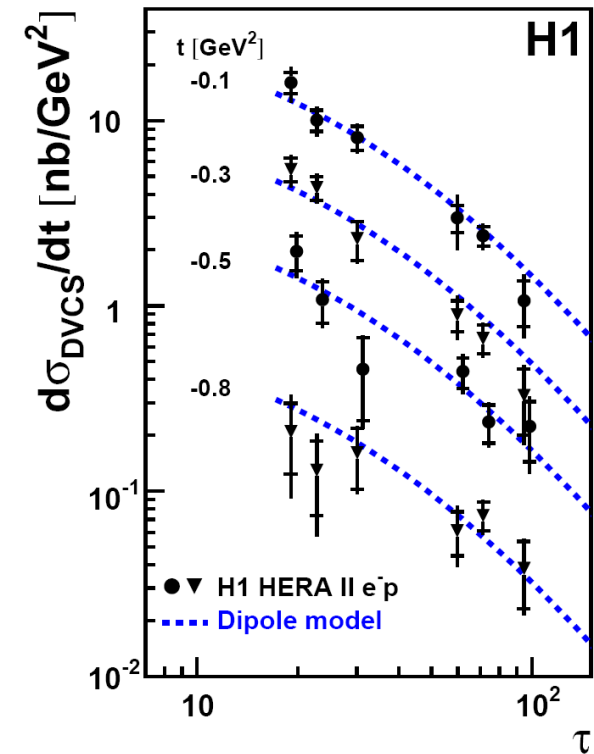
where

$$Q_s(x) = Q_0 (x_0/x)^{-\lambda/2}$$



All the measurements can be described by a single curve as a function of τ .

Geometric scaling property is verified for DVCS



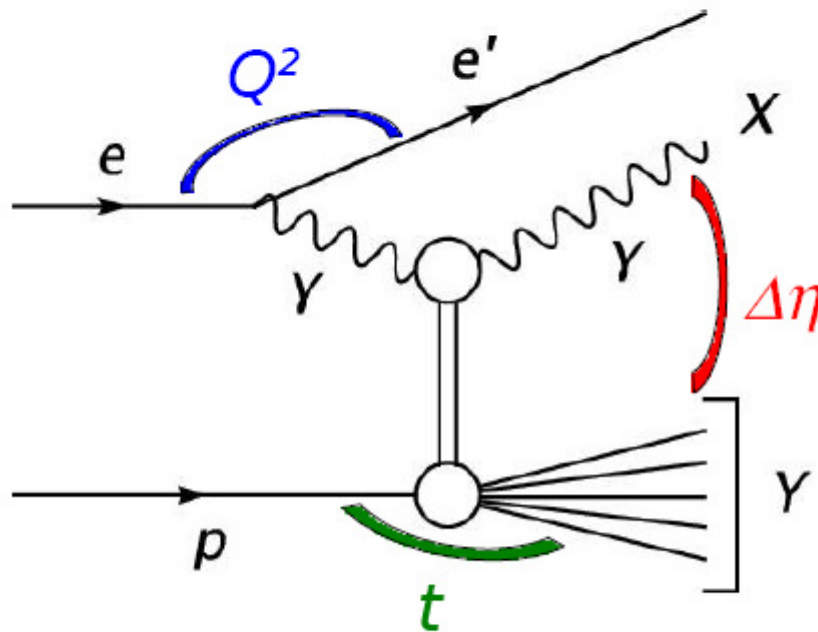
Same saturation scale Q_s^2 for each t bin

Diffractive High t photons

Kinematics variables

High t photon

$(ep \rightarrow e \gamma p)$



$$t \approx -(p_T^\gamma)^2$$

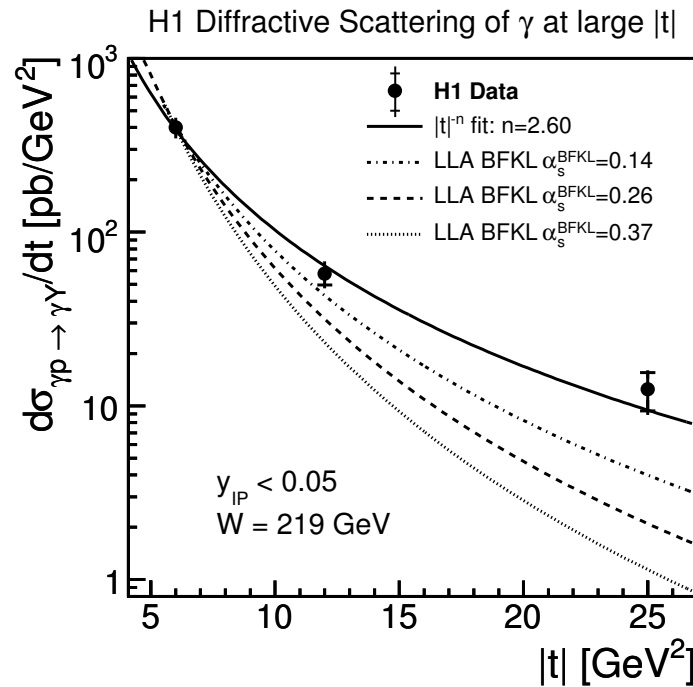
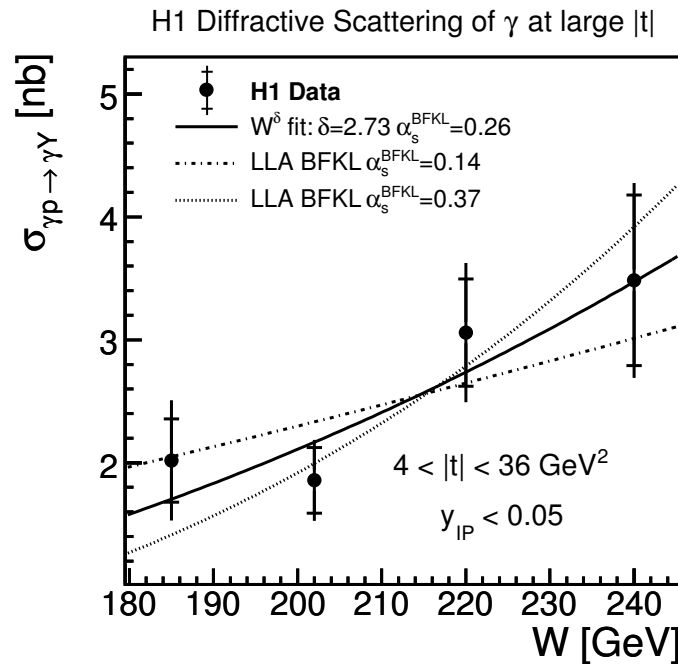
$$x_{IP} = \frac{q \cdot (P - Y)}{q \cdot P} \approx \frac{(E + P_Z)_\gamma}{2E_p} \approx \frac{(P_T^\gamma)^2}{W^2}$$

$$y_{IP} = \frac{P \cdot (q - X)}{q \cdot P} \approx \frac{\sum_Y (E - P_Z)}{2E_p} \approx e^{-\Delta\eta}$$

- ✓ Also clean process with no VM wave function uncertainty
- ✓ Photoproduction with large $t \rightarrow$ hard scale
- ✓ Complementary to DVCS
- ✓ LLA BFKL calculation included in HERWIG MC generator (B. Cox, J. Forshaw J. Phys. G26(2000) 702)

Results

(To be submitted to Physics Letters B)



48 pb-1 9900

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

$175 < W < 247 \text{ GeV}$

$4 < |t| < 36 \text{ GeV}^2$

$y_{\text{IP}} < 0.05$

$E > 8 \text{ GeV}$

$\Delta\eta > 2$

Strong energy dependence:

$$\delta = 2.73 \pm 1.02^{+0.56}_{-0.78}$$

$$\text{Fit } \sim |t|^{-n} : n = 2.60 \pm 0.19^{+0.03}_{-0.08}$$

LLA BFKL (hep-ph/9808455 hep-ph/9902481 hep-ph/9912486) prediction allows a good description of the W dependence whereas the t dependence is too soft

Summary

- ✓ New exciting results on DVCS, from H1 and ZEUS, in a wide kinematic domain.
- ✓ DVCS cross section measurements as a function of Q^2 and W and the differential cross section as a function of t show a hard diffractive behavior.
- ✓ The Beam Charge Asymmetry, needed to estimate the interference between DVCS and BH cross sections, has been measured by H1 for the first time.
- ✓ Very good agreement with NLO QCD predictions based on GPDs and with dipole model.
- ✓ High t photon preliminary results have also been presented