Deeply Virtual Compton Scattering

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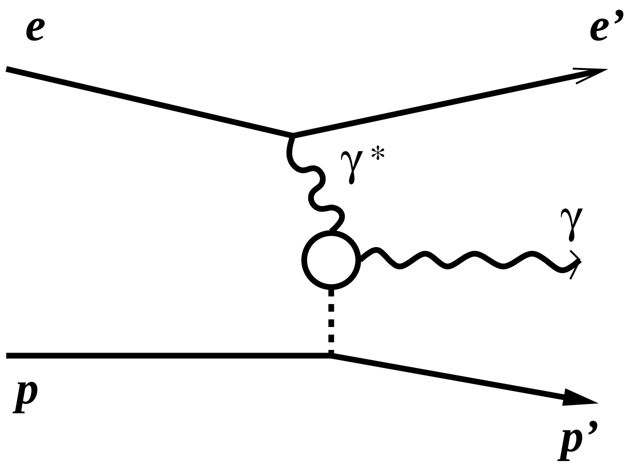
on behalf of the H1 and ZEUS Collaborations



- Introduction to DVCS
- Strategy for measuring DVCS
- Latest H1 results
- Latest ZEUS results
- Summary and outlook

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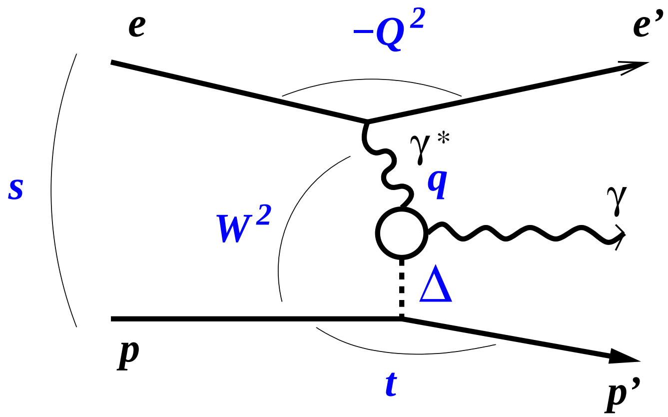
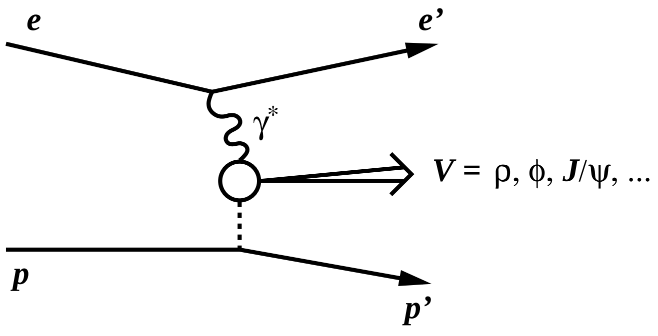
DVCS

DVCS diagram:

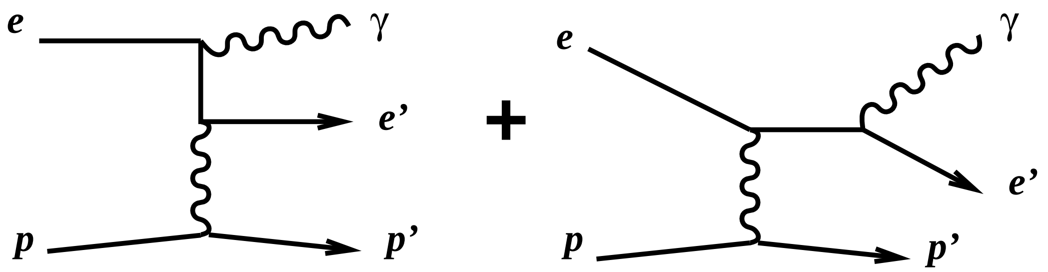


$$s = (e+p)^2$$
$$W^2 = (q+p)^2$$
$$Q^2 = -q^2 = -(e-e')^2 = sxy$$
$$x = Q^2/2p\cdot q$$
$$y = p\cdot q/p\cdot e$$
$$t = \Delta^2 = (p-p')^2 \approx -p_T'^2$$

Compare Vector Meson prodn.

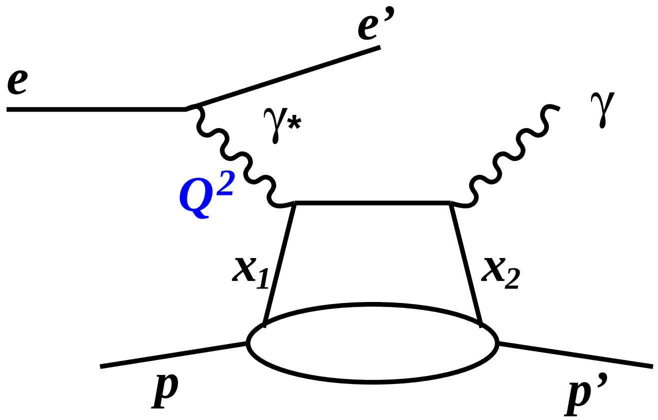


Note: DVCS competes with QED Compton (completely calculable)



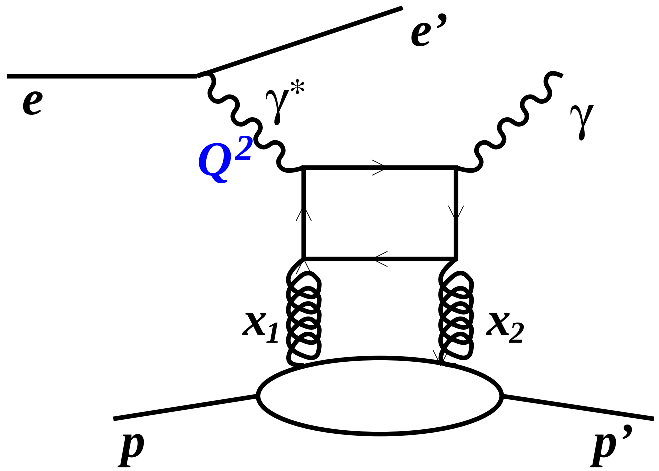
DVCS Process in QCD

Handbag diagram (high-x):



$x_1 \neq x_2$

Dominant contribution at low-x (ZEUS+H1):



Why is DVCS Interesting?

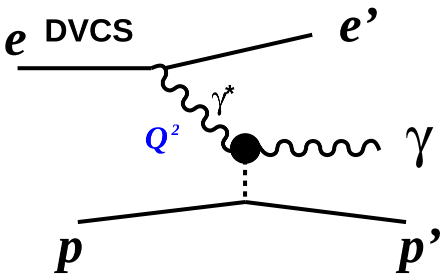
Skewed Parton Distributions.

- Generalisations of the usual pdfs for non-forward scattering.
- A probe for correlations in the parton distributions.

Interference Term.

- Interference of QCD amplitude with QED amplitude.
- Allows for measurement of real part of a QCD amplitude.

QCD-BASED MODEL PREDICTIONS AT LOW-x



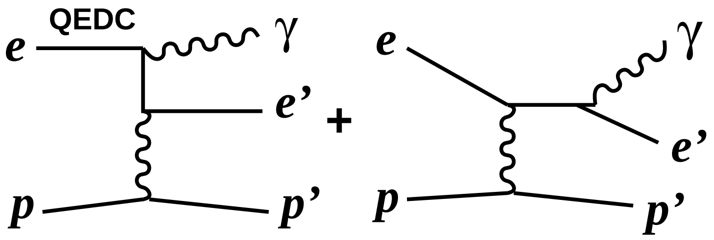
not predicted by models

$$\frac{d\sigma^{\mathrm{DVCS}}}{dxdydtd\phi_r} \sim \frac{1}{Q^6} e^{-B|t|}(1+\eta^2)$$

$$\eta = \frac{Re(A(\gamma^* p \to \gamma p))}{Im(A(\gamma^* p \to \gamma p))}$$

$$\frac{d\sigma^{\mathrm{INT}}}{dxdydtd\phi_r} \sim \pm \frac{1}{Q^5} \eta \frac{e^{-B|t|/2}}{\sqrt{|t|}} \cos\phi_r$$

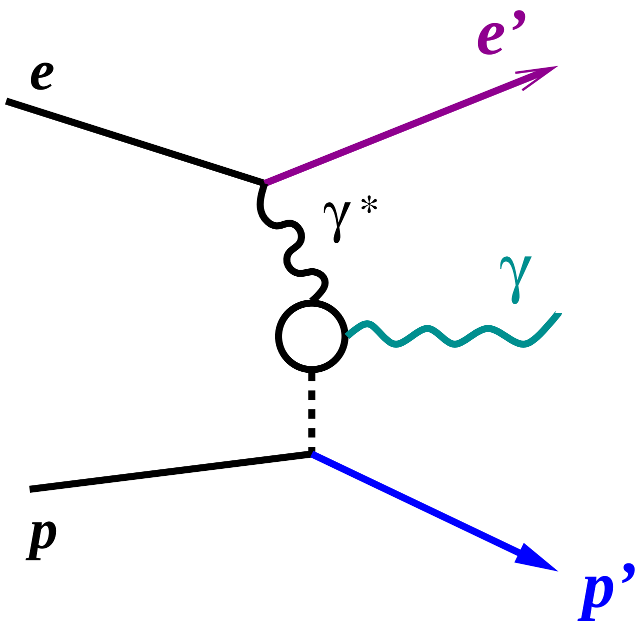
$$\phi_r = \phi'_e - \phi'_p$$



$$\frac{d\sigma^{\mathrm{QEDC}}}{dxdydtd\phi_r} \sim \frac{1}{Q^4} \frac{1}{|t|}$$

Predictions by [Frankfurt, Freund and Strikman, Phys.Rev.D58 (1998) 114001] and [Donnachie and Dosch, Phys.Lett.B502 (2001) 74] used as input to MC generators

INVESTIGATING DVCS AT HERA IS CHALLENGING



- e typically scatters at low angles
  $\rightarrow$ no tracks in the event (no vertex)
  $\rightarrow$ kinematics poorly reconstructed

- low γ energy in central region, $1 < E_\gamma < 5$ GeV
  $\rightarrow$ energy resolution is poor

- scattered proton is not observed
  $\rightarrow$ only e and γ in final state

- $\sigma^{\mathrm{DVCS}} \ll \sigma^{\mathrm{QEDC}}$

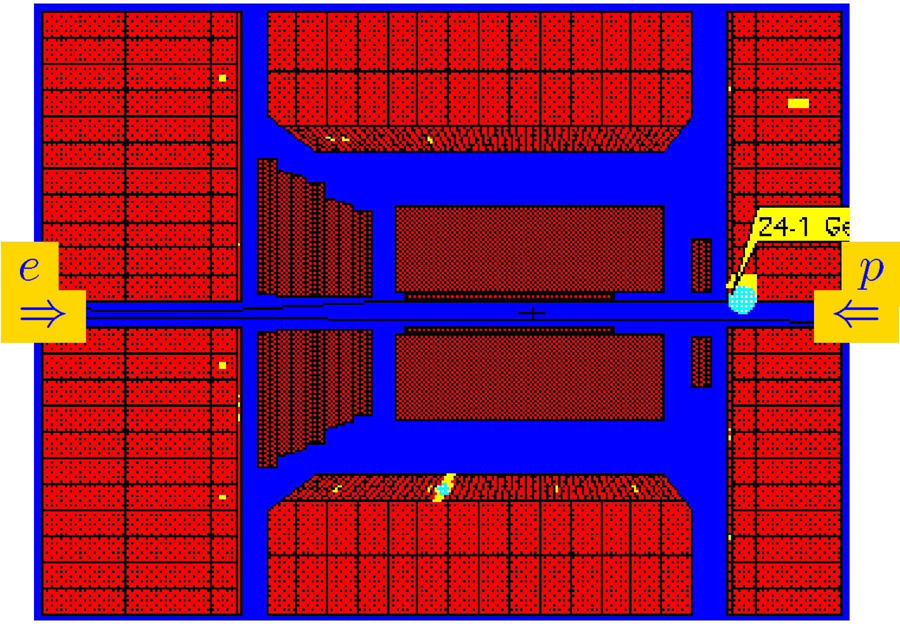
Nevertheless, DVCS has been observed at HERA
$\Rightarrow$ First observation by ZEUS presented at Tampere in 1999 [hep-ex/0003030]

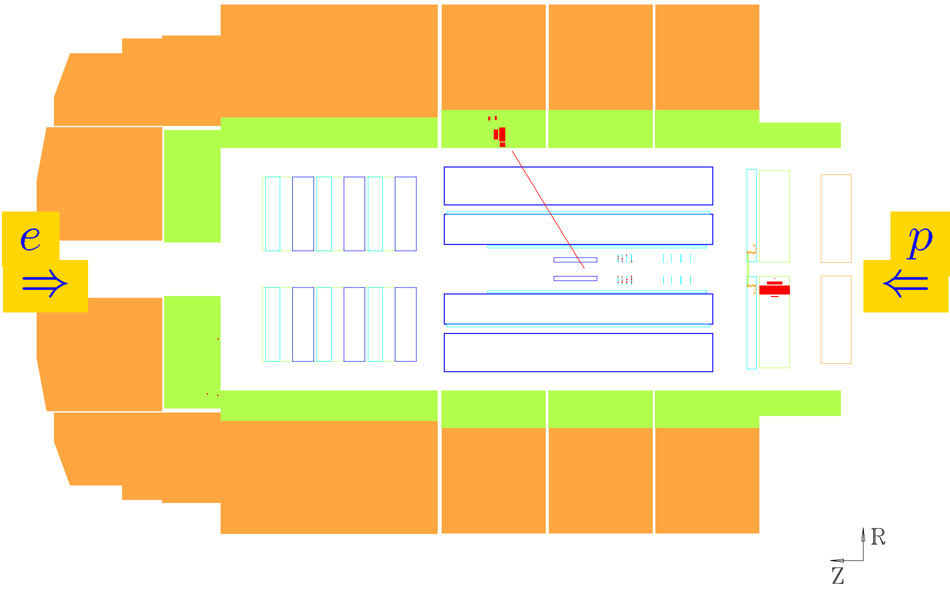
Strategy for extracting cross section

Topology studied and analysis strategy is same for both ZEUS and H1:

case 1: γ sample (enriched DVCS)
Both DVCS and QEDC contribute

case 2: e^+ sample (control)
QEDC alone contributes





If QEDC MC describes case 2, use it to subtract QEDC contribution in case 1

Comparison of ZEUS and H1 analyses

Main selection requirements:

H1	ZEUS
1 EM cluster in Lar with $p_T > 1$ GeV	1 EM cluster in BCAL with $E_T^{\text{BCAL}} > 3$ GeV
1 EM cluster in SpaCAL with $E > 15$ GeV	1 EM cluster in RCAL with $E^{\text{RCAL}} > 10$ GeV
No other cluster with $E > 0.5$ GeV	Remaining CAL energy < 0.2 GeV
0 or 1 tracks, must point to cluster	0 or 1 tracks, must point to cluster
$2 < Q_e^2 < 20\ \text{GeV}^2$	$5 < Q_e^2 < 100\ \text{GeV}^2$
$30 < W_{\text{DA}} < 120$ GeV	$40 < W_{\text{DA}} < 140$ GeV
$(-1.15 < \eta_{\text{Lar}} < 1.5)$	$-0.6 < \eta_{\text{BCAL}} < 1.0$

Events satisfying selection cuts:

H1	ZEUS
$338(e) + 172(\gamma)$	$1059(e) + 537(\gamma)$
from 8pb^{-1} of '97 e^+p data	from 37pb^{-1} of '96-'97 e^+p data

Cross section definitions:

H1	ZEUS
$2 < Q^2 < 20\ \text{GeV}^2$	$5 < Q^2 < 100\ \text{GeV}^2$
$30 < W < 120$ GeV	$40 < W < 140$ GeV
$\lvert t\rvert < 1\ \text{GeV}^2$	$E_T^\gamma > 3$ GeV
	$-0.6 < \eta_\gamma < 1.0$

H1 CONTROL PLOTS

Control sample→ (primarily QEDC)

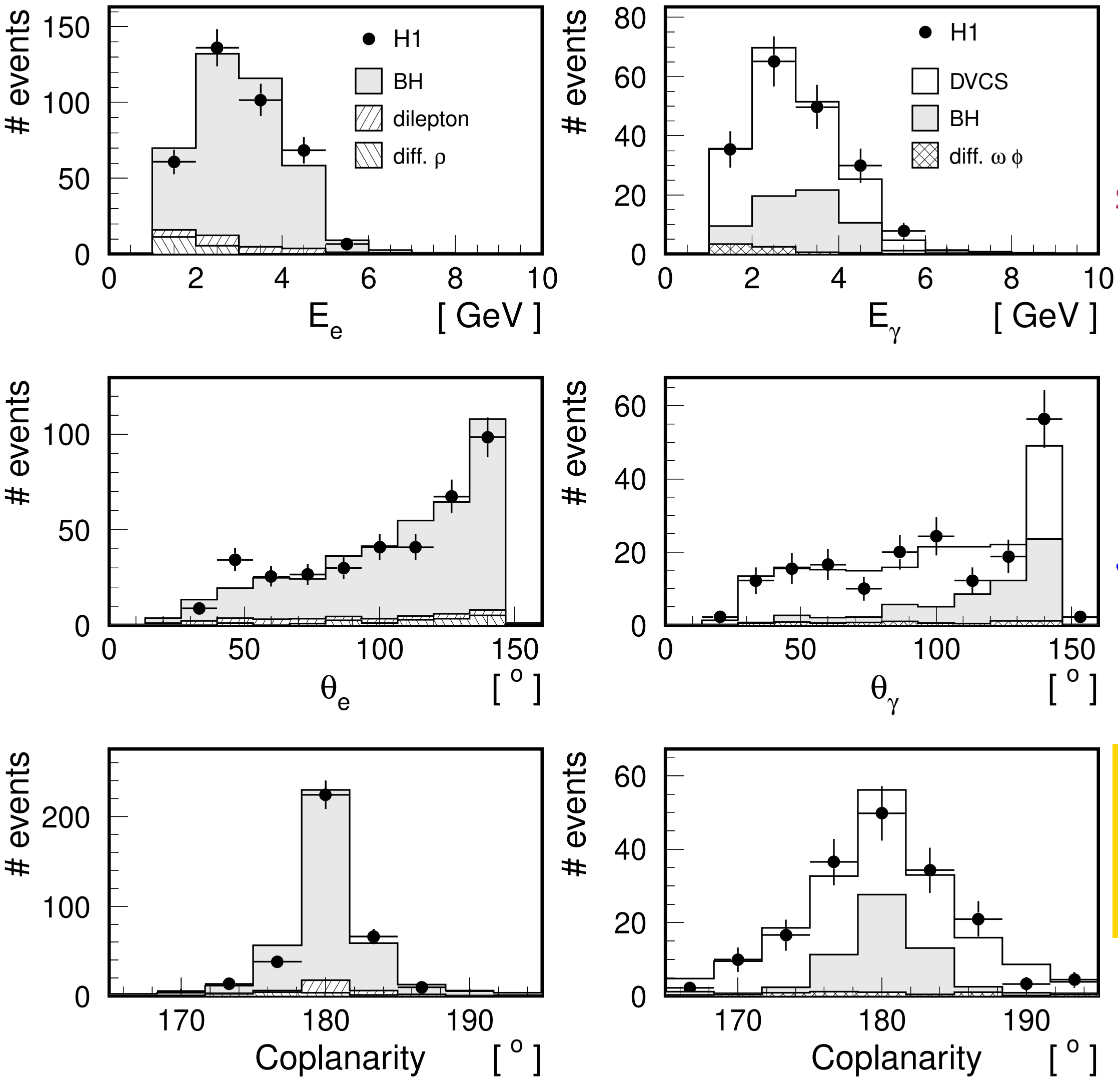
← Enriched DVCS sample (primarily DVCS)

Good agreement between data and MC

DVCS MC scaled to agree with data

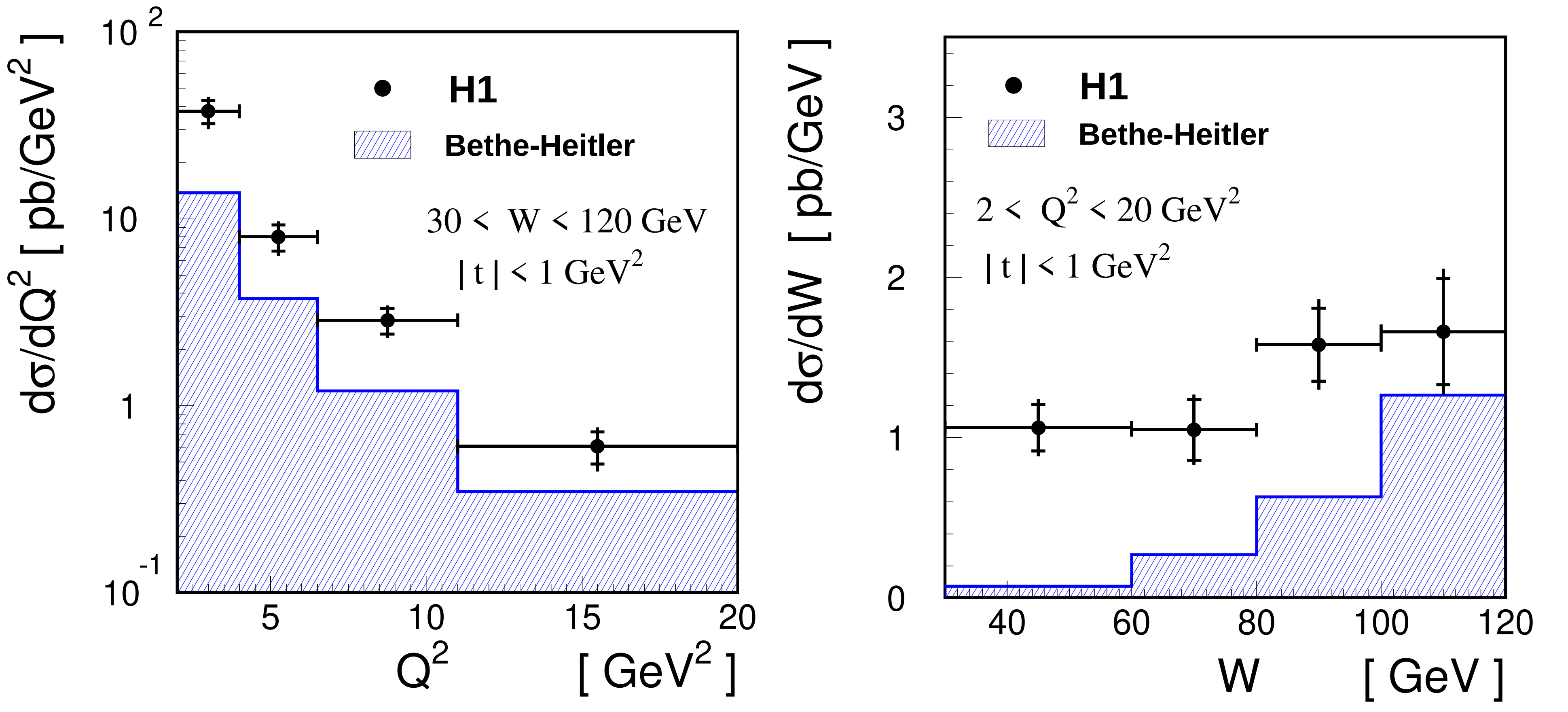
Detector well understood

Good agreement between data and MC



H1 $e^+p \rightarrow e^+p\gamma$ cross sections

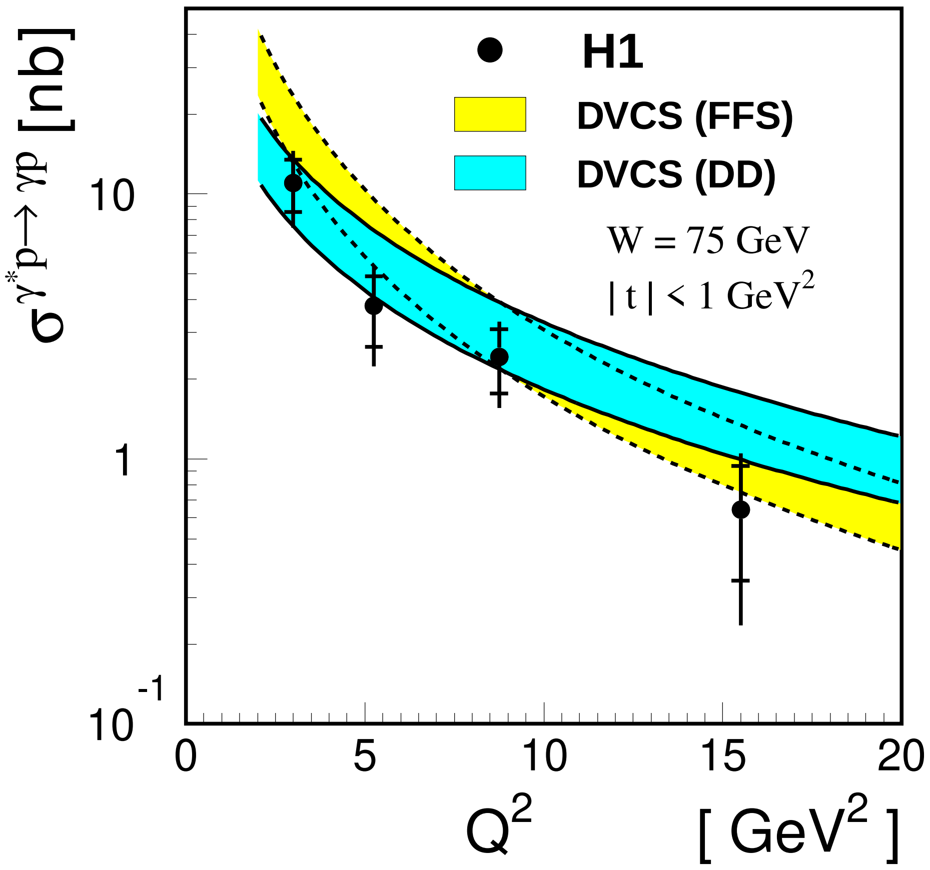
Differential cross sections $d\sigma/dQ^2$ and $d\sigma/dW$

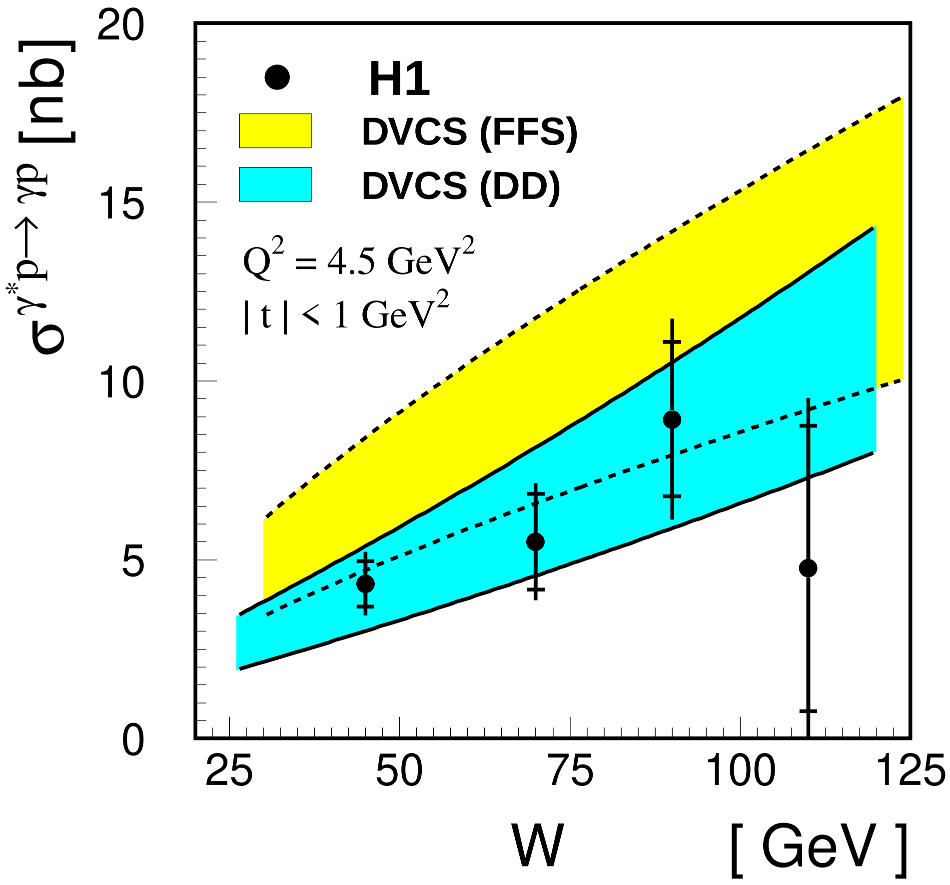


Clear excess above QED Compton prediction

H1 DVCS cross sections

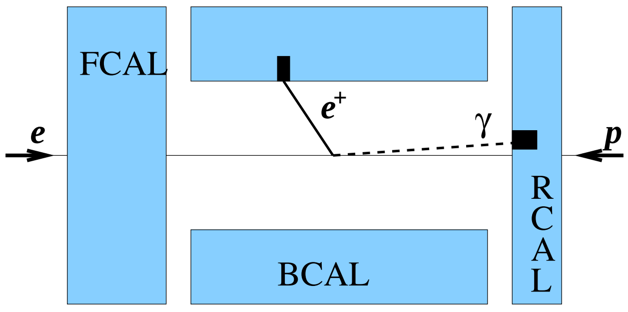
Cross sections for elastic DVCS process $\sigma^{\gamma^* p \to \gamma p}$





Cross sections in general agreement with QCD predictions

ZEUS BCAL e^+ SAMPLE

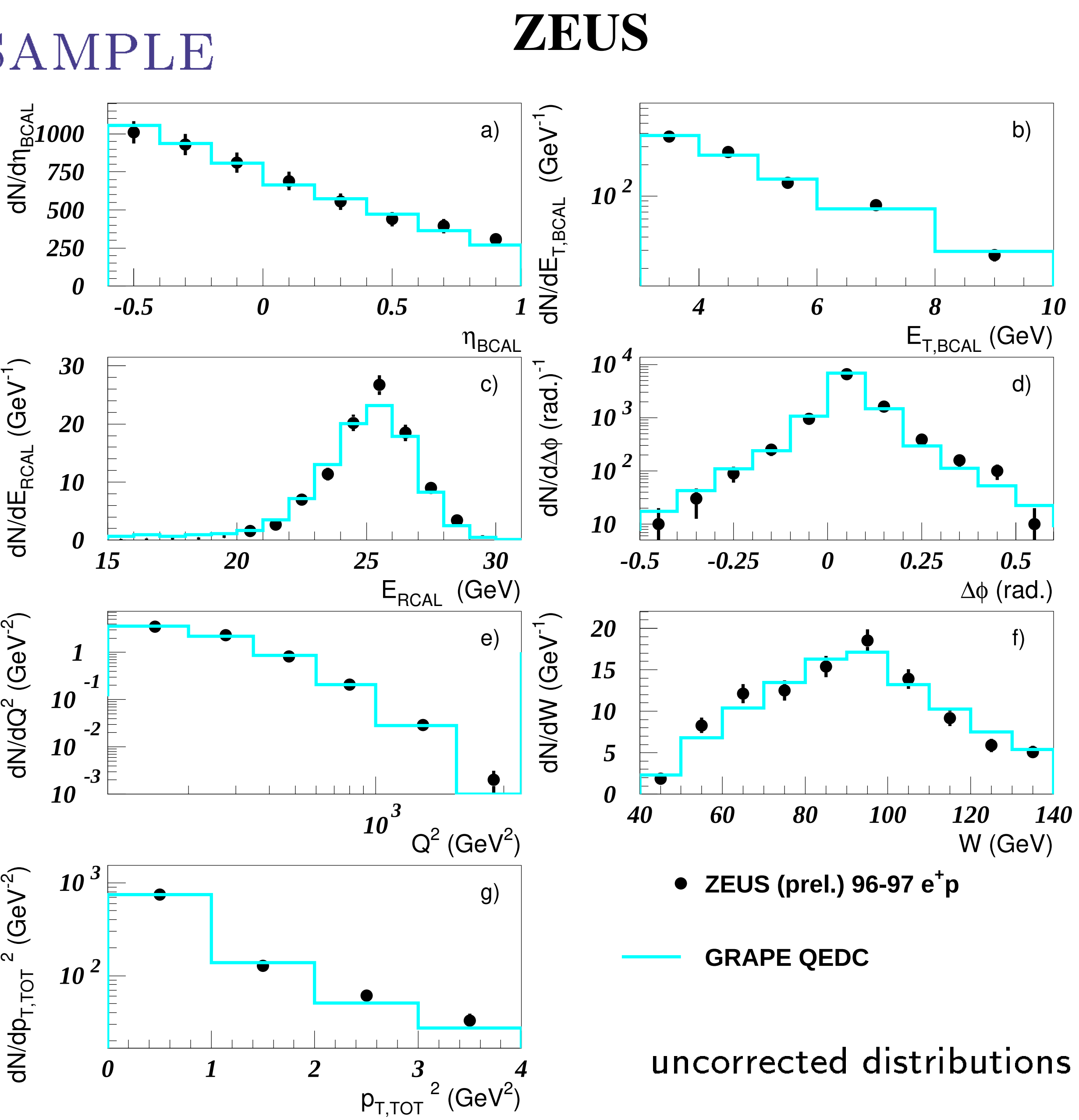


Contains QEDC only

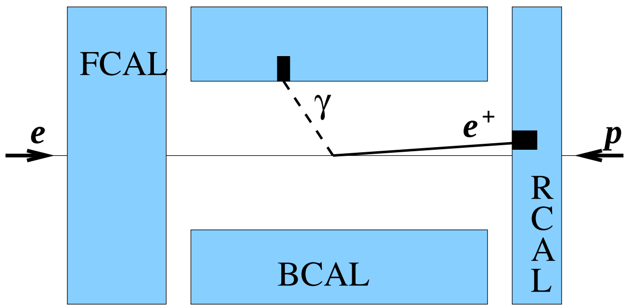
QEDC MC e^+ sample normalised to data

Very good agreement between MC and data

Use MC to subtract the QEDC contribution to the γ sample



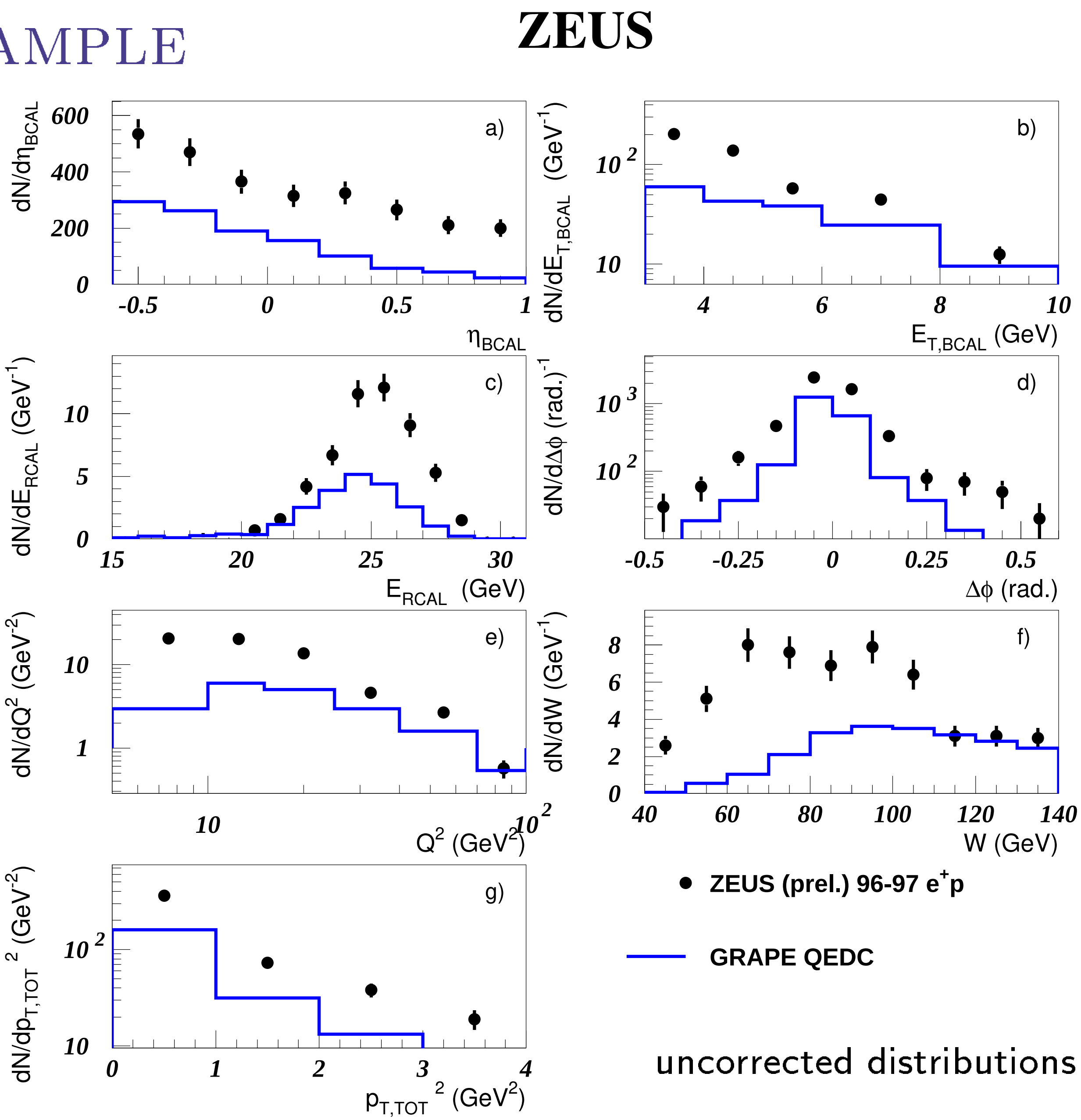
ZEUS BCAL γ SAMPLE



Contains DVCS and QEDC

Normalisation of γ sample constrained by comparison of e^+ samples in data and MC

Clear excess above QEDC prediction



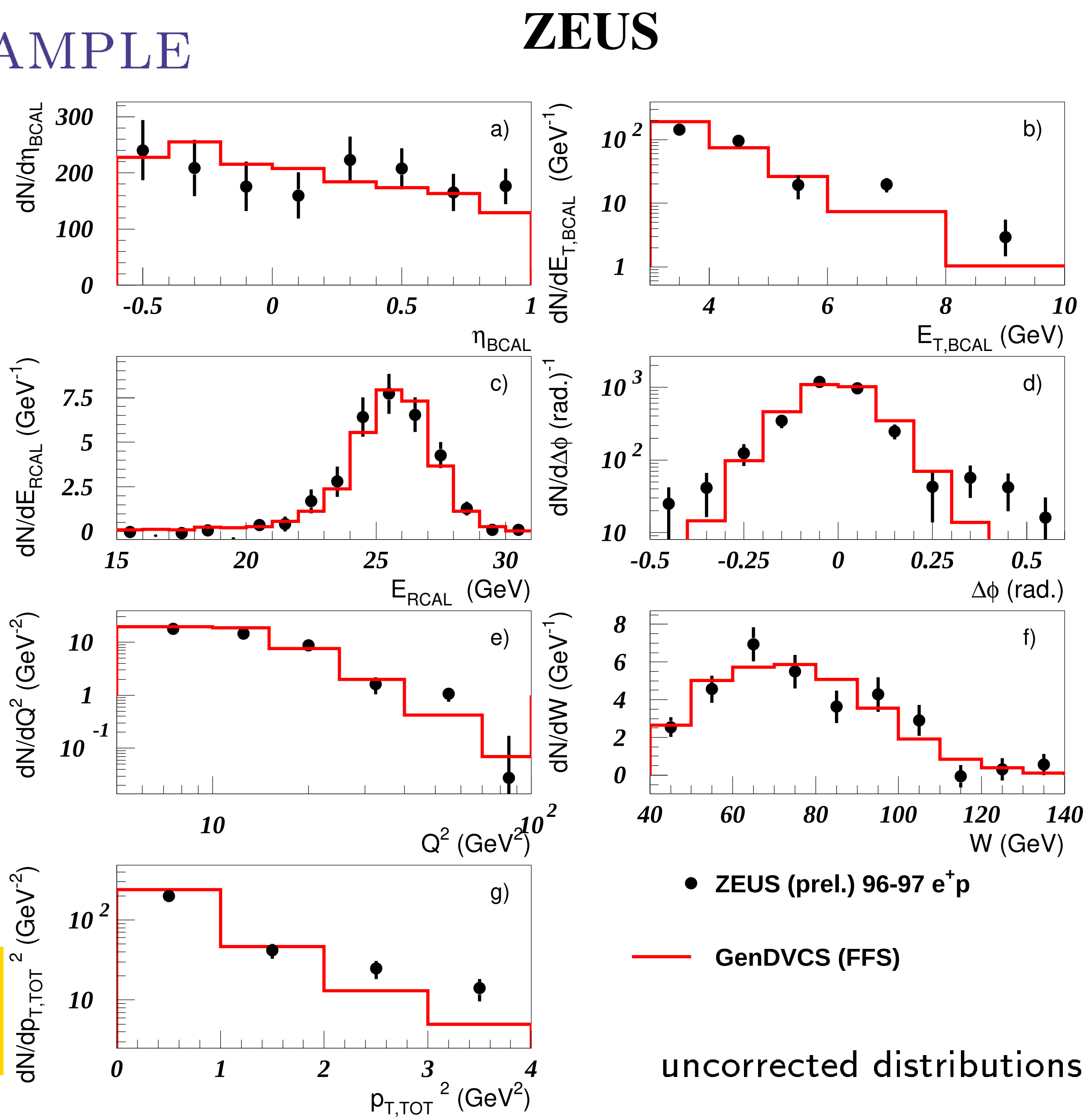
ZEUS BCAL γ SAMPLE

After QEDC subtraction

GenDVCS prediction
normalised to data

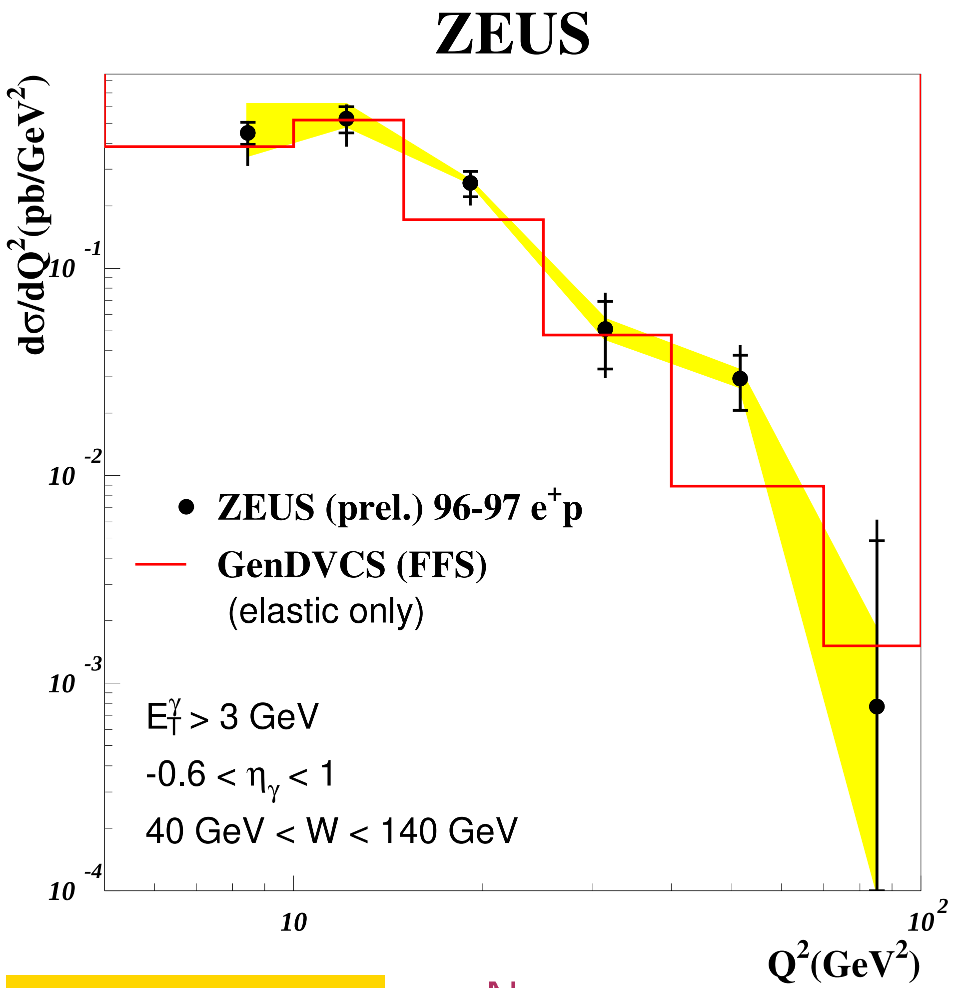
Can use GenDVCS to
unfold to cross section

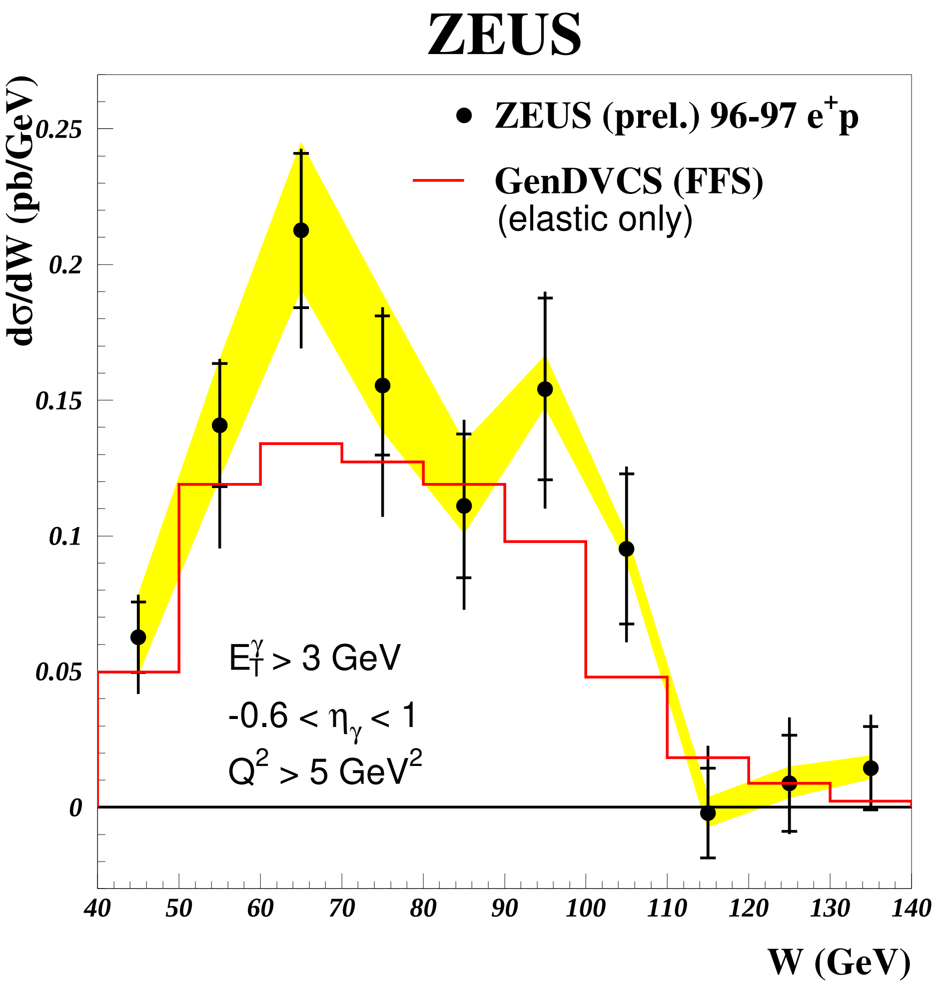
Data in reasonable agreement with GenDVCS prediction



uncorrected distributions

ZEUS DVCS cross sections $d\sigma/dQ^2$ and $d\sigma/dW$





DVCS prediction reproduces data

Note:

- Data are not corrected for proton-dissociation (20%)
- Choice of t-slope ($B = 4.5$ GeV^{-2}) in MC affects normalisation

Summary and Outlook

- Excess of photons over the QED Compton expectation clearly established at both H1 and ZEUS
- Event distributions of excess are inconsistent with QED Compton but generally consistent with deeply virtual Compton scattering
- QED Compton background subtracted and DVCS cross section measured
- DVCS predictions generally reproduce measurement

⋆ DVCS analysis at HERA only just beginning. ZEUS has analysed 37 pb^{-1} of data and H1 only 8 pb^{-1}. HERA II promises another $\sim$1 fb^{-1} in five years!

⋆ Future measurements will focus on t-distribution, interference term, and ultimately skewed parton distributions