Prompt Photons and DVCS at HERA

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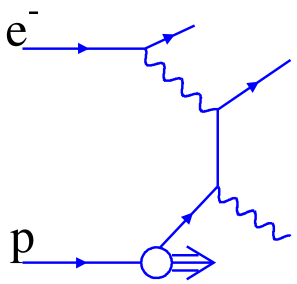
Representing the H1 and ZEUS collaborations

Outline:

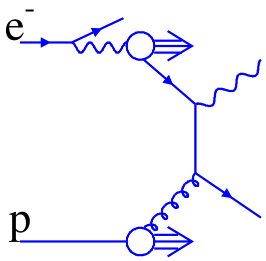
- **Introduction**
- **Prompt Photons (ZEUS)**
- **DVCS (H1 and ZEUS)**
- **Summary**

INTRODUCTION

Prompt Photons



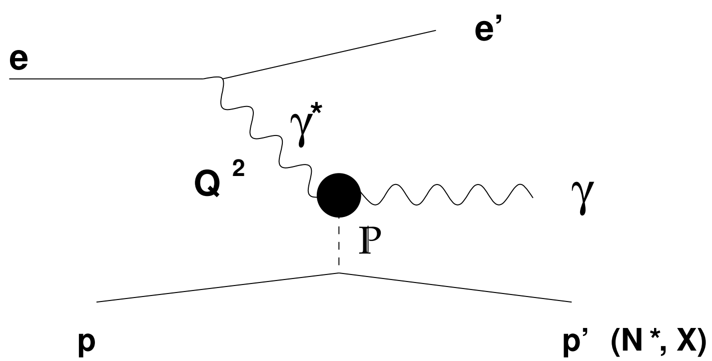
Direct Prompt γp



Resolved Prompt γp

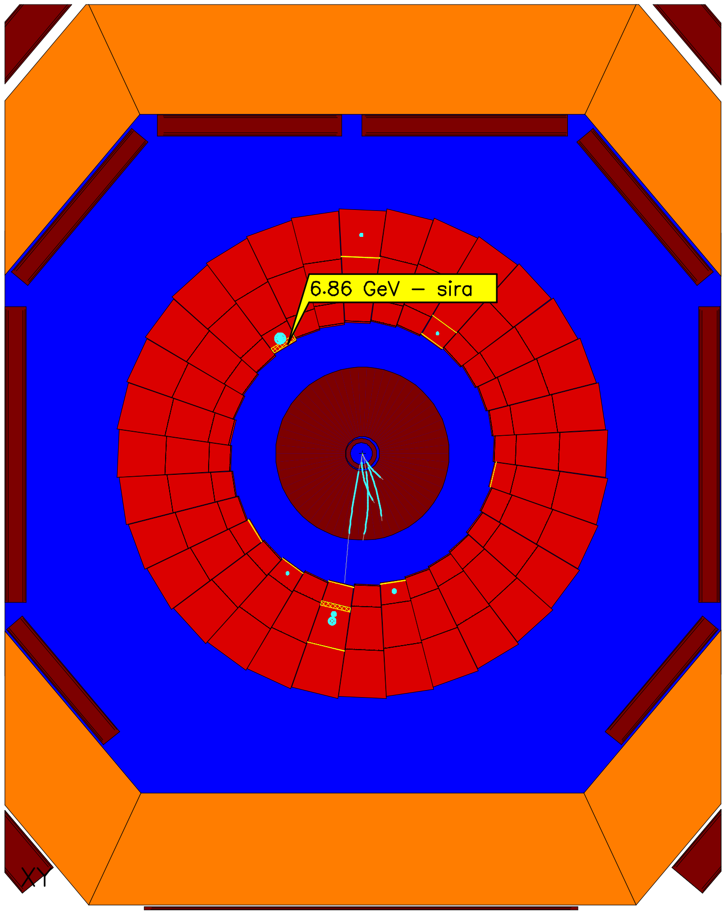
- Sensitive to parton level interactions
- Clean signature
- Sensitive to parton structure of photon
- Possible to extract $\langle k_T \rangle$ - intrinsic parton momentum in proton - from direct events

Deeply Virtual Compton Scattering (DVCS)



- Study of diffraction without VM wave functions
- Sensitive to skewed parton distributions (2 parton correlations)
- Interference between DVCS and QED Compton
  $\Rightarrow$ Real part of QCD amplitude

Prompt Photons



A prompt photon event in ZEUS

$$E_e = 27.5\,\mathrm{GeV}$$

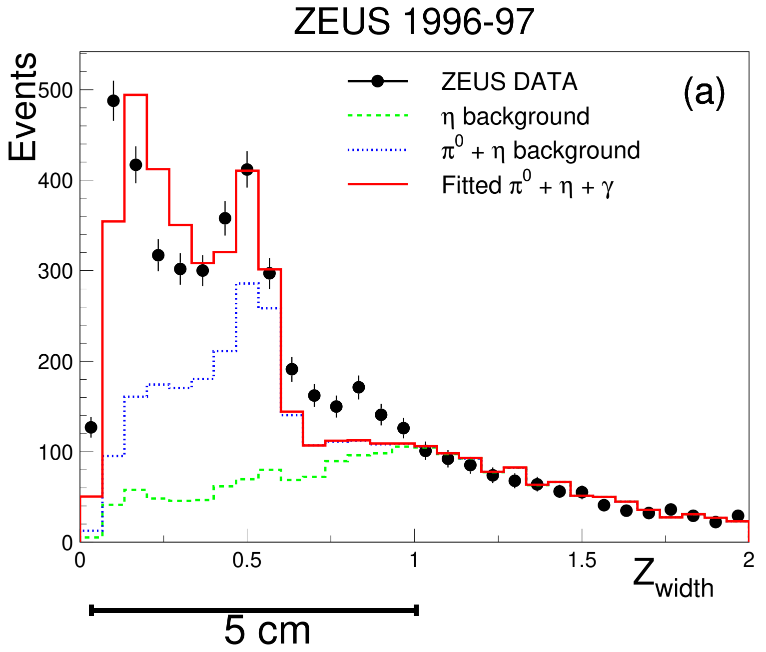
$$E_p = 820\,\mathrm{GeV}$$

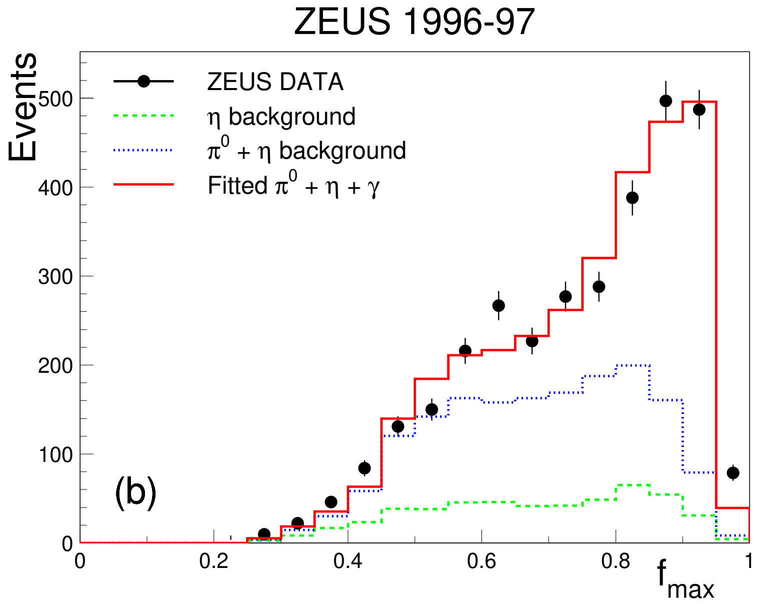
- Signature is isolated γ + jet
- No e^+ seen $\Rightarrow Q^2 < 1\,\mathrm{GeV}^2$
- Event selection cuts:

$$E_T^{jet} > 5\,\mathrm{GeV}, -1.5 < \eta^{jet} < 1.8$$
$$E_T^{\gamma} > 5\,\mathrm{GeV}, -0.7 < \eta^{\gamma} < 0.9$$

- No other cluster in unit (η,ϕ) cone
- ZEUS calorimeter has good granularity to separate π^0 and η^0 background

BACKGROUND SUBTRACTION





f_{max} = fraction of total energy in highest energy calorimeter cell

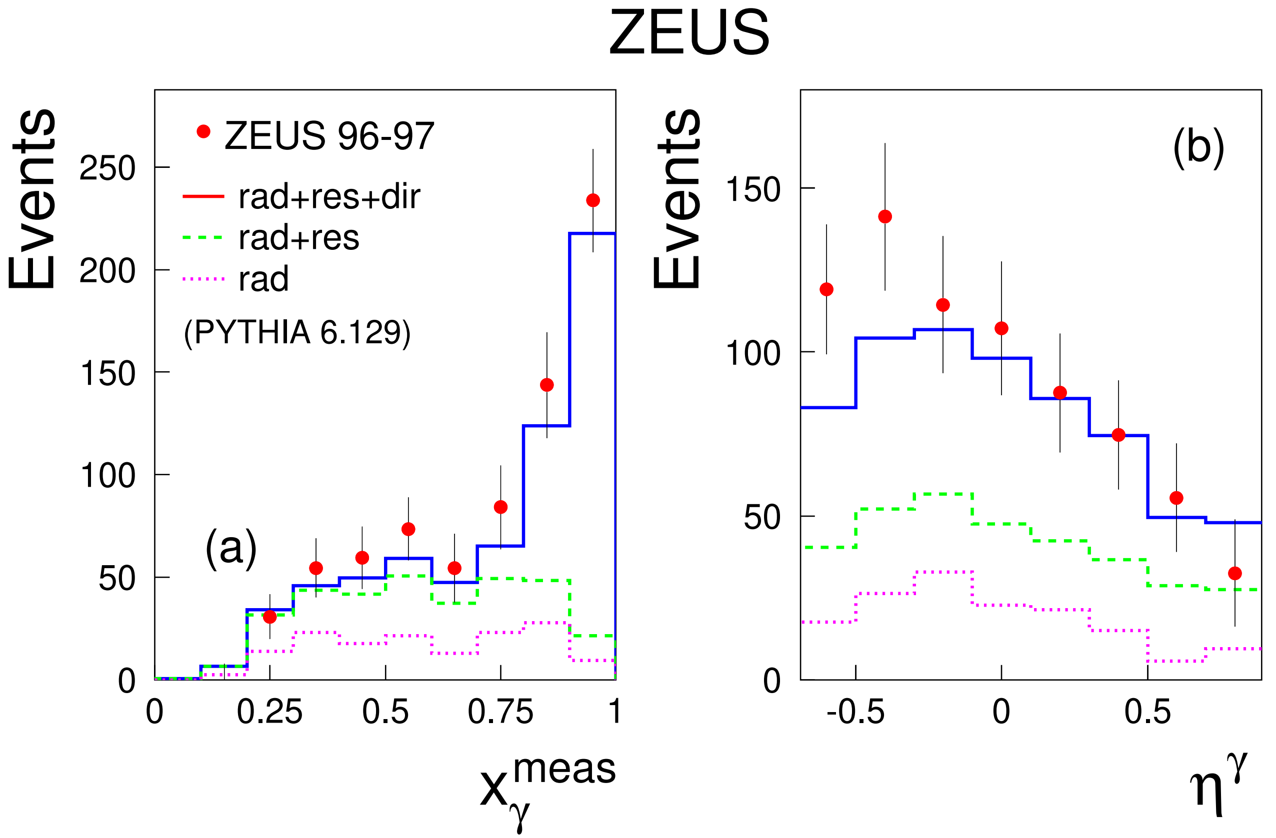
Z_{width} = size of calorimeter cluster

- Fitted MC describes data well
- f_{max} insensitive to π^0/η^0 ratio

Demand $Z_{width} < 0.65$

Statistical subtraction of π^0 and η^0 is possible

SELECTION OF DIRECT EVENTS

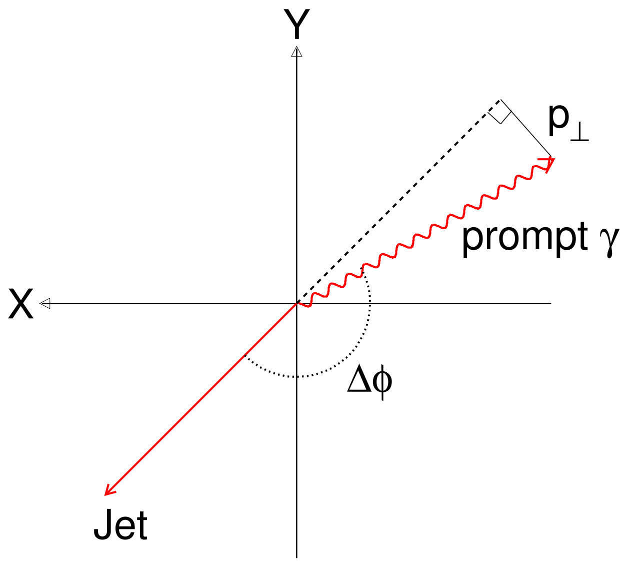


$$x_\gamma^{\rm meas} = \frac{1}{2E_e y_{JB}} \sum_{\gamma+{\rm jet}} (E - p_z)$$

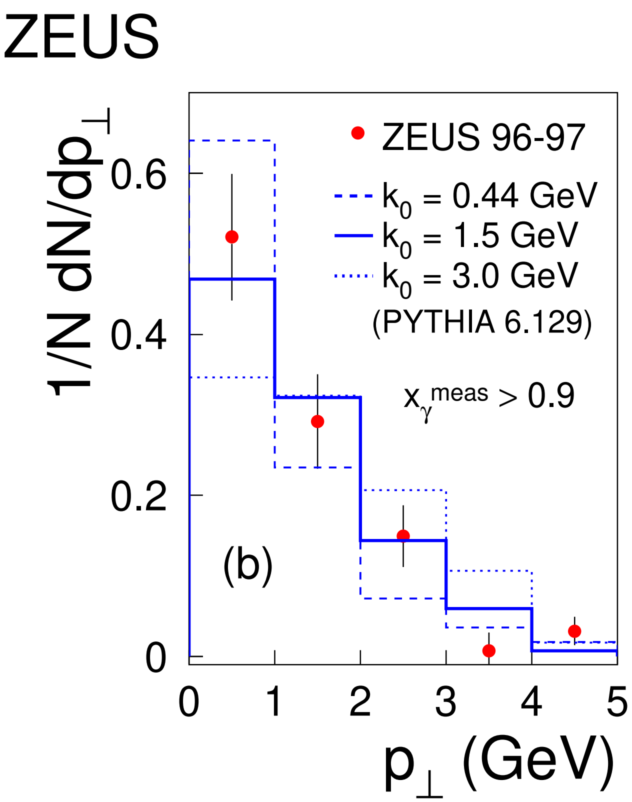
(fraction of incoming γ energy in QCD subprocess)

Select $x_\gamma > 0.9$ for direct sample

MEASUREMENT OF $\langle k_T \rangle$



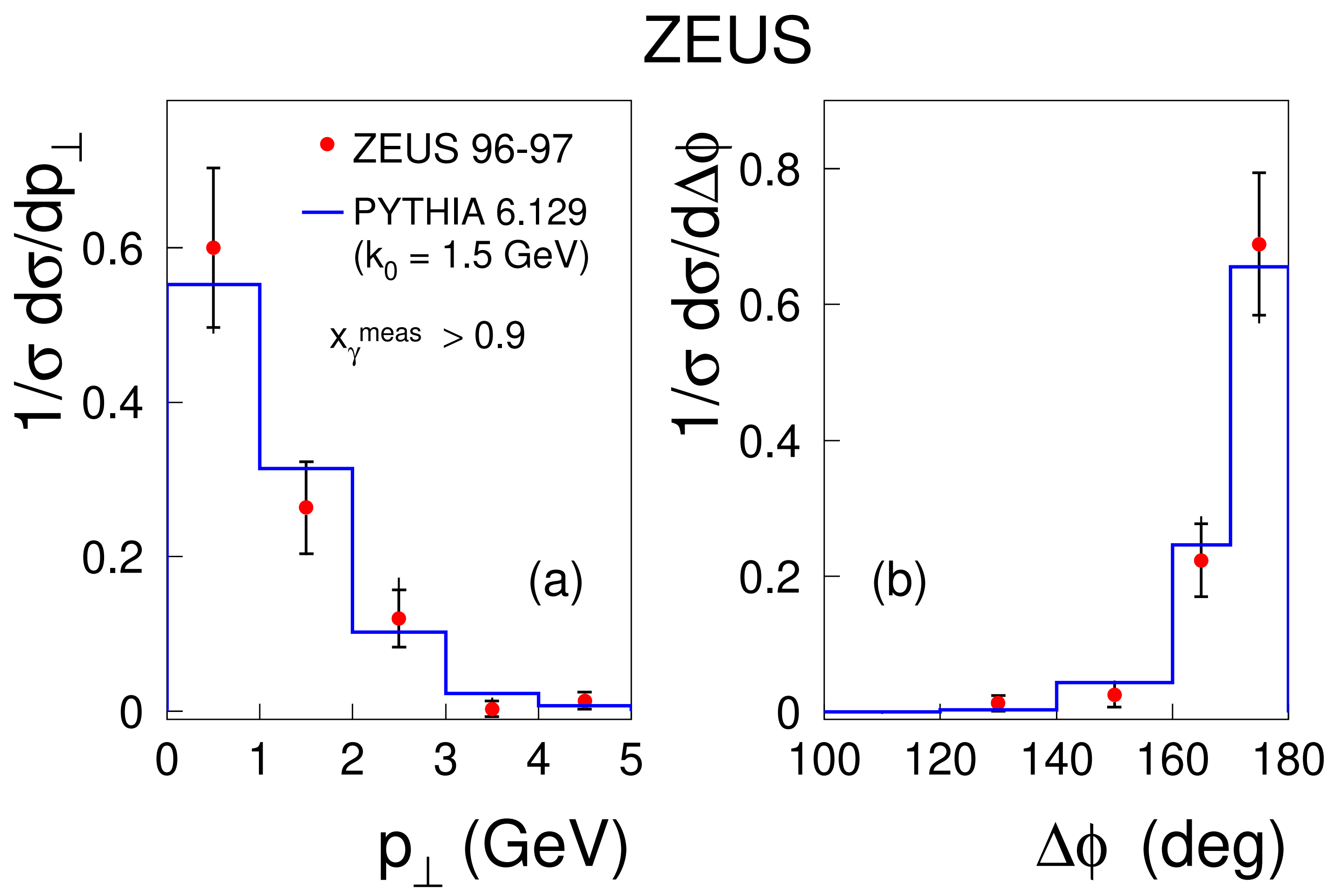
$p_\perp$ and $\Delta\phi$ are sensitive to $\langle k_T \rangle$



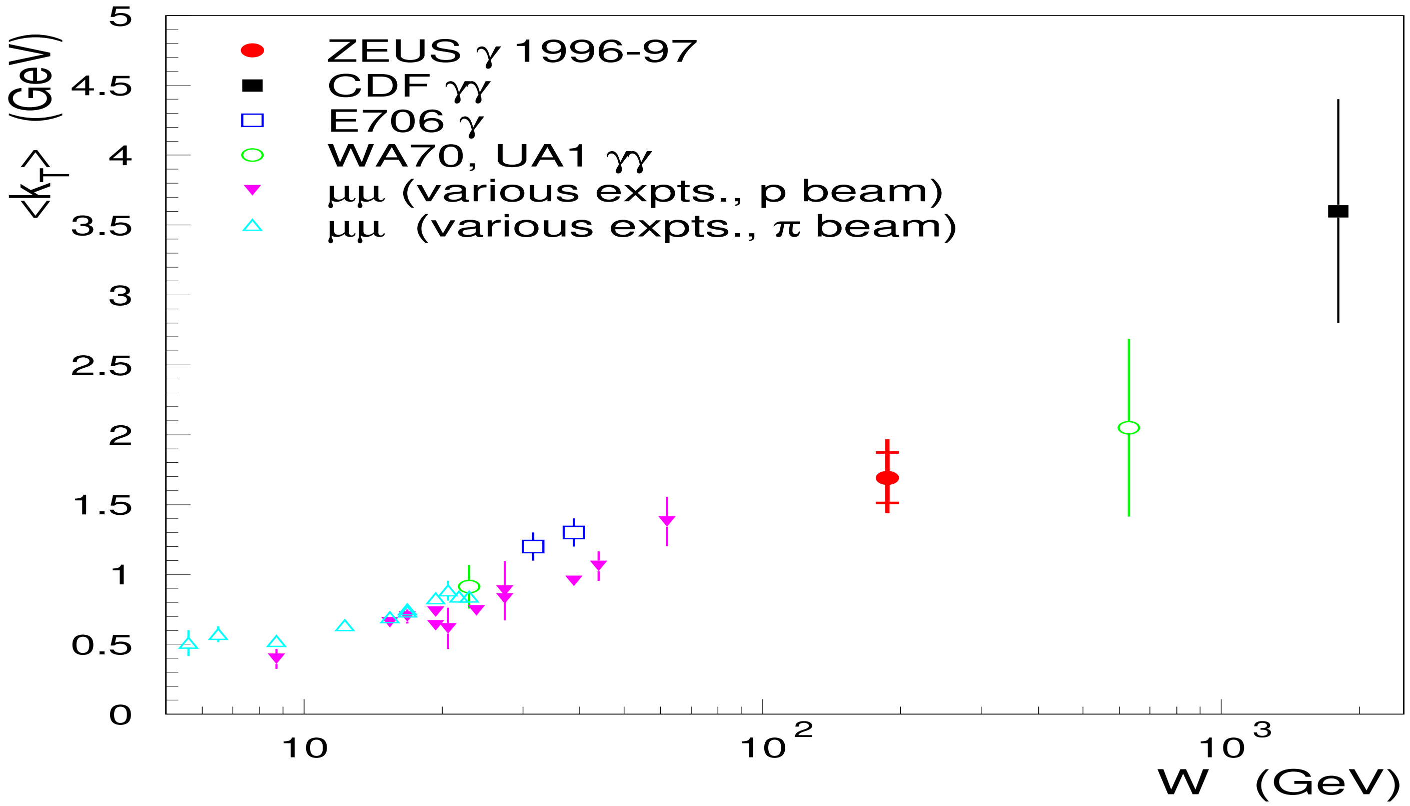
- $x_\gamma > 0.9$
- Vary k_0 parameter in PYTHIA $\left(k_0 = \sqrt{\frac{4}{\pi}} \langle k_T^{\rm intr} \rangle\right)$
- Determine $\langle k_T^{\rm intr} \rangle$ from fit at detector level with extra k_0 points
- Add parton shower contribution (from PYTHIA) to get $\langle k_T \rangle$

$$\langle k_T \rangle = 1.69 \pm 0.18^{+0.18}_{-0.20}\,\mathrm{GeV}$$

Normalized Cross Sections



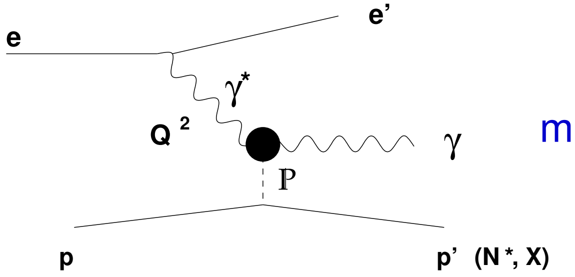
PROMPT PHOTONS – RESULTS



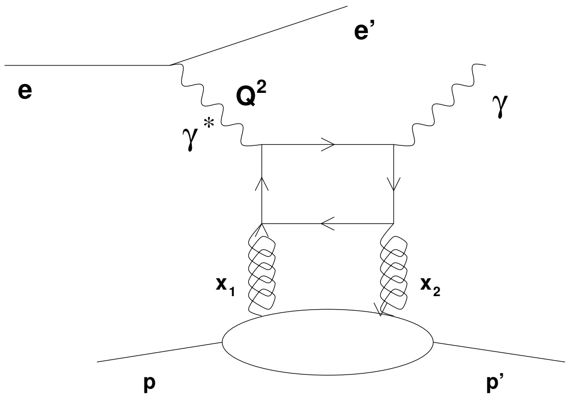
- $\langle k_T \rangle$ has been measured from prompt photons
- Result is consistent with the rising trend seen elsewhere

Deeply Virtual Compton Scattering

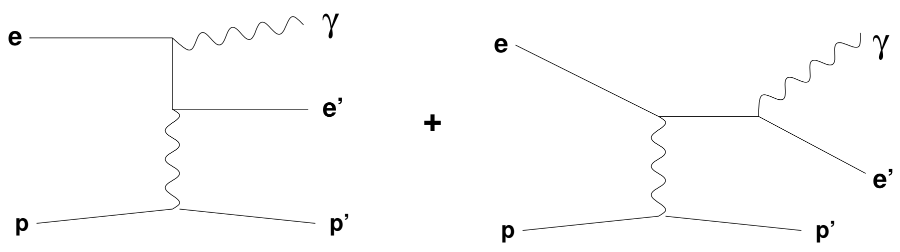
DVCS



modelled as

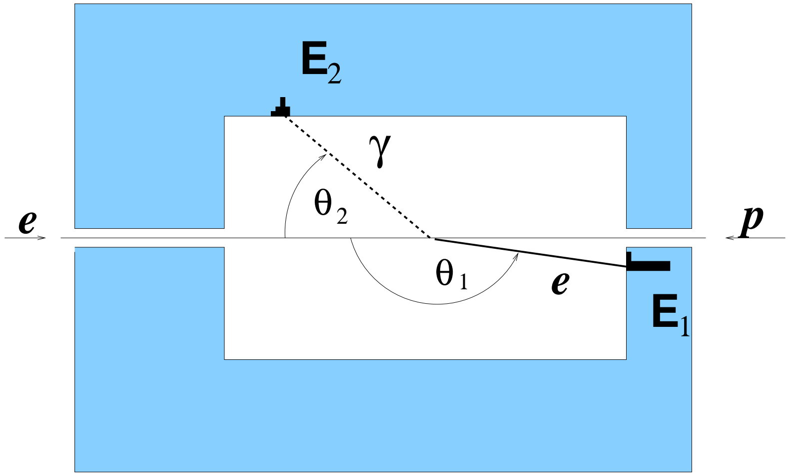


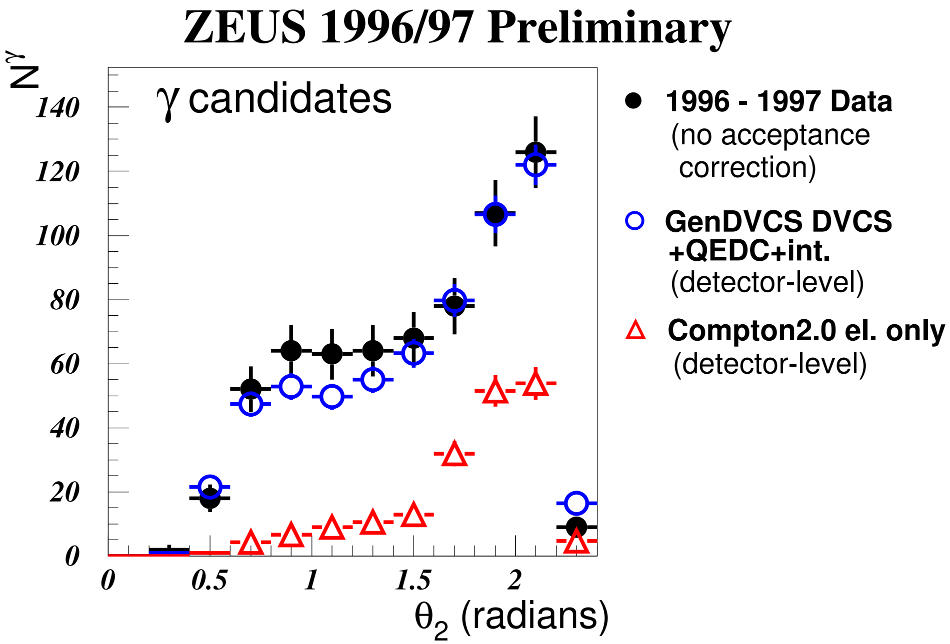
Bethe-Heitler



- LO QCD calculation by L.Frankfurt, A.Freund and M.Strikman (FFS) for DVCS and Bethe-Heitler including interference term
- Two independent MC generators for H1 and ZEUS

ZEUS – First observation of DVCS





$\theta_1 > 2.8, E_1 > 10\,\mathrm{GeV}$

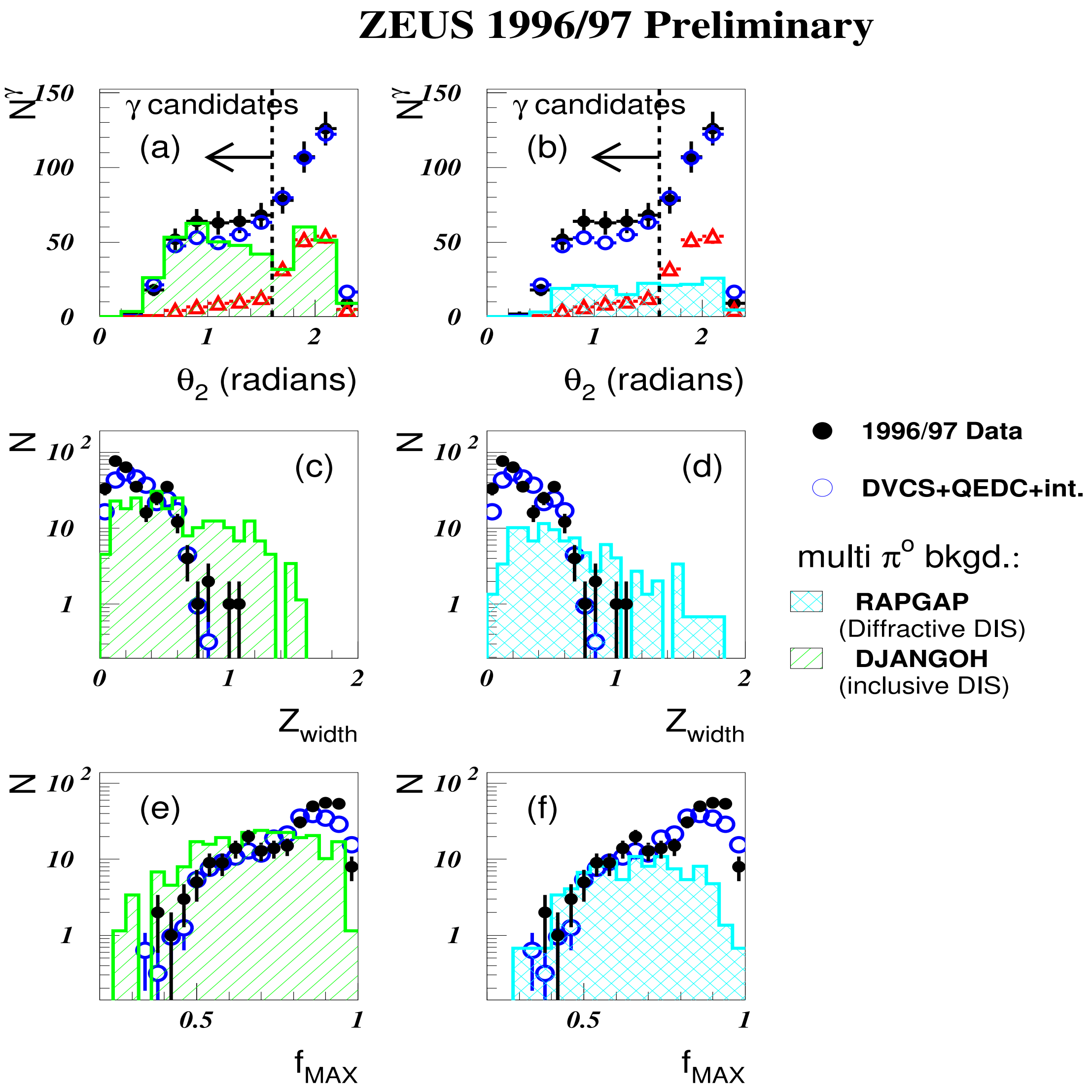
$\theta_2 < 2.4, E_2 > 2\,\mathrm{GeV}$

$|\theta_1 - \theta_2| > 0.8$

$Q^2 > 6\,\mathrm{GeV}^2$

- Shower shapes studied and found to be inconsistent with π^0 and η^0 production
- Excess of events over QEDC prediction
  $\Rightarrow$ DVCS signal
- Data agrees with DVCS+QEDC Monte Carlo

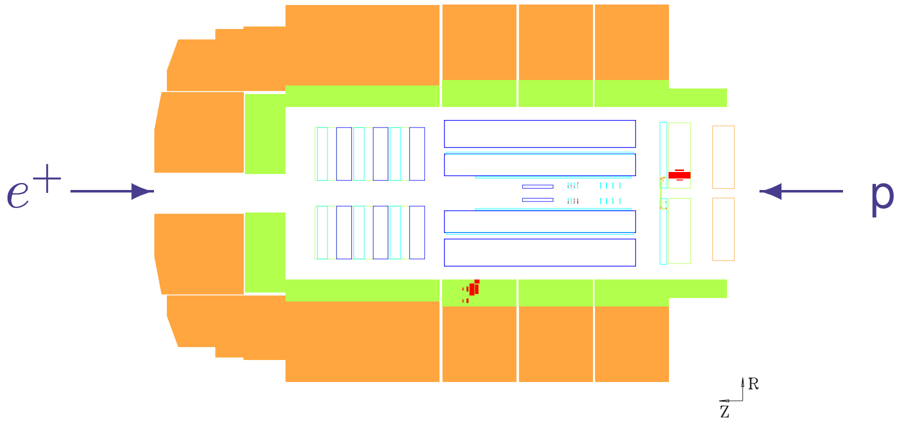
ZEUS – CHECKS ON π^0 AND η^0 BACKGROUND



- Data compared to RAPGAP and DJANGOH Monte Carlo
- Neither describes single hadrons well
- Shower shapes inconsistent with π^0 or η^0 production

DVCS: H1 ANALYSIS

DVCS



$E_{back} > 15$ GeV

$p_T > 1$ GeV in LAr cal

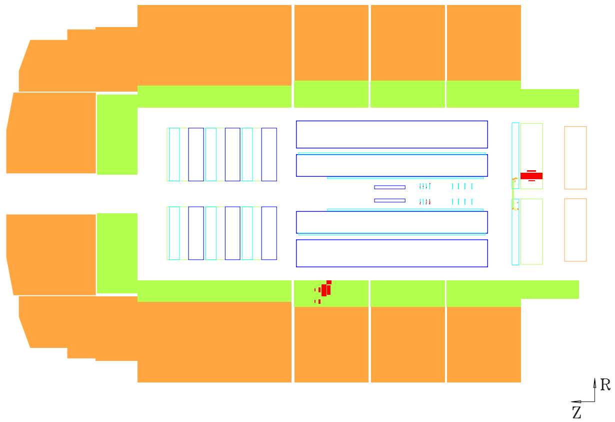
No other clusters > 0.5 GeV

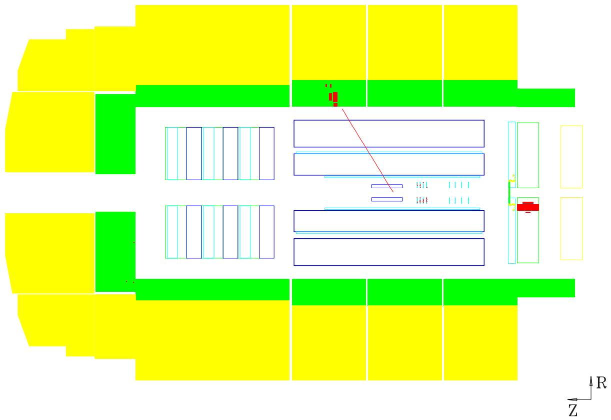
Empty forward detectors

γ-sample

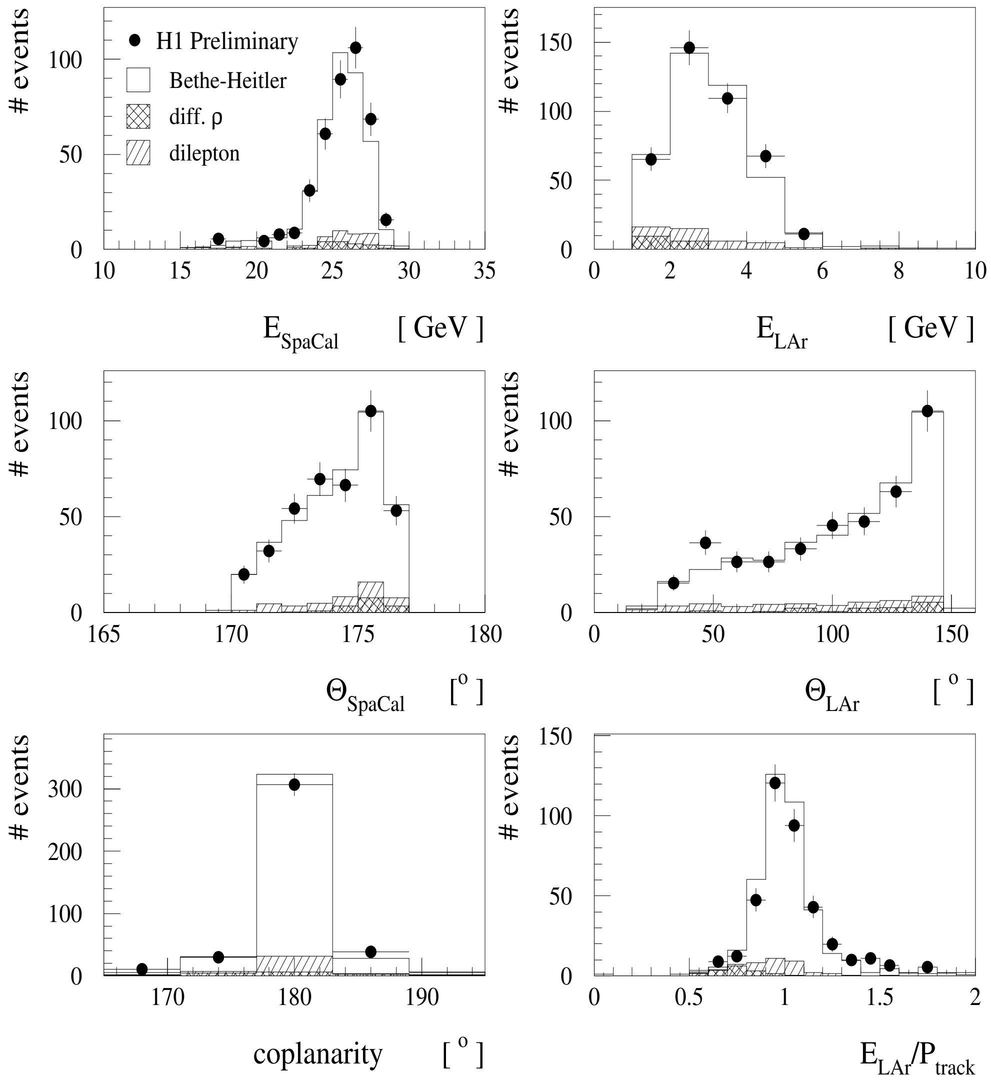
e^+-sample (control)

Bethe-Heitler





DVCS: H1 CONTROL SAMPLE



Bethe-Heitler events

- photon backwards
- e^+ track in central region

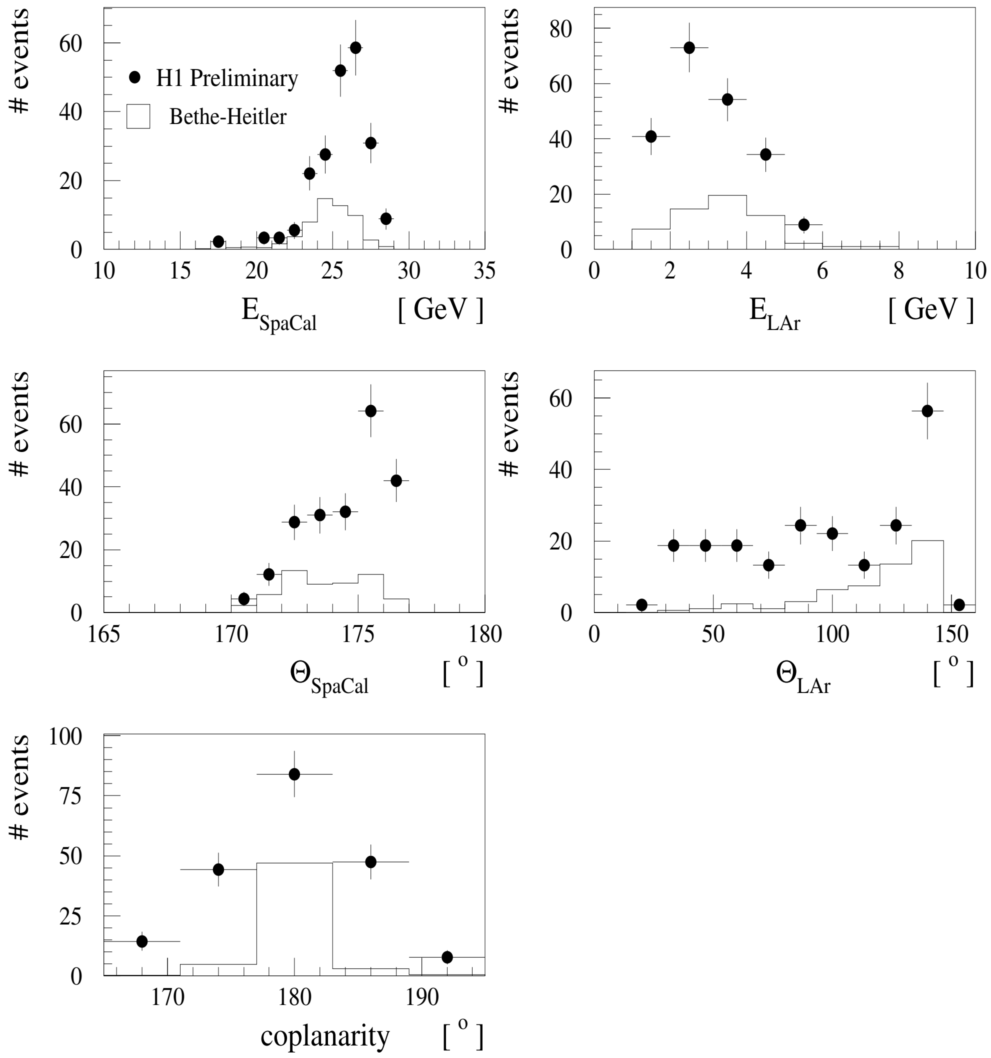
DVCS background negligible

Bethe-Heitler events well modelled by Monte Carlo

⇒ Detector well understood

⇒ Confidence to extract cross section

DVCS: H1 DVCS CANDIDATES



- $2 < Q^2 < 20\,\mathrm{GeV}^2$
- $30 < W < 120\,\mathrm{GeV}$
- $|t| < 1\,\mathrm{GeV}^2$

Large excess of events above Bethe-Heitler prediction

$\Rightarrow$ Clear DVCS signal

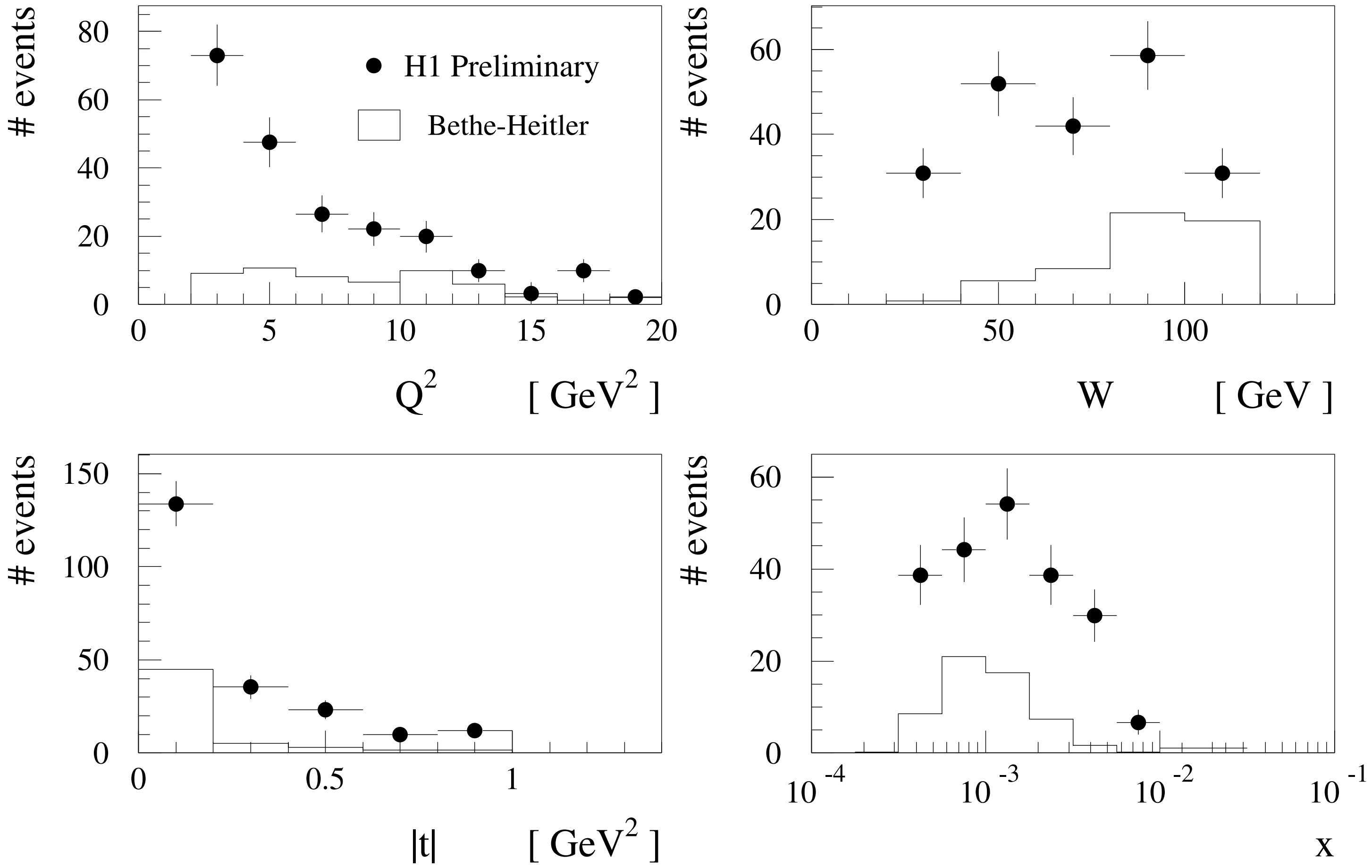
Diffractive events

$\Rightarrow$ flatter t-dependence

$\Rightarrow$ less balanced p_T

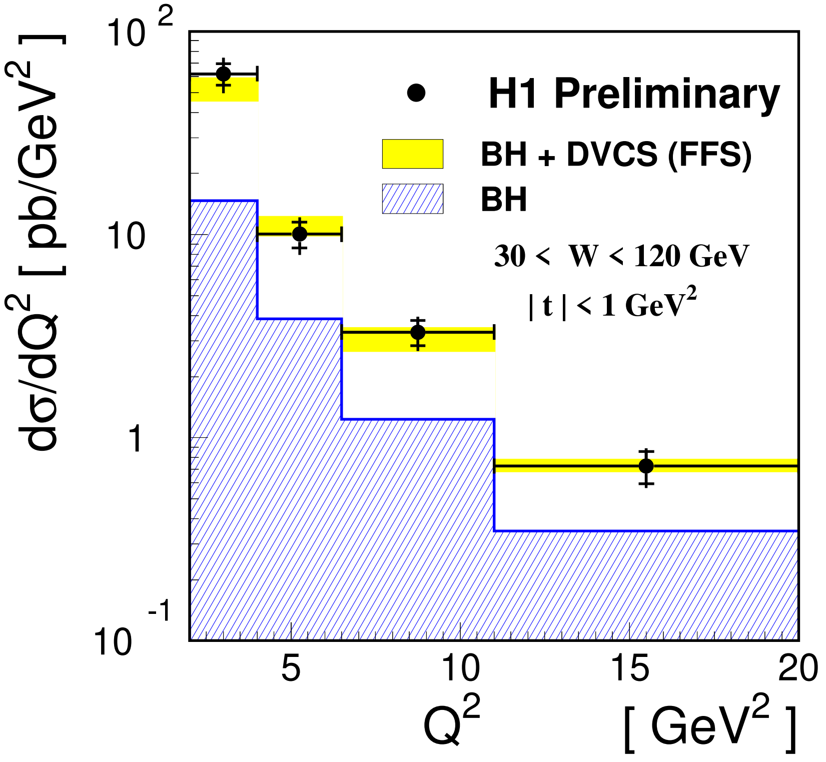
$\Rightarrow$ broader coplanarity distribution

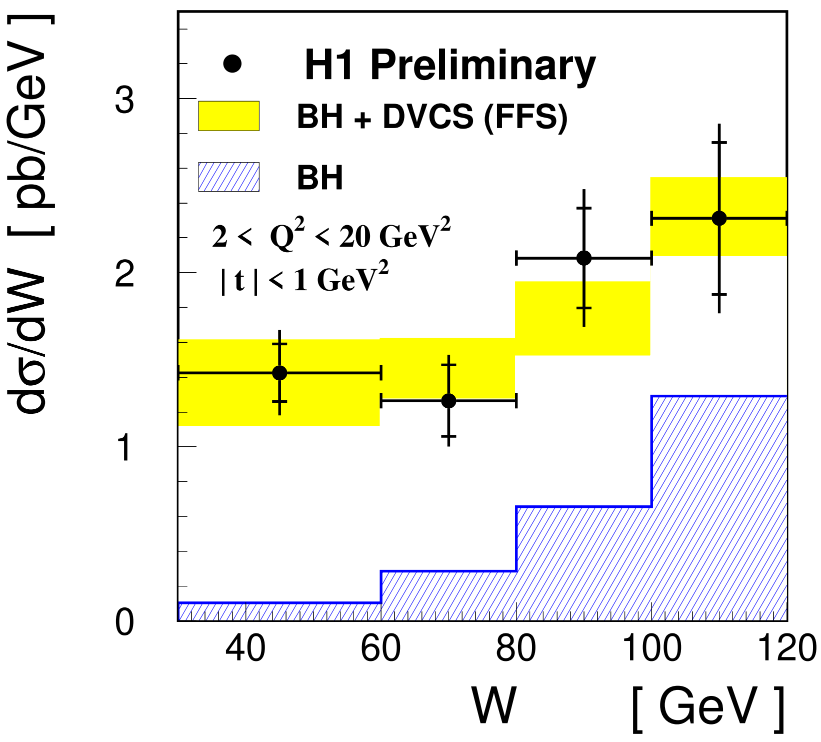
DVCS: H1 EVENT DISTRIBUTIONS



Unnormalized distributions

DVCS: H1 CROSS SECTIONS





Errors on FFS prediction due to uncertainty in t slope (7-10 GeV^{-2})

Results well described by LO QCD model

SUMMARY

Prompt Photons

- Prompt photons provide a clean way to study QCD and photon structure
- A new ZEUS determination of $\langle k_T \rangle$ for the proton at HERA gives

$$\langle k_T \rangle = 1.69 \pm 0.18^{+0.18}_{-0.20}\,\mathrm{GeV}$$

which is consistent with the rising trend as W increases

DVCS

- First signals for DVCS have been seen by H1 and ZEUS
- H1 has measured cross sections in agreement with LO QCD predictions
- Interference between DVCS and QCD Compton is still to be investigated
- Better statistics after the HERA upgrade