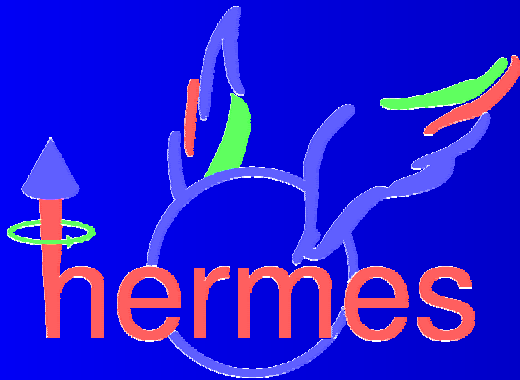# DVCS at HERA

Jochen Volmer

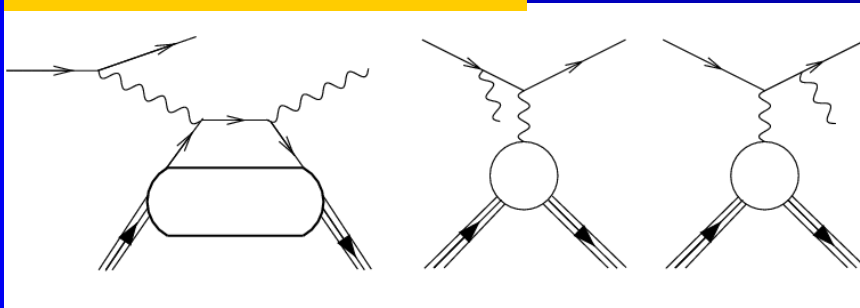DESY-Zeuthen
on behalf of H1, ZEUS
and HERMES

Outline

- Deeply Virtual Compton Scattering
- Generalized Parton Distributions
- DVCS measurements at HERA
  - cross section measurements at H1 and ZEUS
  - azimuthal asymmetries at HERMES
- Conclusion: Plans for HERA II
- Coherent DVCS on the deuteron
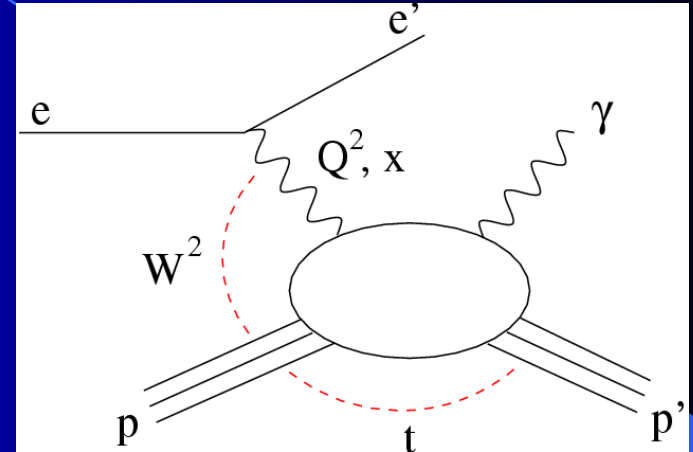
Deeply Virtual Compton Scattering
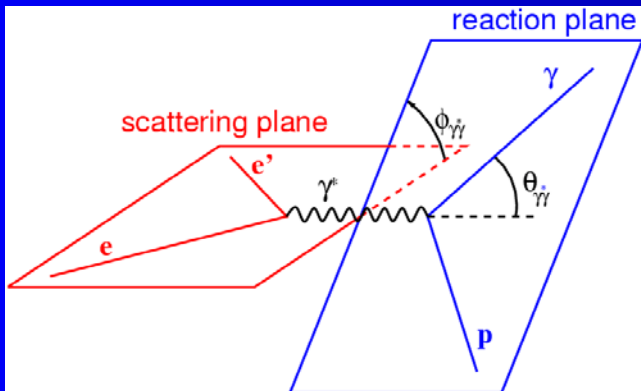
$$e + p \rightarrow e' + \gamma + p$$

kinematical variables

DVCS   Bethe-Heitler

$$d\sigma \propto |\tau_{DVCS} + \tau_{BH}|^2 = |\tau_{DVCS}|^2 + |\tau_{BH}|^2 + \left(\tau^*_{DVCS}\tau_{BH} + \tau^*_{BH}\tau_{DVCS}\right)$$
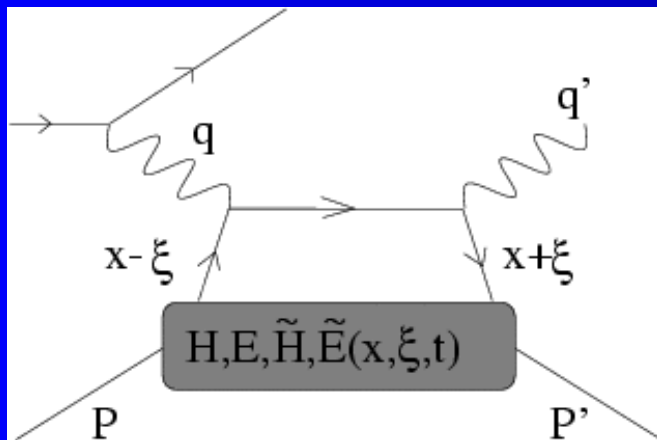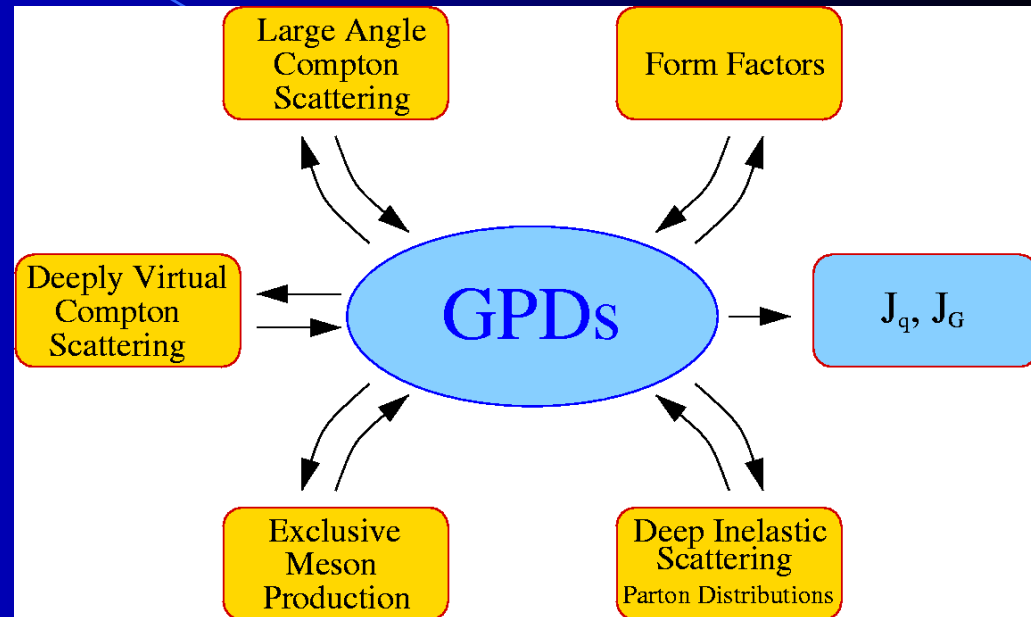

interference term $\Rightarrow$ azimuthal asymmetries:

$$d\sigma_{e^+} - d\sigma_{e^-} \propto \Re(\tau_{DVCS}\tau_{BH})\cos(\varphi_{\gamma^*\gamma})$$

$$d\sigma_{\leftarrow} - d\sigma_{\rightarrow} \propto \Im(\tau_{DVCS}\tau_{BH})\sin(\varphi_{\gamma^*\gamma})$$

Generalized Parton Distributions

In hard exclusive processes DVCS process factorizes, GPD's used to describe soft QCD dynamics

- in forward limit, GPD's coincide with PDF's
- first moments in x equal to nucleon form factors
- Ji sum rule connects GPD's with total quark spin

Examples of models used at HERA:

Frankfurt, Freund, Strikman, Phys.Rev. **D**58(1998)114001

Freund, McDermott, Phys. Rev. **D**65(2002)056012

Vanderhaeghen, Guidal, Guichon, Phys.Rev.Lett. 80(1998)5064

Measurements at H1 and ZEUS
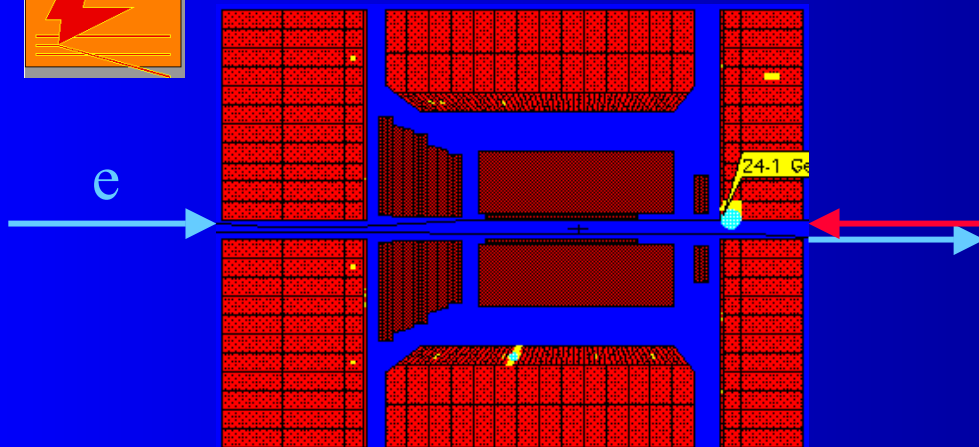
HERA

- 820-920 GeV p
- 27.6 GeV $e^{\pm}$

ZEUS

- $5 < Q^2 < 100$ GeV^2
- $40 < W < 140$ GeV
- 95 pb^{-1} $e^+ p$
- 17 pb^{-1} $e^- p$

H1

- $2 < Q^2 < 20$ GeV^2
- $30 < W < 120$ GeV
- $|t| < 1$ GeV^2
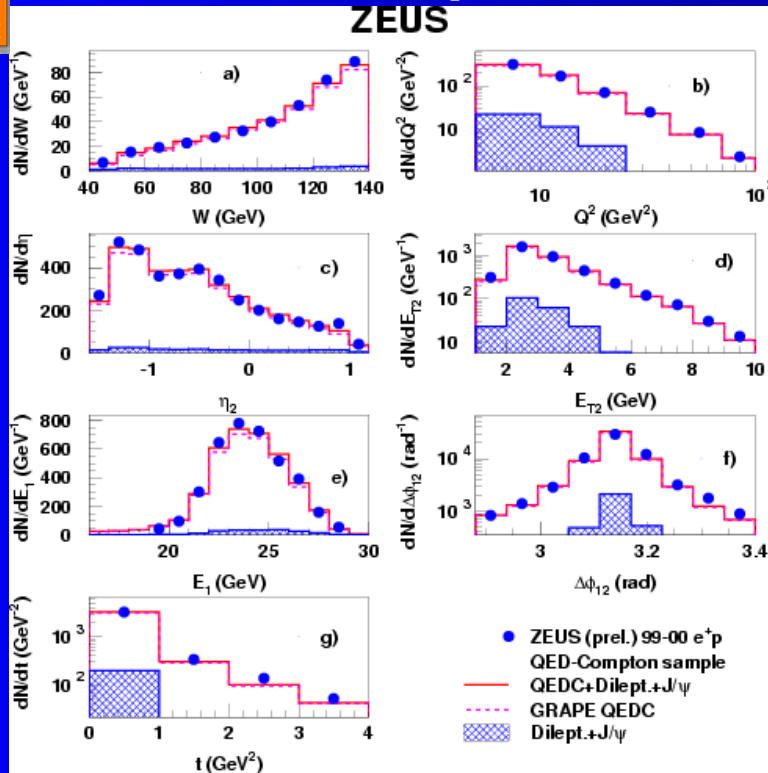- 8 pb^{-1} $e^+ p$

signal sample
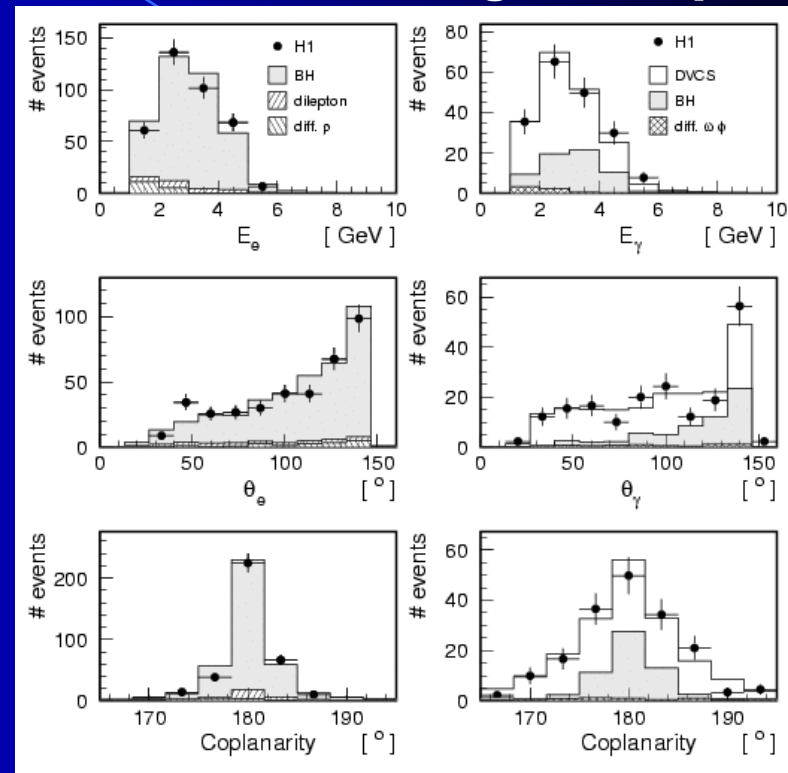
control sample

e
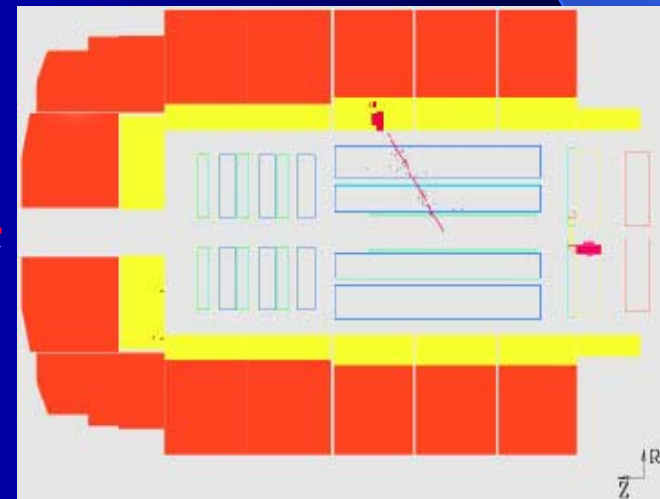
p

Data vs Monte Carlo

ZEUS control sample

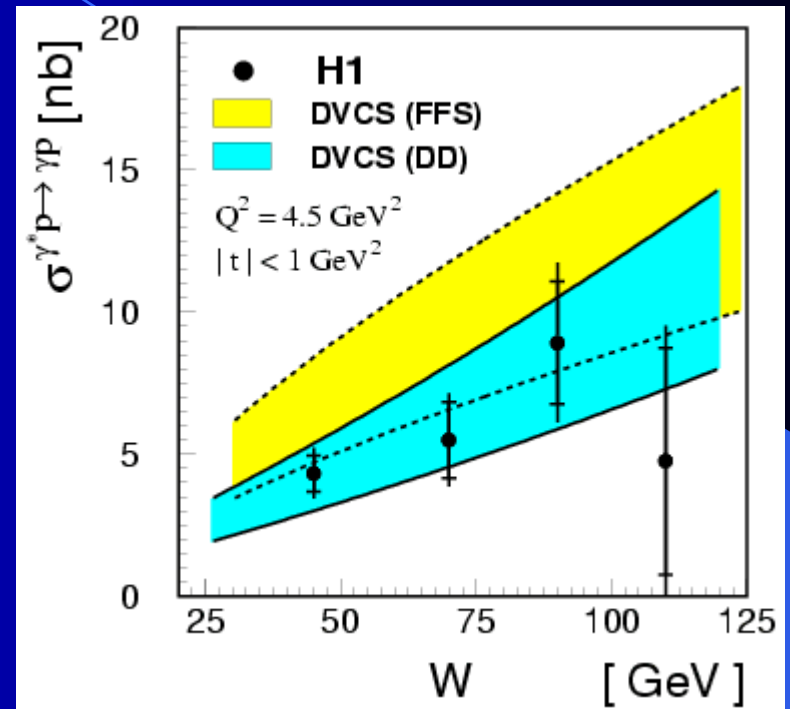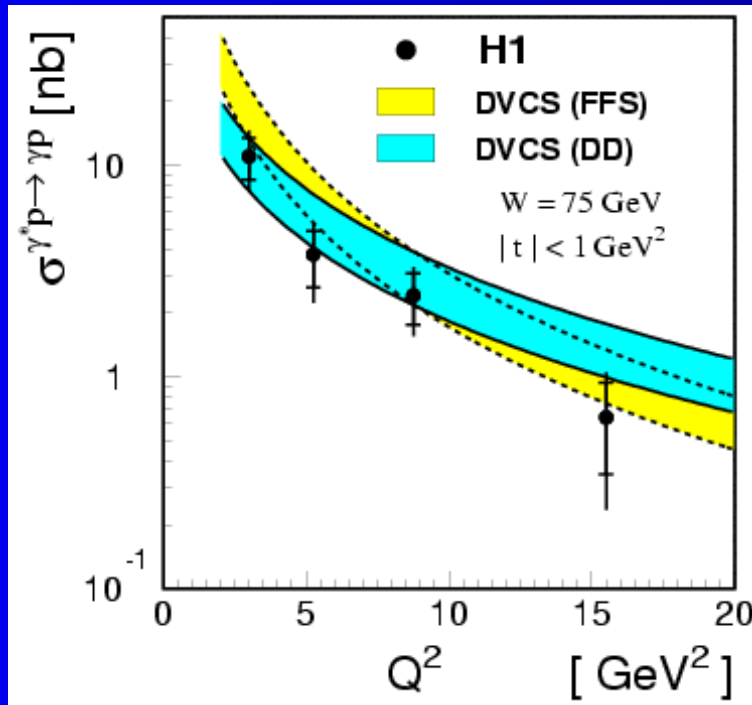**H1 control and signal samples**

- H1 and ZEUS detector responses are well understood
- QED Compton and other background contributions are under control
- clear DVCS signal has been observed

Results from H1
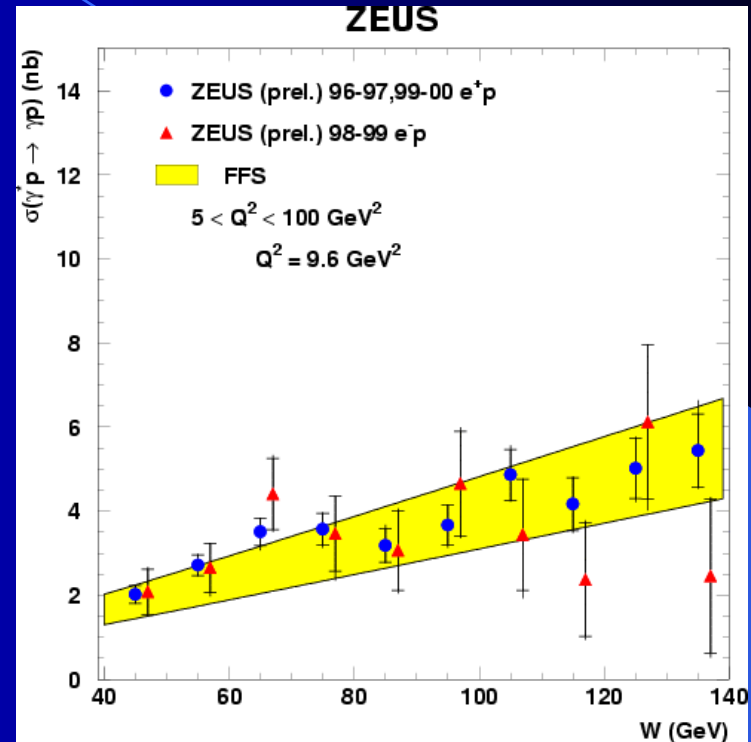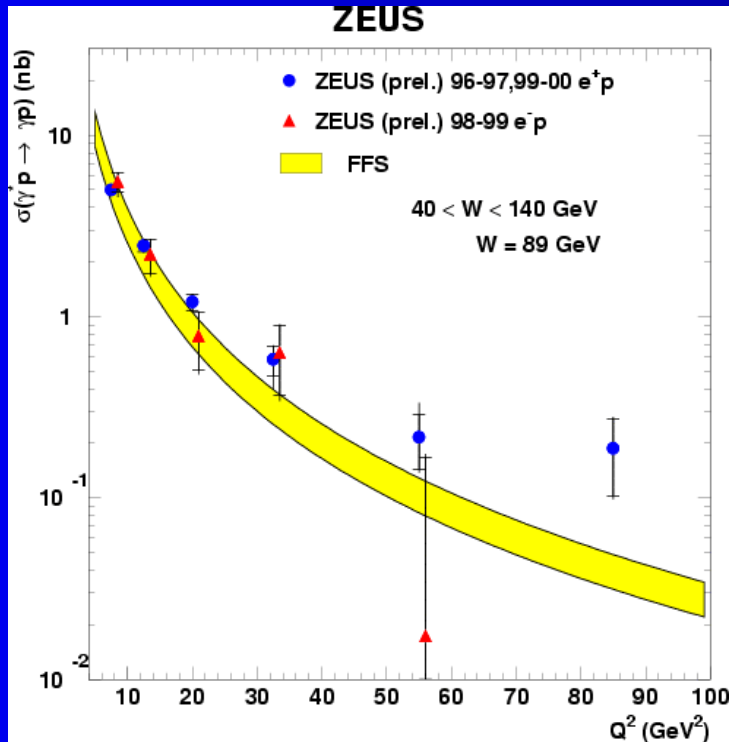
Areas limited by t-slope: b = 5-9 GeV^{-2}

Frankfurt, Freund, Strikman (FFS): GPD based model
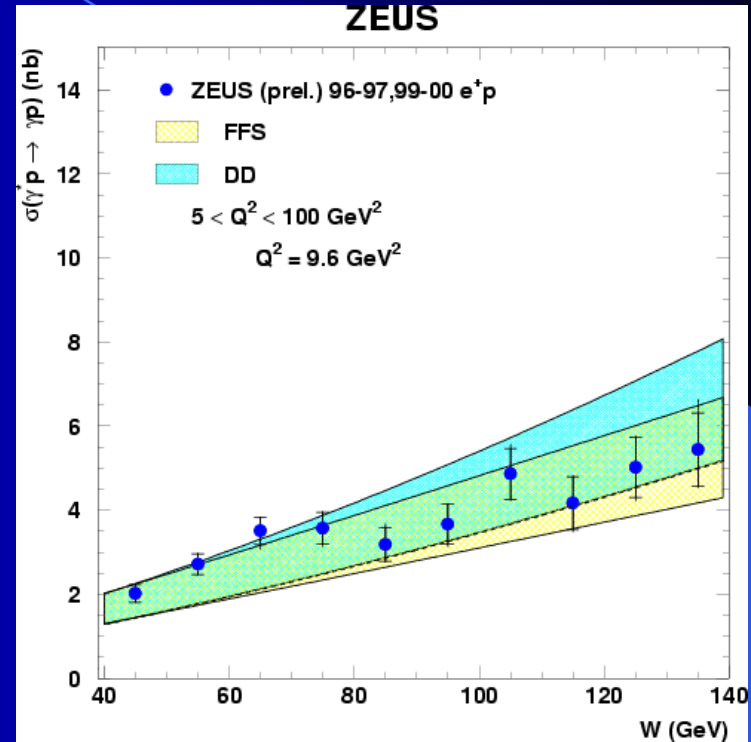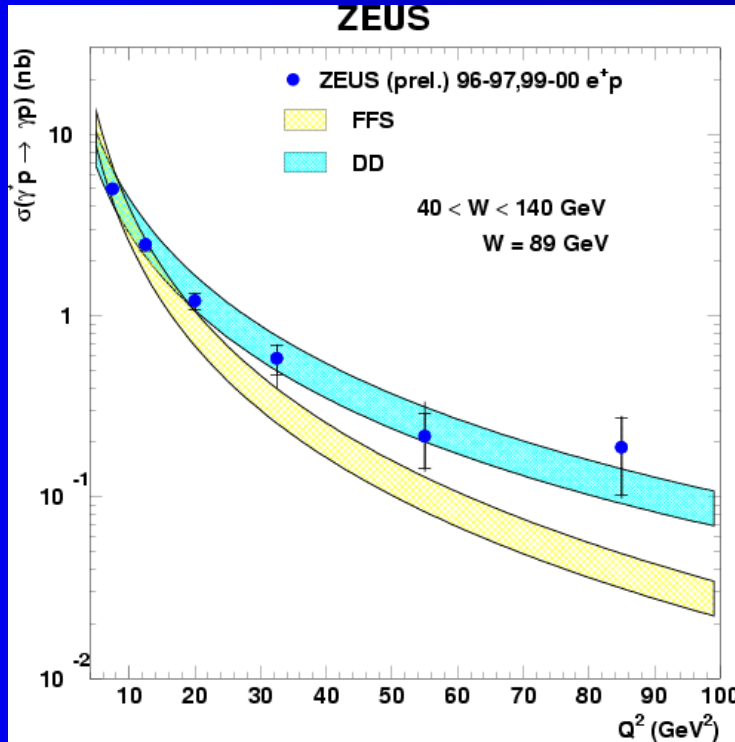Donnachie, Dosch (DD): based on Colour Dipole Model

Results from ZEUS (1)

(preliminary)

- first DVCS cross section measurement at HERA for electrons
- consistency of electron and positron data
- W slope like W^δ with $\delta = 0.78 \pm 0.10 \Rightarrow$ rise in gluon density

Results from ZEUS (2)

(preliminary)

- data favor shallower Q^2 slope of DD model
- W dependence not significantly different between FFS and DD
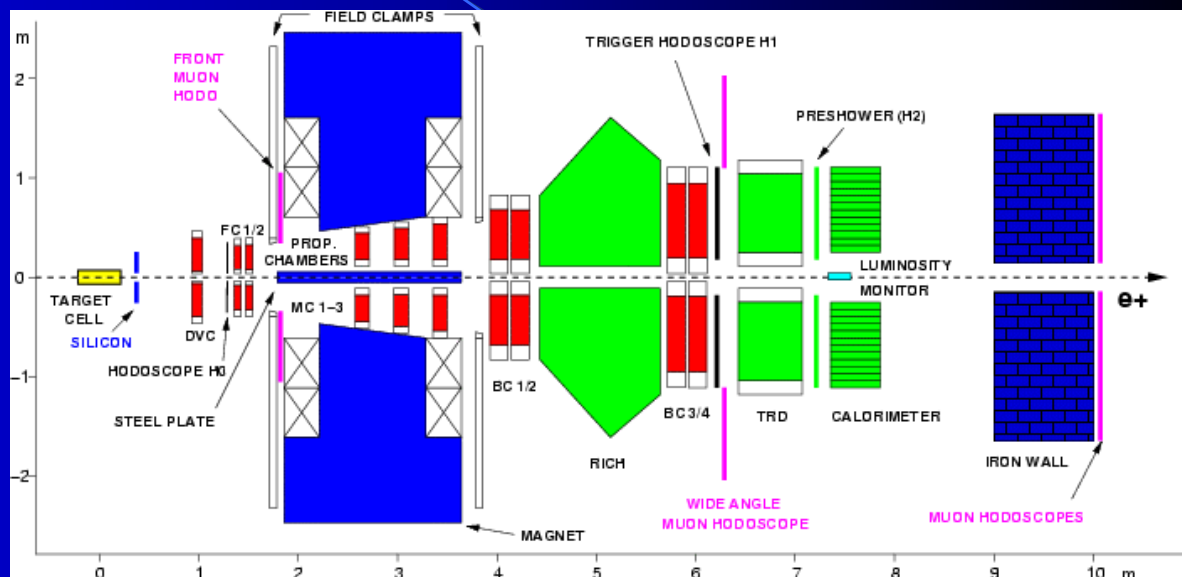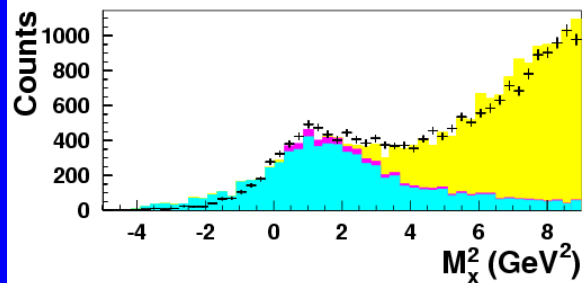
Azimuthal Asymmetries at HERMES

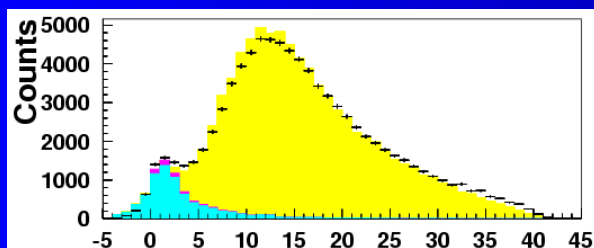$Q^2 > 1$ GeV^2

$W > 2$ GeV

$y < 0.85$

full $\varphi_{\gamma\gamma}$-coverage

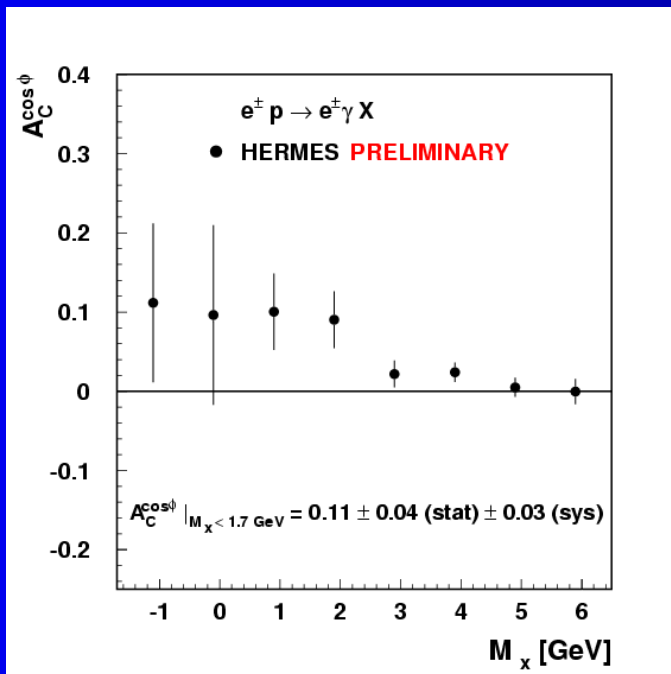up to $\vartheta_{\gamma\gamma} = 70$ mrad

- 27.6 GeV e$^\pm$ beam, avg polarization 55%
- hydrogen, deuterium target
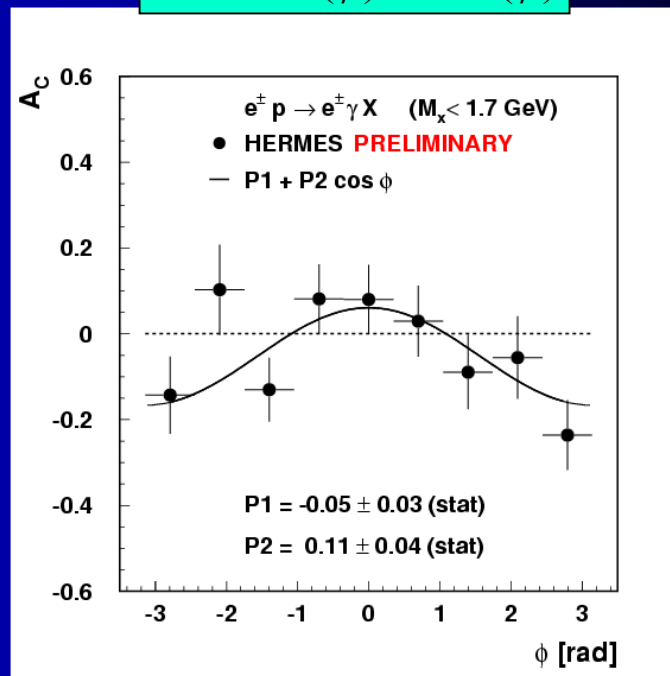- e$^+$ (e$^-$) in both (one) helicity states

Beam Charge Asymmetry

(hep-ex/0207029)

$<Q^2> = 2.6 \text{ GeV}^2$ $<x_{Bj}> = 0.11$ $<-t> = 0.27 \text{ GeV}^2$

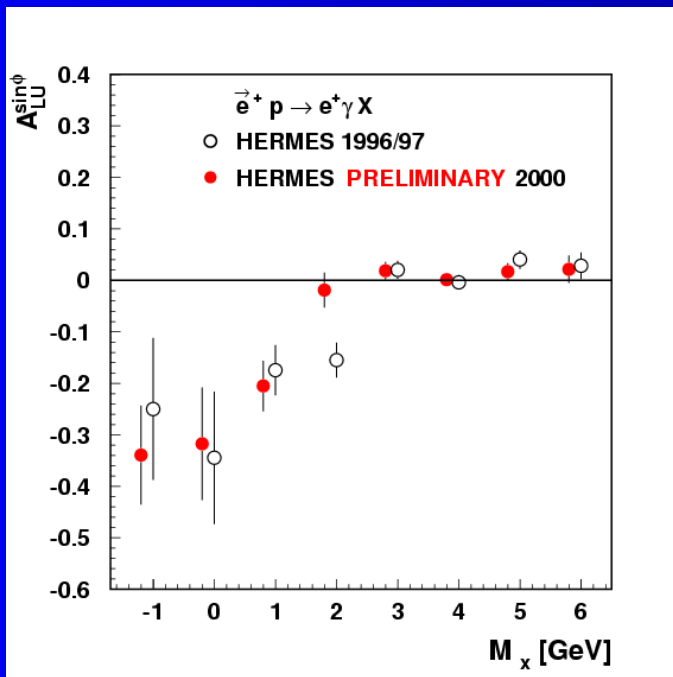$$A_C = \frac{N^{e^+}(\varphi) - N^{e^-}(\varphi)}{N^{e^+}(\varphi) + N^{e^-}(\varphi)}$$

$$A_C^{\cos\varphi} = \frac{1}{N^{e^+}}\sum_{i=1}^{N^{e^+}}\cos\varphi_i - \frac{1}{N^{e^-}}\sum_{i=1}^{N^{e^-}}\cos\varphi_i$$

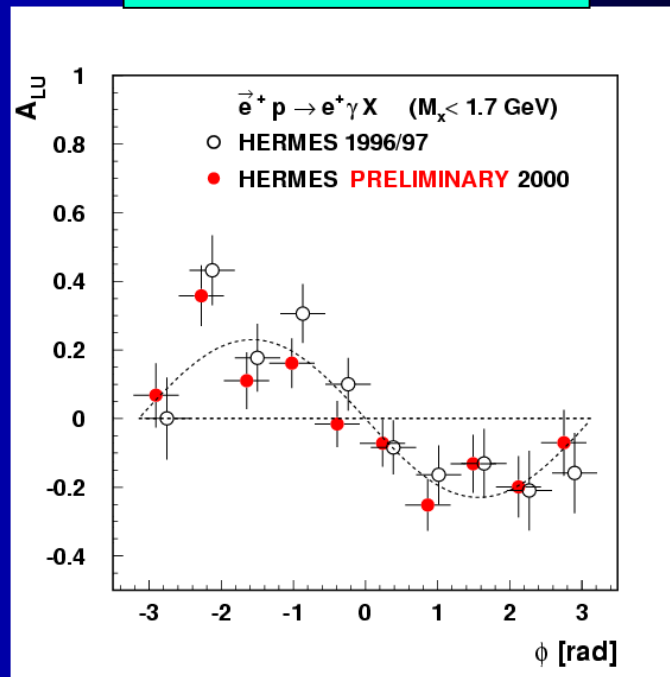$$A_C = 0.11 \pm 0.04(stat) \pm 0.03(syst)$$ in exclusive region

Beam Helicity Asymmetry

(Phys.Rev.Lett. 87(2001)182001)

$$<Q^2> = 2.6 \text{ GeV}^2 \quad <x_{Bj}> = 0.11 \quad <-t> = 0.27 \text{ GeV}^2$$

$$A_{LU} = \frac{1}{\langle P_l \rangle} \frac{N^+(\varphi) - N^-(\varphi)}{N^+(\varphi) + N^-(\varphi)}$$

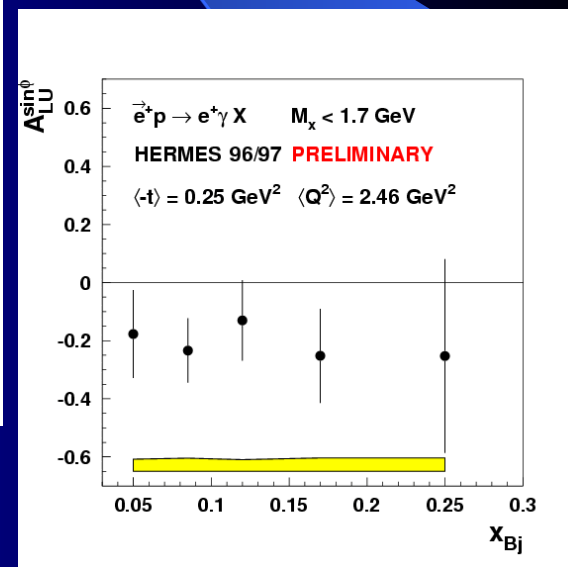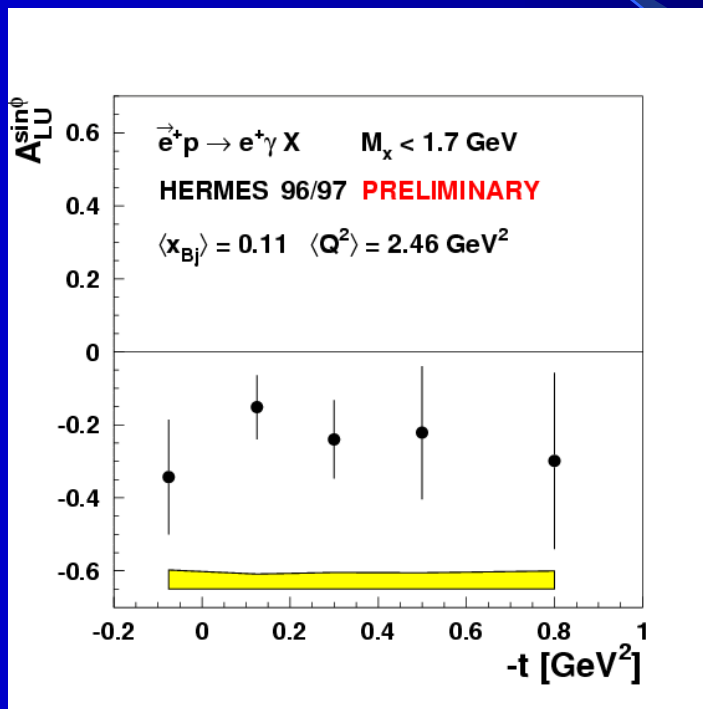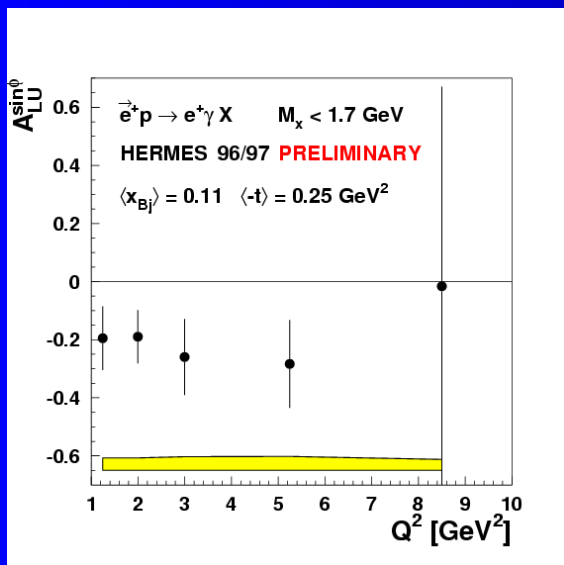$$A_{LU}^{\sin\varphi} = \frac{2}{N} \sum_{i=1}^{N} \frac{\sin\varphi_i}{(P_l)_i}$$

$$A_{LU} = -0.23 \pm 0.04\,(stat) \pm 0.03\,(syst) \quad \text{in exclusive region}$$

Kinematic Dependences

(preliminary)

No strong dependences of A_{LU} on Q^2, t or x_{Bj} are observed

GPD based models (e.g., Vanderhaeghen et al.) predict weak t-dependence of A_{LU}

Future Prospects: DVCS at HERA II

- **HERA**
  - spin rotators around H1 and ZEUS
- **H1**
  - VFPS in 2003 $\Rightarrow$ measurement of t at small W
  - BST $\Rightarrow$ precise measurement of ϑ_e, φ_e, z_{vrtx}, φ_γ
  - measurement of azimuthal asymmetries
- **ZEUS**
  - microvertex detector $\Rightarrow$ measurement of ϑ_e, φ_e, z_{vrtx}, φ_γ
  - polarization/charge differences
- **HERMES**
  - large acceptance recoil detector in 2004
    - Improved exclusivity
   - Improved t-resolution

Coherent DVCS on the deuteron

F. Cano and B. Pire *(Phys.Rev.Lett. 87(2001)142302, hep-ph/0206215)*

- GPD based model for DVCS on the deuteron
- IA: convolution of photon-nucleon interaction and deuteron wave function
- diagram is suppressed above $x_{Bj} = 0.2$
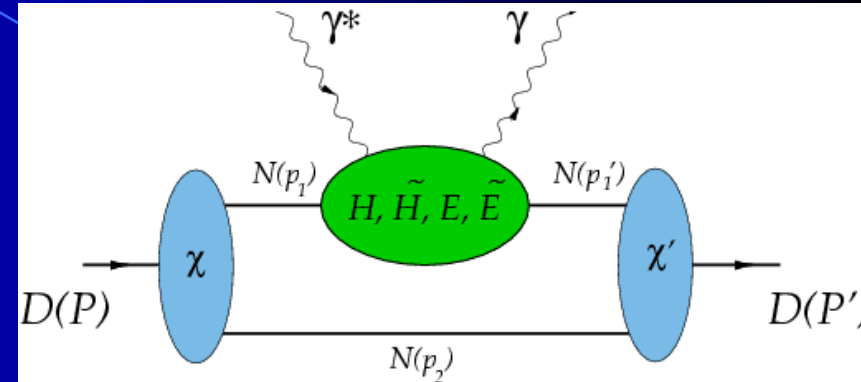
Predictions

Cano/Pire model includes
- helicity conserv. GPDs
- Paris potential for deuteron w.f.
- elastic deuteron form factors for BH
- predictions so far for HERMES and Jlab kinematics
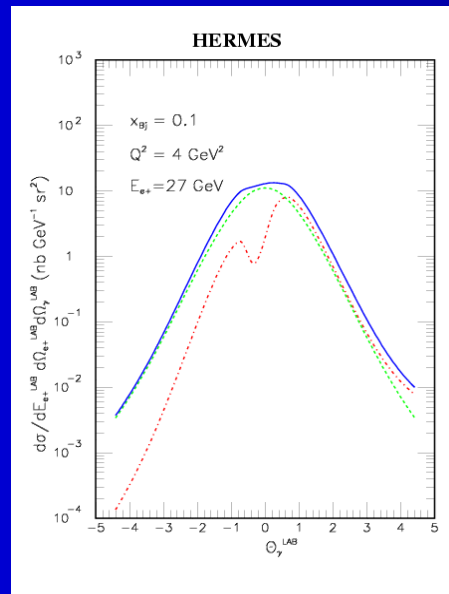
Beam helicity asymmetry

- sign and magnitude as in proton case
- strong $\sin 2\varphi$ component
- HERMES and JLab working on deuteron data