Generalized Parton Distributions – Experimental Status & Future Facilities

Wolf-Dieter Nowak

DESY, 15738 Zeuthen, Germany

I3HP Topical Workshop on Hadron Physics
St. Andrews, 30 August - 1 September 2004

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Physics Motivation II

Generalized Parton Distributions:

Unified theoretical description of inclusive and (hard) exclusive processes

H^q, $\tilde{H}^q$: reduce to ordinary PDFs for $t \rightarrow 0$
E^q, $\tilde{E}^q$: do not exist in DIS

t: momentum transfer at nucleon vertex

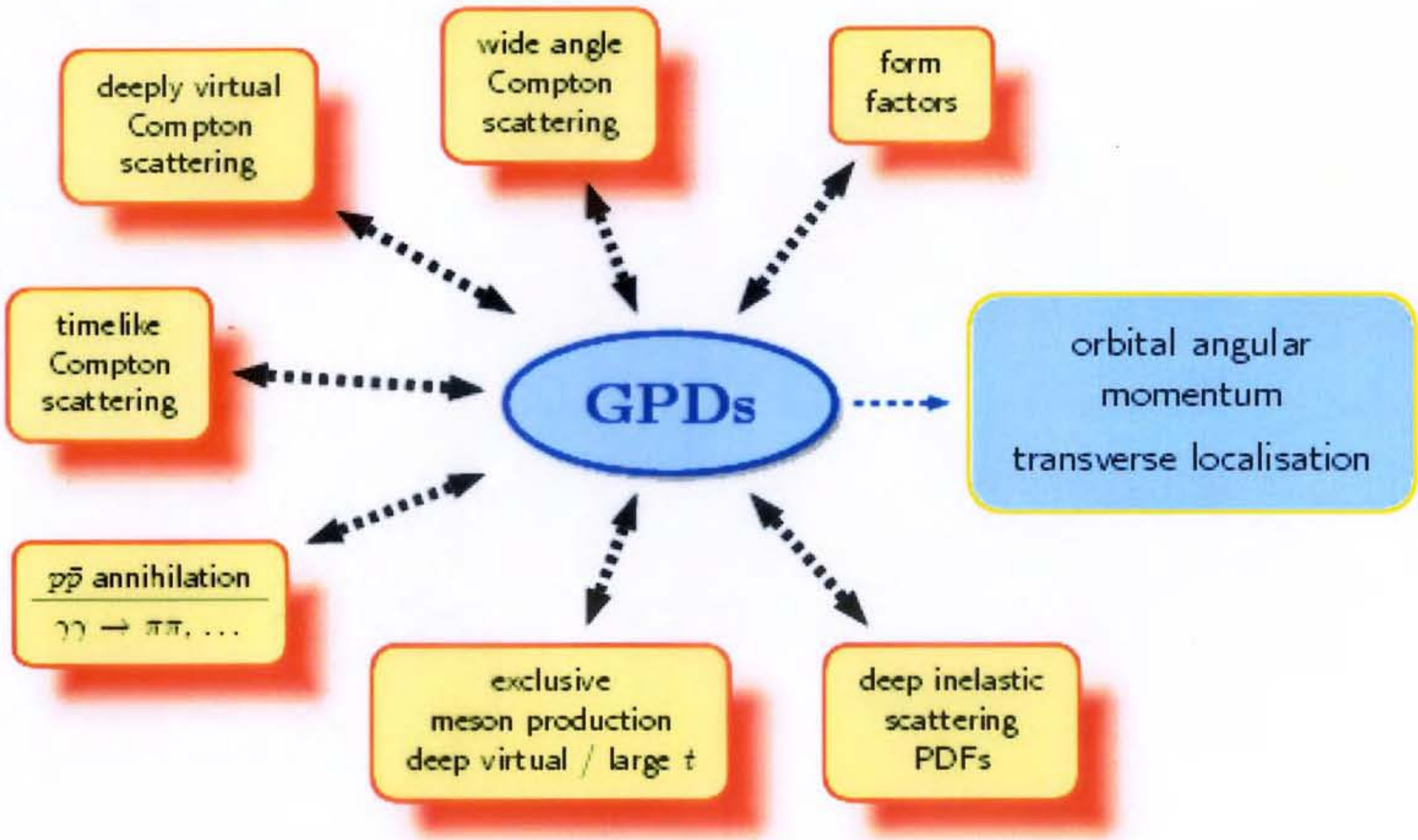
Access to Generalized Parton Distributions

Exclusive processes bear qualitatively new information on structure of the nucleon

- Dependence of GPDs on momentum transfer t allows conclusions on parton distribution(s) transverse to nucleon's direction of motion $\Rightarrow$ 3-dimensional picture of the nucleon

- 2nd moment of 'unpolarized' GPDs H^q and E^q allows, in limit of vanishing t, determination of total angular momentum, carried by quarks q

Generalized Parton Distributions (GPDs)



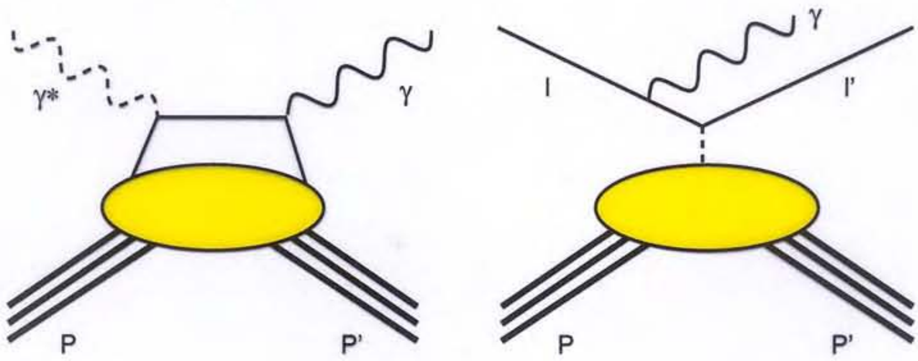
GPDs and DVCS

Simplest hard exclusive process: $ep \to ep\gamma$
$(\gamma^* p \to \gamma p)$

Consider $\gamma^* p$ in Bjorken limit $\Longrightarrow$
Deeply Virtual Compton Scattering

- Highly virtual quark in γ^* scattering
  $\longrightarrow$ propagates perturbatively
- Simplest (and dominating) QCD mechanism to form Compton final state: quark radiates real γ and falls back to nucleon ground state
  ('hand-bag' subprocess in pQCD)

$\Downarrow$



DVCS   Bethe-Heitler

$$d\sigma \sim |\tau_{BH} + \tau_{DVCS}|^2 = |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \mathcal{I}$$

$$\mathcal{I} = \tau_{BH}^* \tau_{DVCS} + \tau_{BH} \tau_{DVCS}^*$$

- DVCS dominated by BH in most of kin. region
- Interference term: access to DVCS amplitudes

$\Rightarrow$ Use BH as an 'amplifier' to study DVCS

GPDs and DVCS (II)

- Generalized Parton Distributions: generalization of usual Parton Distributions and nucleon form factors
- Usual parton distributions (PDs): probability to find a parton in the nucleon with momentum fraction x
- GPDs: interference of 2 wave functions: parton with $x + \xi$ emitted from nucleon, parton with $x - \xi$ falls back (GPDs sensitive to momentum correlations)

Variables:

- Parton long. momentum fractions x and ξ
- $\gamma^* \rightarrow \gamma$ mom. transfer $\Delta^2 = (p_{\gamma^*} - p_\gamma)$ (or t)

In DVCS: 4 (chirally-even) quark GPDs (per flavor)

$H^q(x, \xi, \Delta^2)$, $\widetilde{H}^q(x, \xi, \Delta^2)$ Nucleon-hel. conserving

$E^q(x, \xi, \Delta^2)$, $\widetilde{E}^q(x, \xi, \Delta^2)$ Nucleon-hel. non-cons.

$\Downarrow$ $\Downarrow$

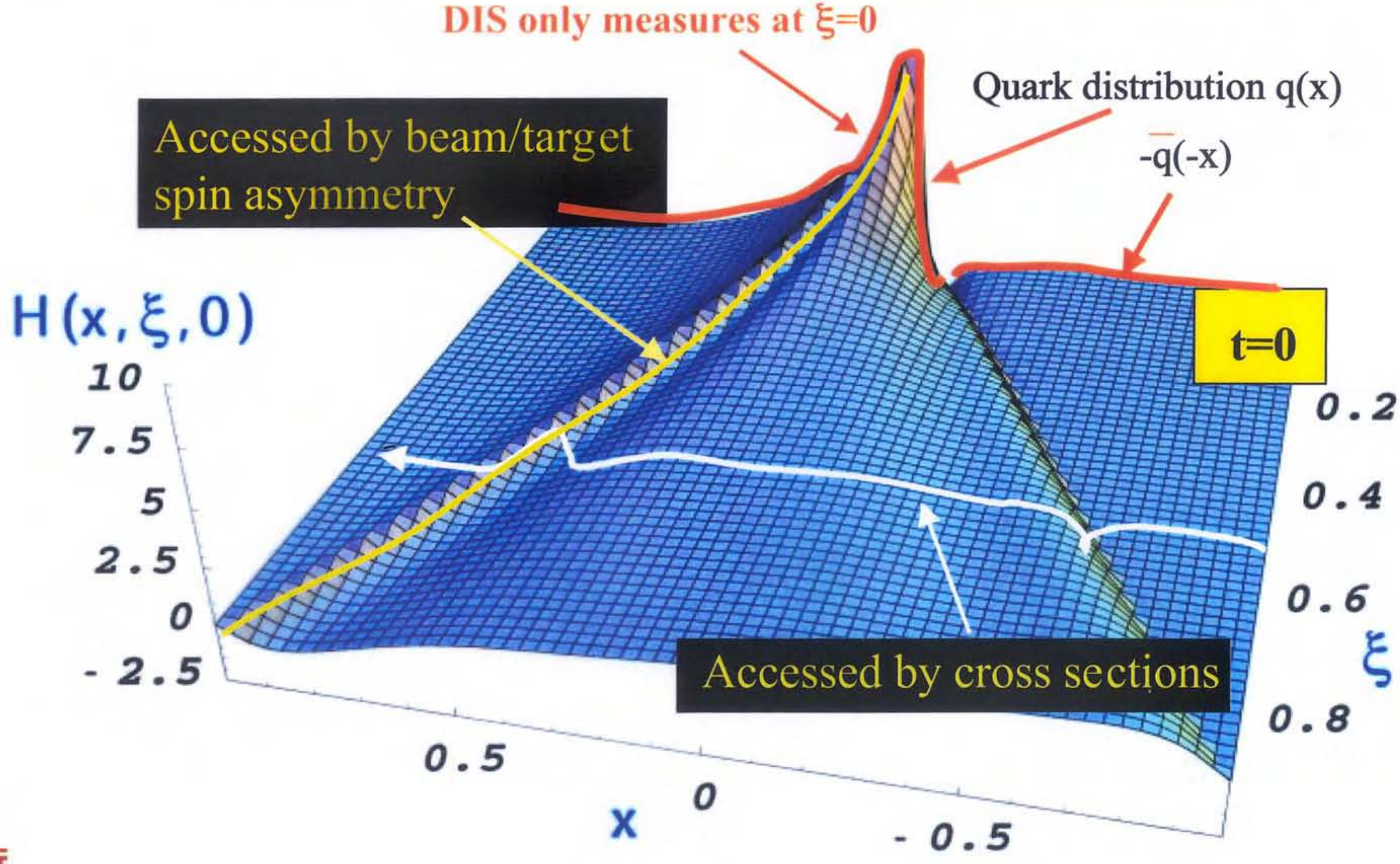
'unpolarized' 'polarized' GPDs

In the limit $\Delta^2 = 0$ (i.e. $\xi = 0$):

$$H^q(x, 0, 0) = q(x), \quad \widetilde{H}^q(x, 0, 0) = \Delta q(x)$$

$q(x)$ and $\Delta q(x)$: quark distr. and quark helicity distr.
(no 'usual' PD equivalents for E^q and $\widetilde{E}^q$)

Modeling Generalized Parton Distributions



GPDs and DVCS (III)

1st MOMENTS connected via sum rules to form factors.

2nd MOMENT of unpolarized GPDs in limit $\Delta^2 = 0$:

$\Longrightarrow$ total quark angular momentum [X.Ji]:

$$J_q = \frac{1}{2}\int_{-1}^{+1} dx\, x \left[H^q(x,\xi,\Delta^2=0) + E^q(x,\xi,\Delta^2=0)\right]$$

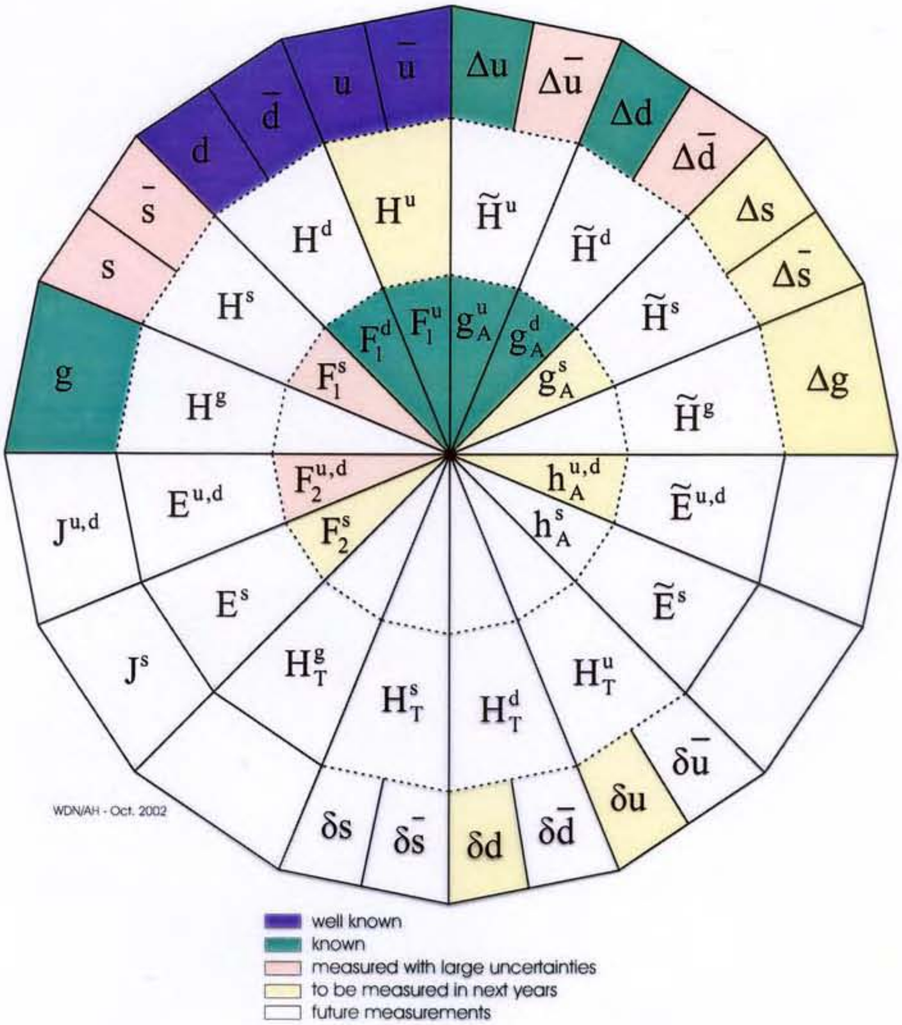
Real and imaginary parts of DVCS amplitudes $\mathcal{H}_1, \widetilde{\mathcal{H}}_1, \mathcal{E}_1, \widetilde{\mathcal{E}}_1$ can be expressed through GPDs $H, \widetilde{H}, E, \widetilde{E}$. ($P$ denotes Cauchy's principal value):

$$\begin{aligned}
\mathrm{Im}\,\mathcal{H}_1 &= -\pi \sum_q e_q^2 (H(\xi,\xi,\Delta^2) - H(-\xi,\xi,\Delta^2)) \\
\mathrm{Im}\,\widetilde{\mathcal{H}}_1 &= -\pi \sum_q e_q^2 (\widetilde{H}(\xi,\xi,\Delta^2) + \widetilde{H}(-\xi,\xi,\Delta^2)) \\
\mathrm{Re}\,\mathcal{H}_1 &= \sum_q e_q^2 \Big[P\int_{-1}^{+1} H(x,\xi,\Delta^2)\Big(\frac{1}{x-\xi}+\frac{1}{x+\xi}\Big)dx\Big] \\
\mathrm{Re}\,\widetilde{\mathcal{H}}_1 &= \sum_q e_q^2 \Big[P\int_{-1}^{+1} \widetilde{H}(x,\xi,\Delta^2)\Big(\frac{1}{x-\xi}-\frac{1}{x+\xi}\Big)dx\Big]
\end{aligned}$$

Analogous expressions for amplitudes $\mathcal{E}_1$, $\widetilde{\mathcal{E}}_1$.

$\Longrightarrow$ Extraction of GPDs will be a complex task

Exp. Status on Parton Distr.'s



(cf. W.-D. N., hep-ex/0210409)

Generalized Parton Distributions:

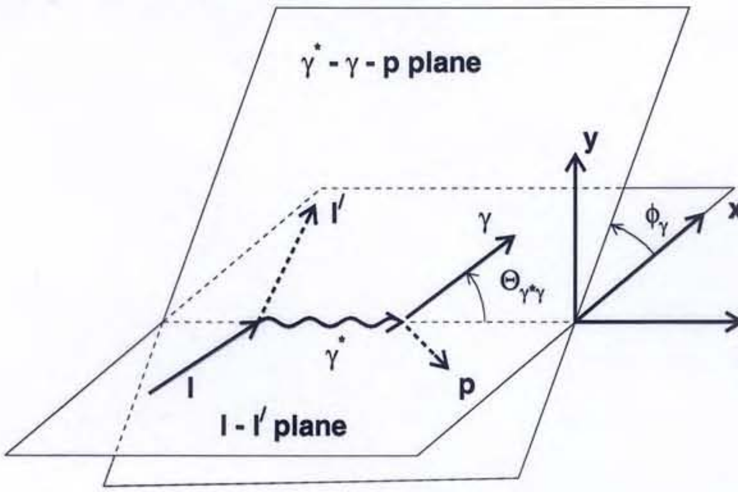
$H^q, \tilde{H}^q, E^q, \tilde{E}^q$ CHIRALLY-EVEN QUARK GPDs
$H_T^q, \tilde{H}_T^q, E_T^q, \tilde{E}_T^q$ CHIRALLY-ODD QUARK GPDs

Forward Parton Distributions:

$q(x, Q^2)$ QUARK NUMBER DENSITY DISTRIBUTION (f_1^q)
$\Delta q(x, Q^2)$ QUARK HELICITY DISTRIBUTION (g_1^q)
$\delta q(x, Q^2)$ QUARK TRANSVERSITY DISTRIBUTION (h_1^q)

ϕ-DEPENDENCE OF ASYMMETRIES

DVCS KINEMATICAL CONFIGURATION:



ϕ_γ: azimuthal angle between scattering and reaction plane.

ϕ_γ: ASYMMETRIES SHOW DIFFERENT CHARACTERISTICS

A) MEASURE LEPTON CHARGE ASYMMETRY:

unpolarized beam, unpolarized target

$$A_{ch} \sim d\sigma(e^+p) - d\sigma(e^-p) \sim \cos(\phi_\gamma) \times \mathrm{Re}\mathcal{I}$$

$\Rightarrow$ access to real part of (certain combination of) GPD amplitudes

B) Measure lepton helicity asymmetry:

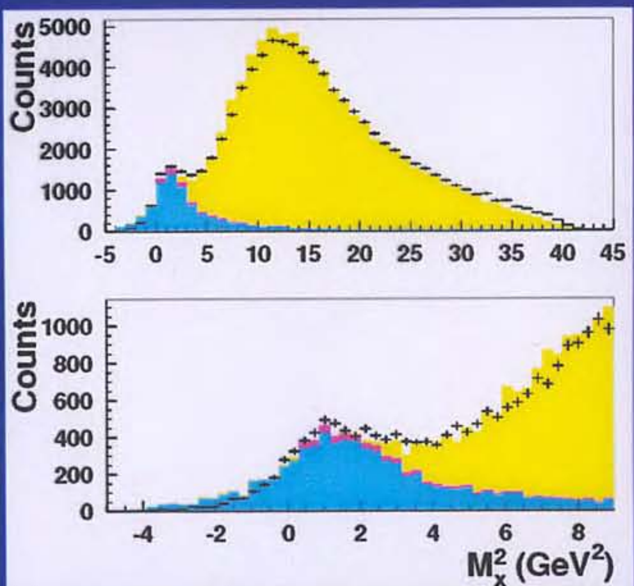
long. polarized beam, unpolarized target

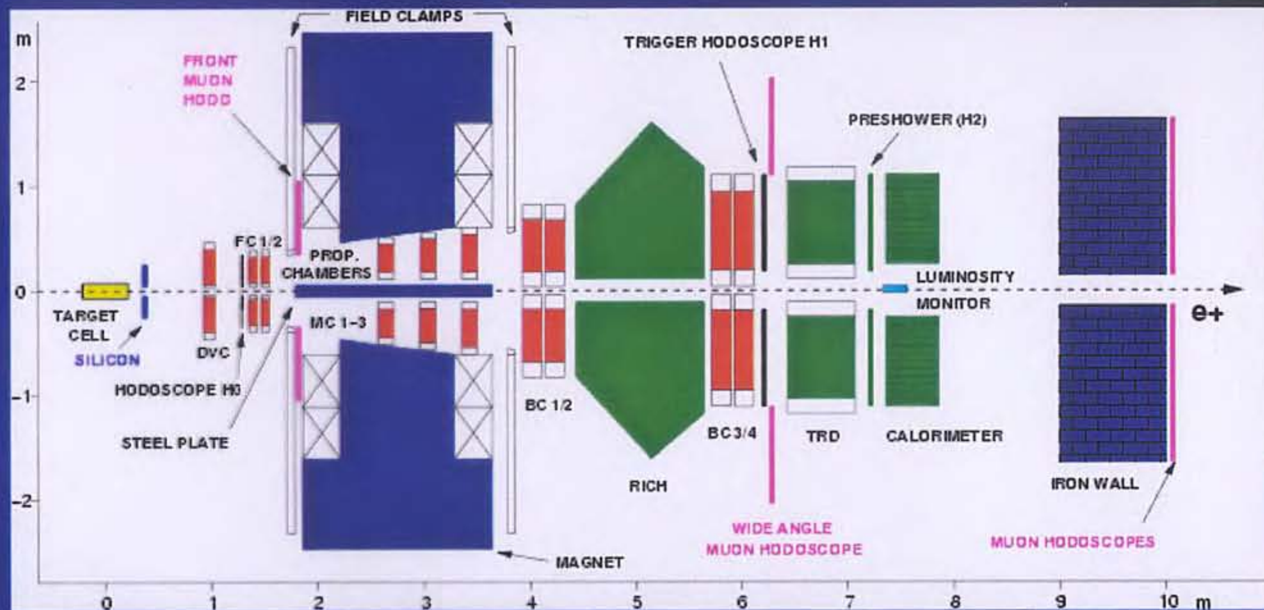
$$A_{LU} \sim d\sigma(\overrightarrow{e^+}p) - d\sigma(\overleftarrow{e^+}p) \sim \sin(\phi_\gamma) \times \mathrm{Im}\mathcal{I}$$

$\Rightarrow$ access to imaginary part of (certain combination of) GPD amplitudes

Azimuthal Asymmetries at HERMES

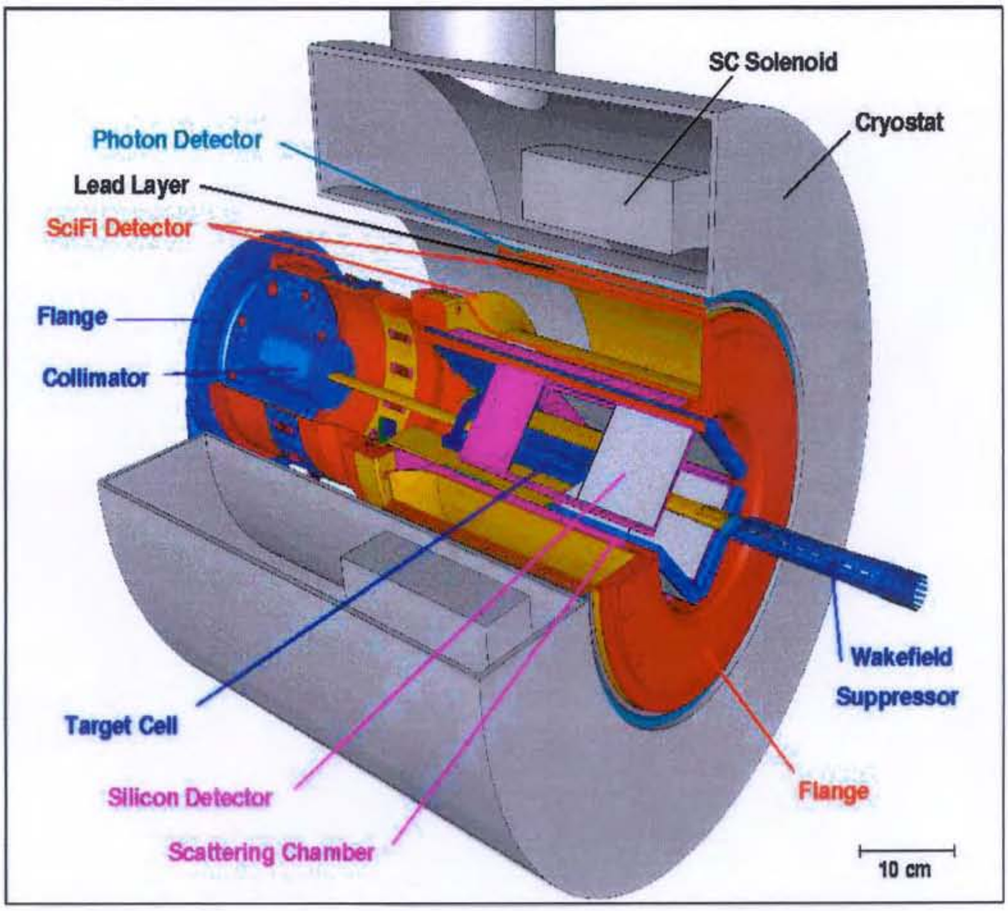
$Q^2 > 1$ GeV^2
$W > 2$ GeV
$y < 0.85$
full $\varphi_{\gamma\gamma}$-coverage
up to $\vartheta_{\gamma\gamma} = 70$ mrad



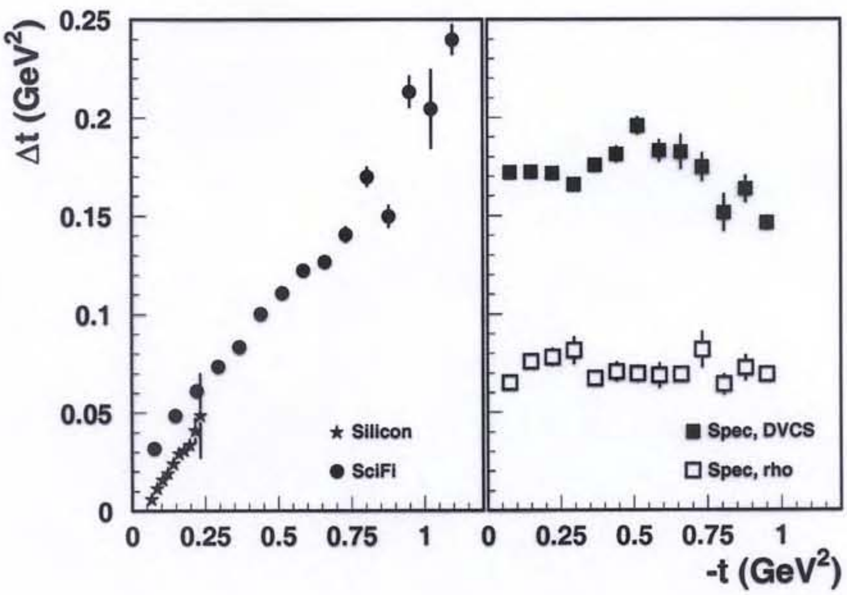


- 27.6 GeV $e^{\pm}$ beam, avg polarization 55%
- hydrogen, deuterium target
- e^+ (e^-) in both (one) helicity states

A new Recoil Detector for Hard Exclusive Reactions



Considerable improvement in t resolution:



2005+

DVCS PROJECTIONS FOR RUNNING WITH HERMES RECOIL DETECTOR

▷ GPDS MODELED ACCORDING TO
[M.VANDERHAEGHEN, P.GUICHON, M.GUIDAL, PRD 60 (99) 094017]
MOST SIMPLE ANSATZ IS TO NEGLECT ξ DEPENDENCE.
THEN E.G.

$$\begin{aligned} H^{u/p}(x,\xi,\Delta^2) &= u(x)\,F_1^{u/p}(\Delta^2)/2 \\ H^{d/p}(x,\xi,\Delta^2) &= d(x)\,F_1^{d/p}(\Delta^2) \\ H^{s/p}(x,\xi,\Delta^2) &= 0 \end{aligned}$$

SIMILAR EXPRESSIONS FOR $H^{q/p} \rightarrow \widetilde{H}^{q/p}$.

▷ $u(x)$ AND $d(x)$:
USUAL UNPOLARIZED QUARK DISTRIBUTIONS

▷ PROTON AND NEUTRON EL.MAGN. FORM FACTORS USED TO CONSTRUCT FLAVOR-DEPENDENT DIRAC AND PAULI FORM FACTORS

▷ ASSUMED INTEGRATED LUMINOSITY: $2\ fb^{-1}$
(ALREADY EXPECTED FOR RUNNING 1 YEAR WITH UNPOLARIZED TARGET; PLANNED ARE 2 YEARS)

▷ HERMES ACCEPTANCE TAKEN IN ACCOUNT FOR ALL INVOLVED PARTICLES

▷ KINEMATICAL CUTS

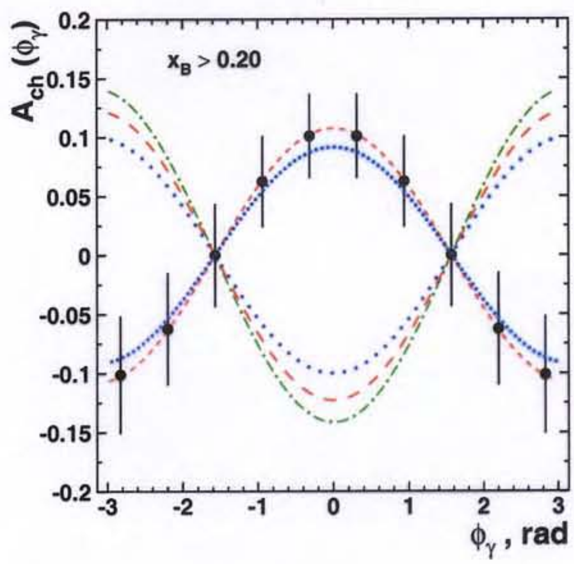
$E_e > 3.5\ GeV \quad E_\gamma > 1\ GeV \quad P_p > 0.2\ GeV$

$W^2 > 4\ GeV^2 \quad Q^2 > 1\ GeV^2 \quad 15 < \Theta_{\gamma\gamma^*} < 70\ mrad$

HERMES DVCS RESULTS AND 2006 ASYMMETRY PROJECTIONS

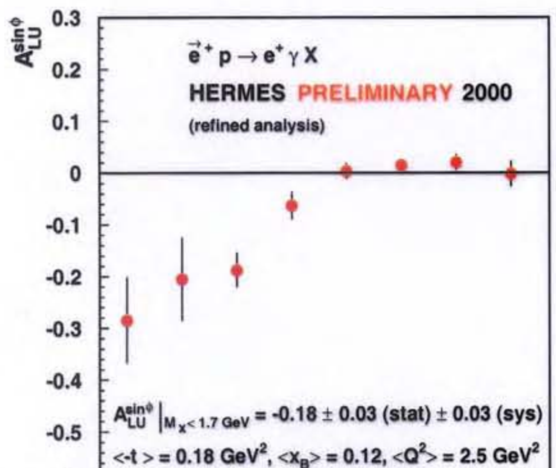
A) Lepton charge asym. (unpol. beam, unpol. target):

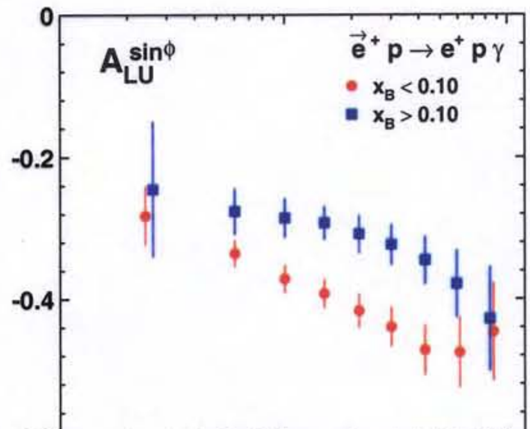
Projection* ($x_B > 0.2$)



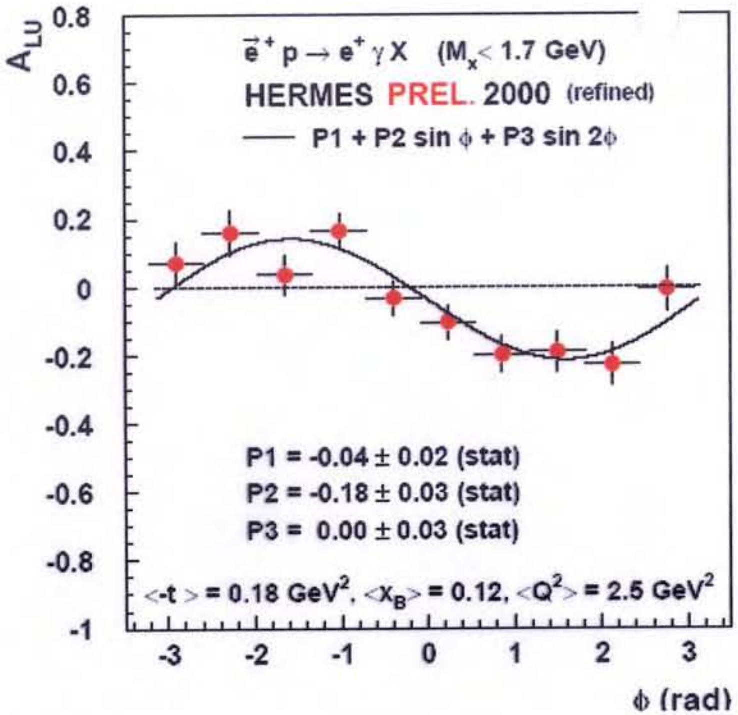
B) Lepton helicity asym. (pol. beam, unpol. target):

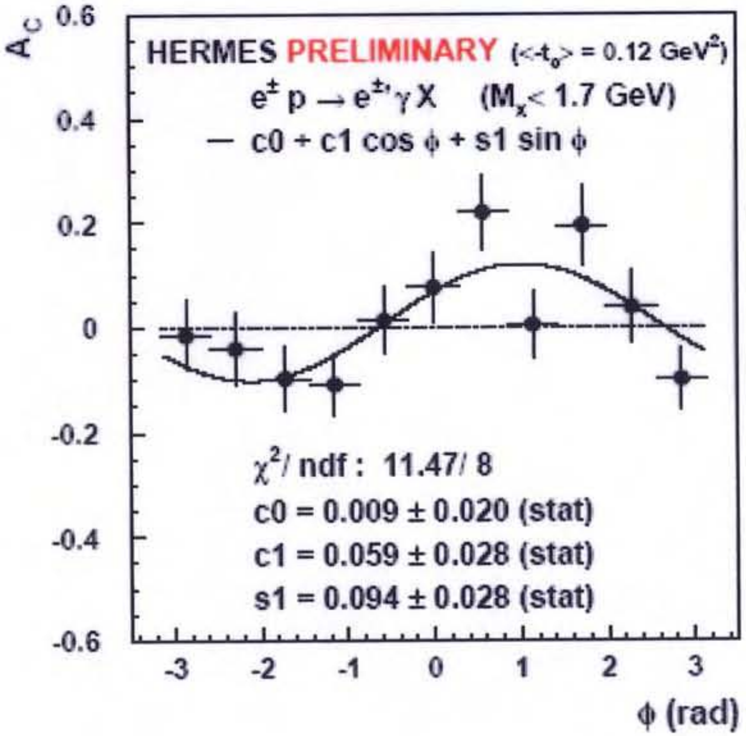
Refined prel. result 2002 — Projection*





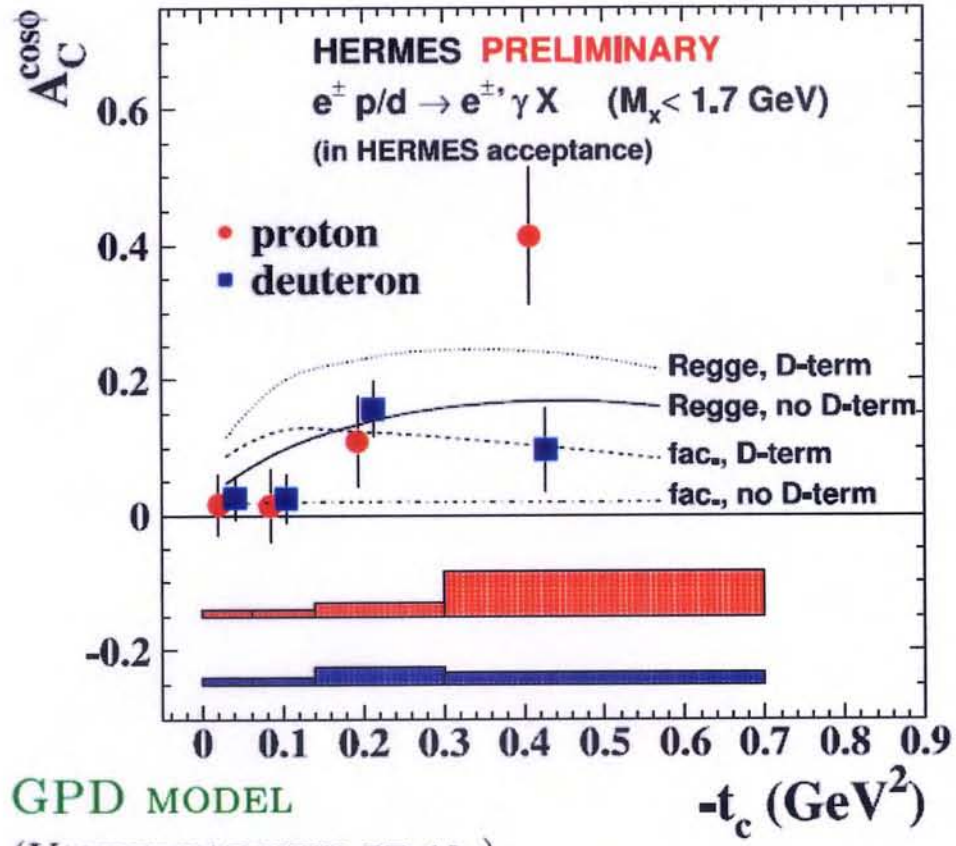
*) Projections: V. Korotkov, W.-D. N., EPJC 23 (2002), 455





beam polarisation asymmetry $\propto \sin(\Phi)\,\mathrm{Im}(A_{DVCS})$

beam charge asymmetry $\propto \cos(\Phi)\,\mathrm{Re}(A_{DVCS})$



GPD MODEL

(VANDERHAEGHEN ET AL.)

prospects for fixed target experiment HERMES
- beam charge and polarisation asymmetries
- tag recoiling proton
- higher statistics at HERA II

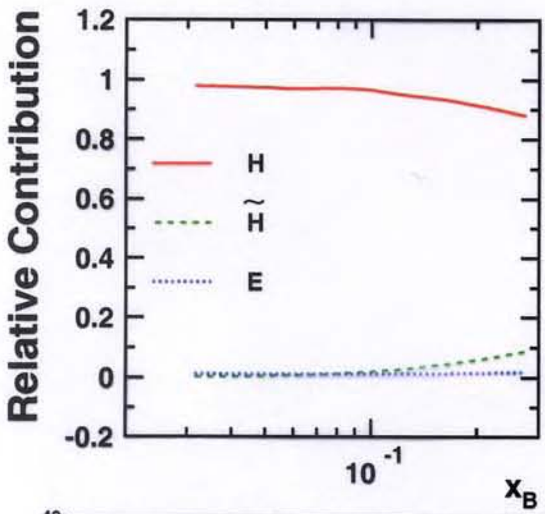
Im$\mathcal{H}$ Measurement in 2006 ? *

Lepton helicity asymmetry: $A_{LU}^{sin\phi} \approx \mathcal{C}_{unp}^{\mathcal{I}} / \mathcal{C}_{unp}^{DVCS}$ with

$$\mathcal{C}_{\rm unp}^{\rm DVCS} = \frac{1}{(2-x_{\rm B})^2}\Big\{4(1-x_{\rm B})\left(\mathcal{H}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{H}}^*\right) - x_{\rm B}^2\Big(\mathcal{H}\mathcal{E}^* + \mathcal{E}\mathcal{H}^* + \widetilde{\mathcal{H}}\widetilde{\mathcal{E}}^* + \widetilde{\mathcal{E}}\widetilde{\mathcal{H}}$$

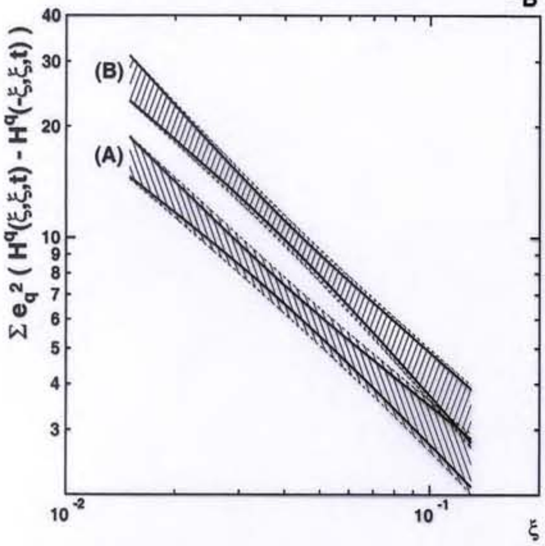
$$- \left(x_{\rm B}^2 + (2-x_{\rm B})^2 \frac{t}{4M^2}\right)\mathcal{E}\mathcal{E}^* - x_{\rm B}^2 \frac{t}{4M^2}\widetilde{\mathcal{E}}\widetilde{\mathcal{E}}^*\Big\}.$$

$$\mathcal{C}_{\rm unp}^{\mathcal{I}} = F_1\mathcal{H} + \frac{x_{\rm B}}{2-x_{\rm B}}(F_1+F_2)\widetilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}$$



At $-t < 0.15$ GeV^2:

Relative contribution of GPD H dominates
$\Rightarrow$ Asymmetry $A_{LU}^{sin\phi}$ mainly depending on Im$\mathcal{H}$



Extraction of Im$\mathcal{H}$ possible:

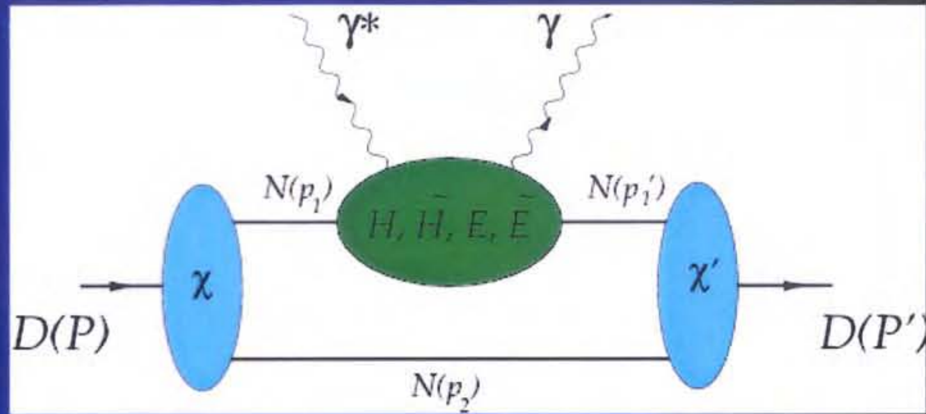
$\Leftarrow$ Two different bands for different GPD param.'s
$\Leftarrow$ Solid line: 1σ stat. errors
$\Leftarrow$ Dashed line: syst. extraction uncertainty added

*) Projections: V. Korotkov, W.-D. N., NPA 711, 175c, (2002)

Coherent DVCS on the deuteron

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

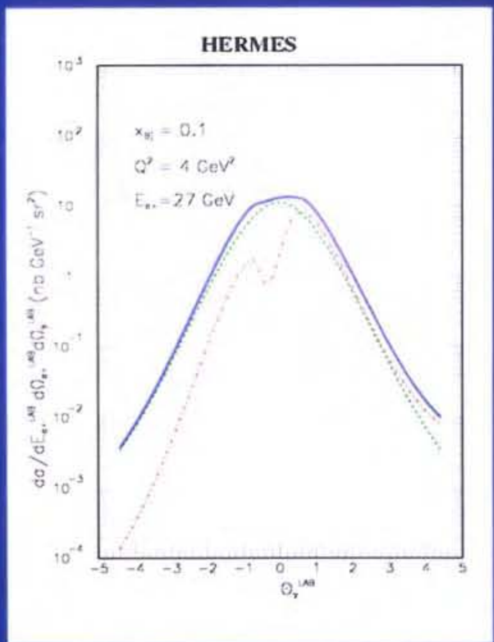
- GPD based model for DVCS on the deuteron
- IA: convolution of photon-nucleon interaction and deuteron wave function
- diagram is suppressed above $x_{Bj} = 0.2$



Predictions

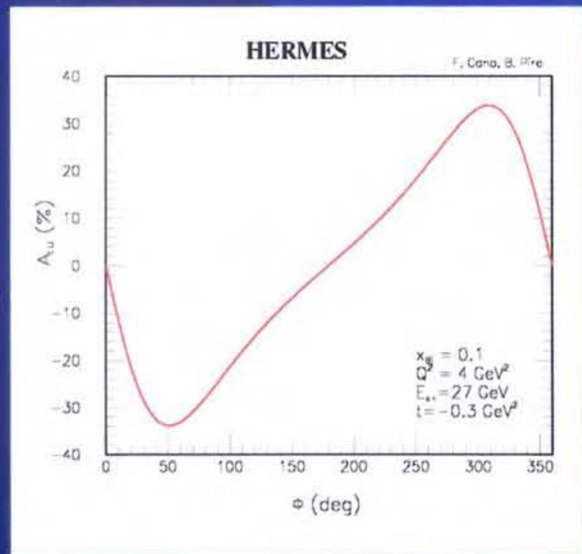
Cano/Pire model includes

- 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 sin2φ component
- HERMES and JLab working on deuteron data



Factorization theorem for meson production

- *Müller* **(1994)** -
- *Ji & Radyushkin* **(1996)** -
- *Collins, Frankfurt & Strikman* **(1997)** -

→ 4 **G**eneralized **P**arton **D**istributions (**GPD**s)

H $\tilde{H}$ conserve nucleon helicity

E $\tilde{E}$ flip nucleon helicity

↓ unpolarized ↓ polarized

→ Quantum number of final state selects different GPDs

Vector mesons (ρ, ω, ϕ): unpolarized GPDs H E

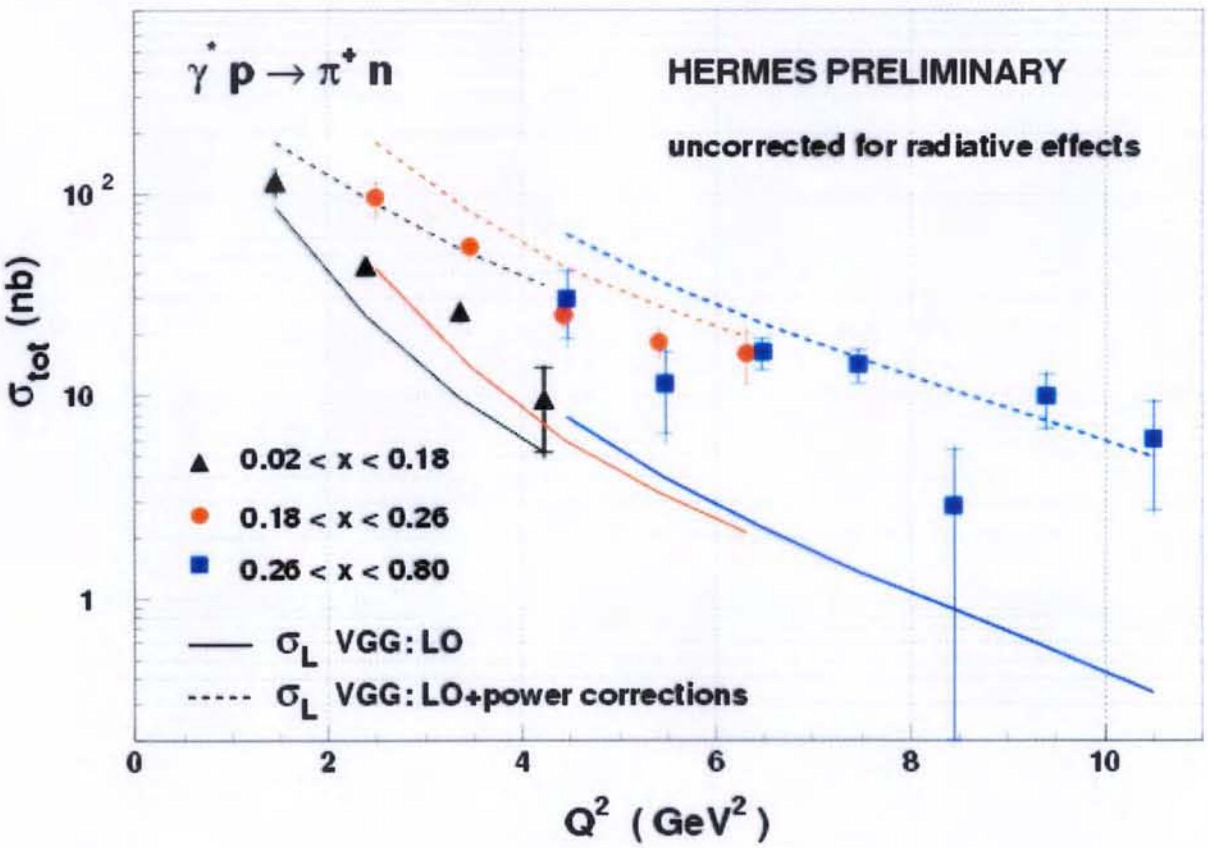
Pseudoscalar mesons (π, η): polarized GPDs $\tilde{H}$ $\tilde{E}$ (pion pole)

→ Factorization for longitudinal photons only

→ $$\frac{d\sigma_L}{dt} \xrightarrow[\text{for fixed } x_B \text{ and } t]{\text{asymptotically}} \frac{1}{Q^6}$$

Cross section: comparison with model

No L/T separation but σ_T suppressed by $1/Q^2$ and $\varepsilon > 0.8$



-Vanderhaeghen, Guichon & Guidal (1999) -

π production:

$\tilde{H}$ pseudovector contribution

$\tilde{E}$ pseudoscalar contribution

(pion pole related to F_π)

→ Q^2 dependence is in general agreement with the theoretical expectation

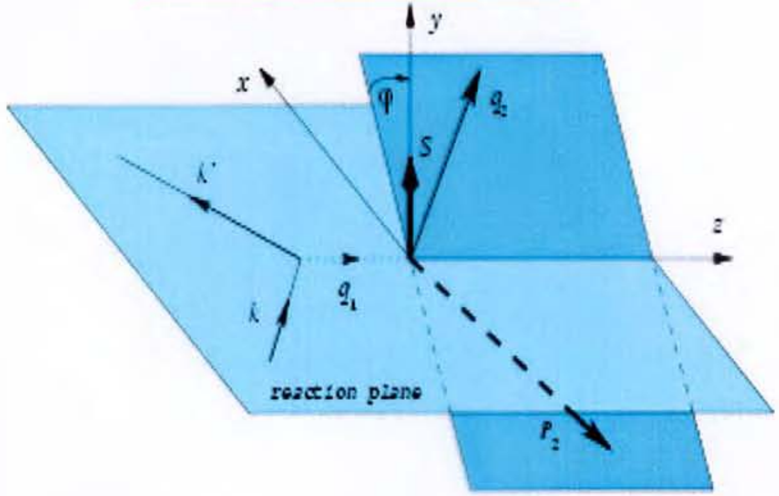
→ Power correction calculations overestimate the data

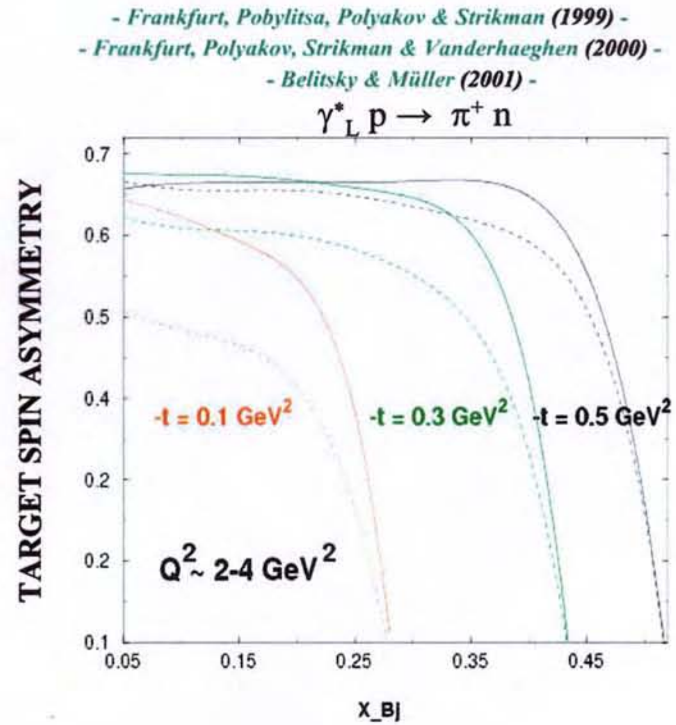
Asymmetry measurement for $e\,p \rightarrow e\,\pi^+ n$

Transverse target spin asymmetry

interference between $\tilde{E}$ and $\tilde{H}$

σ_S: $|S_T| \sin \Phi\ \tilde{E}\,\tilde{H}$





- TSA linear dependence $\tilde{E}.\tilde{H}$ / cross section quadratic combination $(\tilde{E}+\tilde{H})^2$
- TSA higher order corrections cancel: scaling region reached at lower Q^2
- Constrain pole $\tilde{E}$ and non pole $\tilde{H}$ would help the π FF extraction

HERMES-2:

Transverse Target Spin Asymmetry in DVCS

- Up-Down Asymmetry in the target rest frame or Left-Right Asymmetry in HERMES Experiment

$$A_{UT,1}^{DVCS} = \frac{\int_0^{\pi} d\beta \int_0^{2\pi} d\phi d\sigma(\phi,\beta) \cdot 2\cos\phi - \int_{\pi}^{2\pi} d\beta \int_0^{2\pi} d\phi d\sigma(\phi,\beta) \cdot 2\cos\phi}{\int_0^{2\pi} d\beta \int_0^{2\pi} d\phi d\sigma(\phi,\beta)}$$

$$\simeq \langle|\sin\beta|\rangle \cdot \frac{x_B}{y} \cdot \frac{Im\widehat{M}_1}{C_{0,unp}^{BH}}$$

- Left-Right Asymmetry in the target rest frame or Up-Down Asymmetry in HERMES Experiment

$$A_{UT,2}^{DVCS} = \frac{\int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} d\beta \int_0^{2\pi} d\phi d\sigma(\phi,\beta) \cdot 2\sin\phi - \int_{\frac{\pi}{2}}^{\frac{3\pi}{2}} d\beta \int_0^{2\pi} d\phi d\sigma(\phi,\beta) \cdot 2\sin\phi}{\int_0^{2\pi} d\beta \int_0^{2\pi} d\phi d\sigma(\phi,\beta)}$$

$$\simeq -\langle|\cos\beta|\rangle \cdot \frac{x_B}{y} \cdot \frac{Im\widehat{M}_2}{C_{0,unp}^{BH}}$$

DVCS with Unp. Beam on Trans. Target

- Contributions not related to target spin:

$$\left|\mathcal{T}^{BH}_{unp}\right|^2 \propto \frac{c^{BH}_{0,unp} + c^{BH}_{1,unp}\cos\phi + c^{BH}_{2,unp}\cos 2\phi}{P_1(\phi)P_2(\phi)} \qquad (4)$$

$$\mathcal{T}^{I}_{unp} \propto \frac{c^{I}_{0,unp} + c^{I}_{1,unp}\cos\phi + c^{I}_{2,unp}\cos 2\phi + c^{I}_{3,unp}\cos 3\phi}{P_1(\phi)P_2(\phi)}$$

- Contributions related to target spin:

$$\mathcal{T}^{I}_{TP} = \frac{e^6}{x_B y^3 t}\cdot\frac{\cos\phi\sin\beta\cdot Im\widehat{M}_1 - \sin\phi\cos\beta\cdot Im\widehat{M}_2}{P_1(\phi)P_2(\phi)}$$

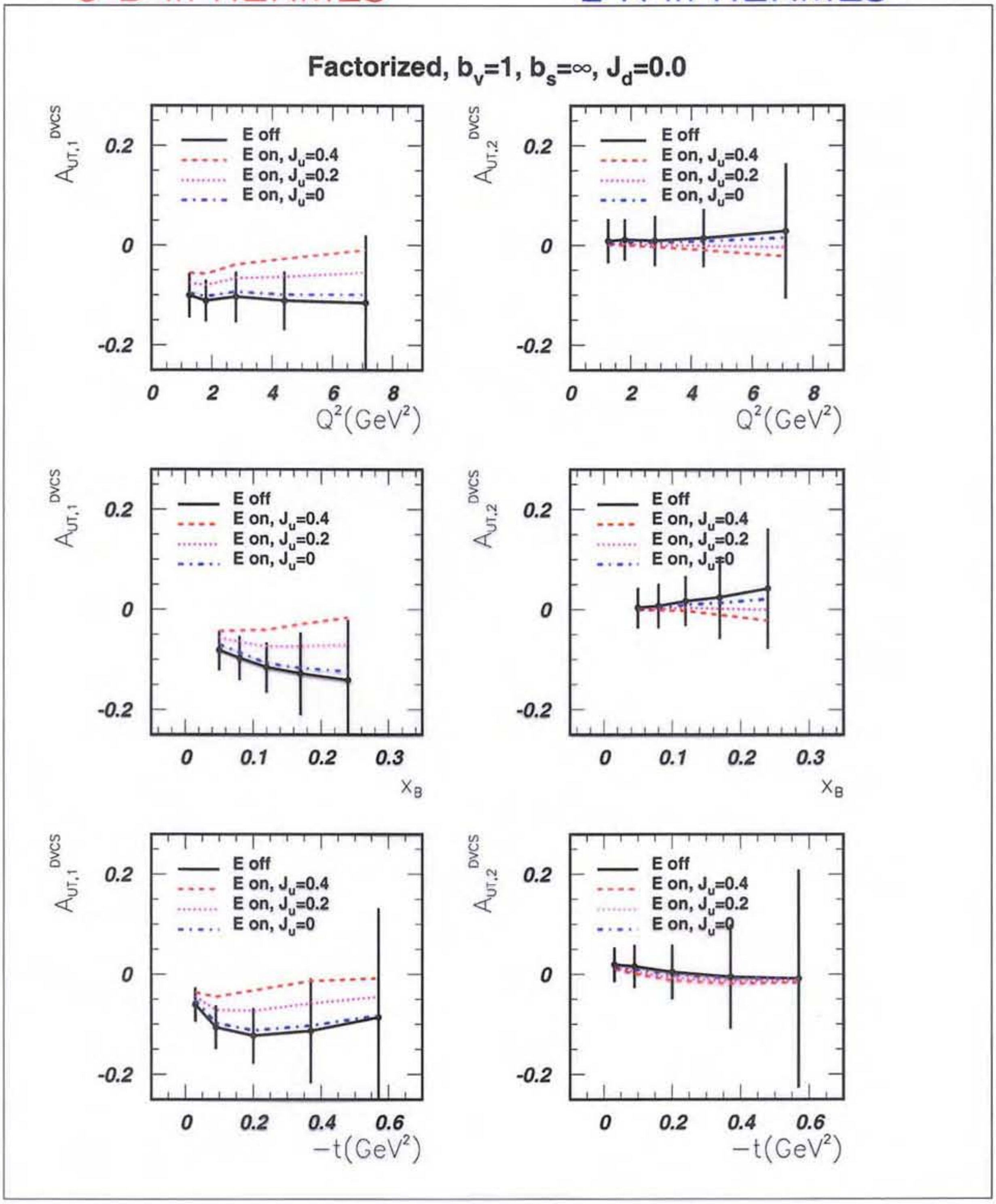
$$\widehat{M}_1 \simeq f(x_B, y, Q^2, t)\cdot\left(F_2\mathcal{H} - F_1\mathcal{E}\right)$$

$$\widehat{M}_2 \simeq f(x_B, y, Q^2, t)\cdot\left(F_2\widetilde{\mathcal{H}} - F_1\xi\widetilde{\mathcal{E}}\right) \qquad (5)$$

Results with Factorized Ansatz

L-R in Rest Frame
U-D in HERMES

U-D in Rest Frame
L-R in HERMES



HERMES: 4M DIS $= 0.1\ \text{fb}^{-1}$

⇒ error ↓ by factor 30 for 100 fb^{-1}

Transverse Target Spin Asymmetries in DVCS

$A_{UT,1}^{DVCS}$ is sensitive to GPD E, and thus to J_u

$A_{UT,1}^{DVCS}$ can be measured at HERMES. With 4M DIS = 0.1 fb^{-1}, a 2σ sensitivity can be reached providing first access to GPD E;

$A_{UT,2}^{DVCS}$ also interesting to measure providing first access to GPD Ẽ.

Projections: F. Ellinghaus, W.-D. Nowak, A. Vinnikov, Z. Ye
HERMES Internal Note 04-008

HERMES - 2 :

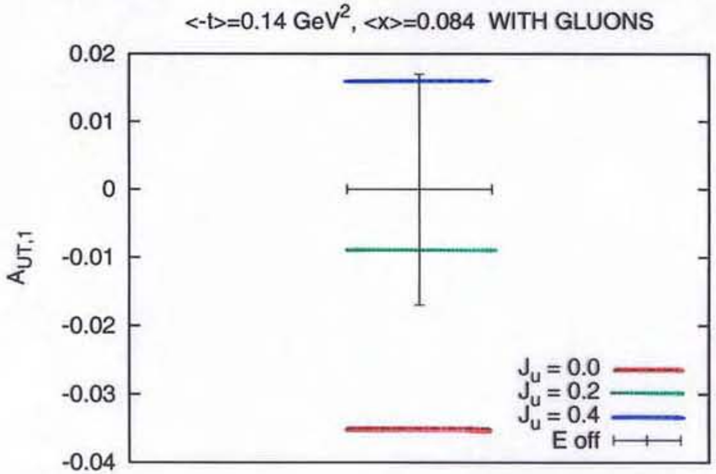
SENSITIVITY OF ELASTIC ρ^0 ELECTROPRODUCTION TO THE GPD E

A_{UT} looks like a unique tool to access the GPD E

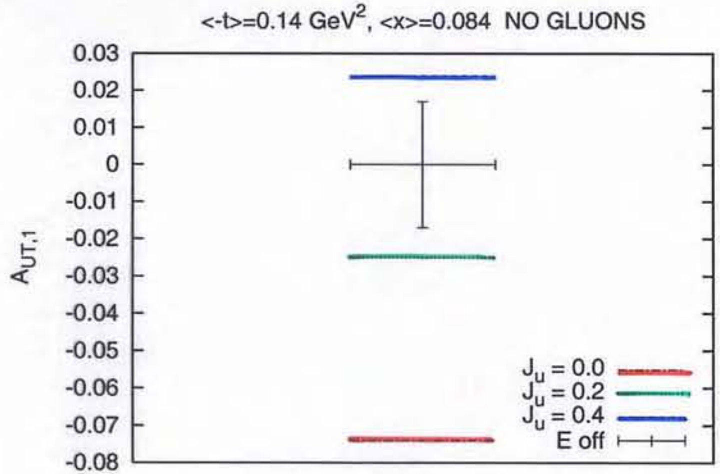
Present parameterizations of E depend on J_u

$\Rightarrow$ A possible way to access J_u ?

PASSIVE GLUONS



NO GLUONS



HERMES-2: transverse target polarization

Projected statistics: 4M DIS = 0.1 fb^{-1} ⇗ error ↓ by factor 30 for 100 fb^{-1}

ELSEVIER

Nuclear Physics A721 (2003) 368c–371c

NUCLEAR PHYSICS A

www.elsevier.com/locate/npe

Deeply Virtual Compton Scattering using COMPASS at CERN

E. Burtin, N. d'Hose, P.A.M. Guichon, J. Marroncle [a]

[a]CEA-Saclay, DSM/DAPNIA/SPHN, F-91191 Gif-sur-Yvette Cedex, France.

In this paper, we present the recent studies our group has conducted in order to show the feasibility of a Deeply Virtual Compton Scattering experiment using COMPASS and its high energy muon beam at CERN. The measurement of the cross section and the beam charge asymmetry in the kinematical domain : $0.03 < x_{bj} < 0.25$ and $1.5 < Q^2 < 7.5$ GeV^2 will provide a check of the factorization and will put strong constraints on the models. Experimental studies show that detection of the DVCS exclusive reaction is feasible with some upgrade of the COMPASS apparatus.

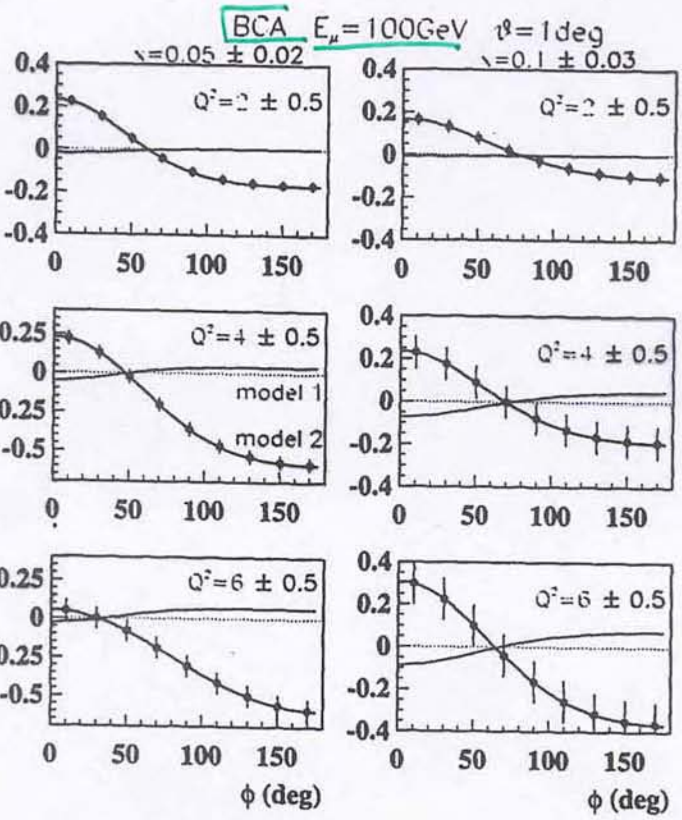
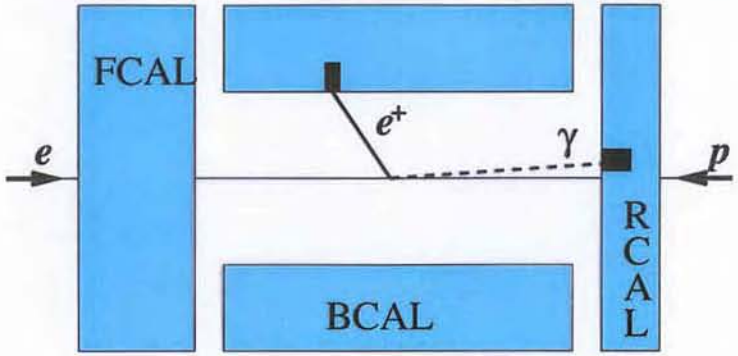


Figure 1. Experimental precision achievable for a 6 month running with 25 % global efficiency. The Beam Charge Asymmetry is plotted as a function of the angle between the leptonic and proton/photon plane. On each plot 2 models of GPD are represented. The first model just fulfills the sum rules while the second model[3] (corresponding to the expected data points) uses Regge theory to relate x and t dependences. This shows that an experiment using COMPASS has good sensitivity to discriminate between models.

H1 & ZEUS

DVCS - event topology

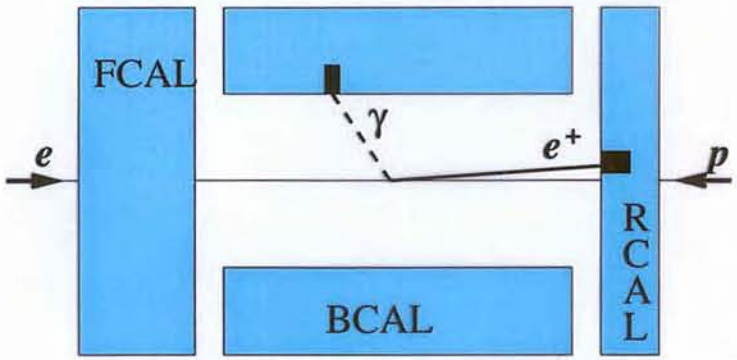


γ from QED bremsstrahlung emitted

in e-beam direction

e^+ sample CONTROL SAMPLE

only BH contributes, 7000 events



γ sample ENRICHED WITH DVCS

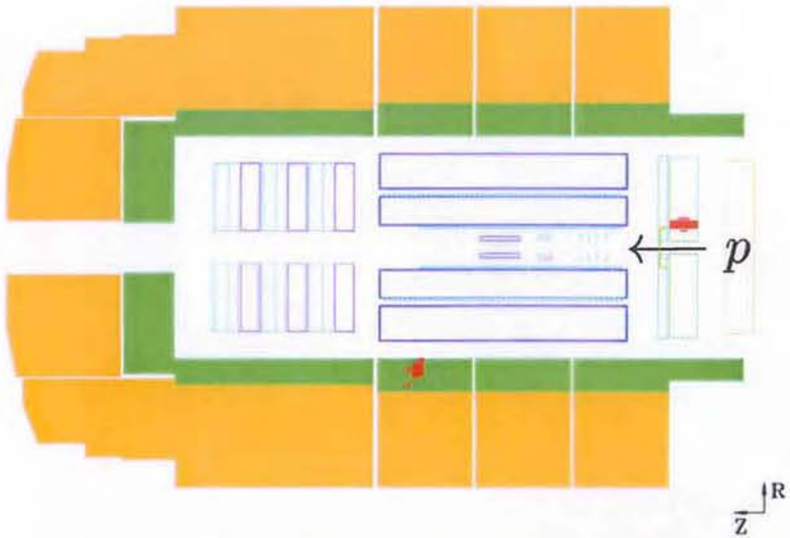
both BH and DVCS contribute, 4000 events

BH MC describes data in control sample

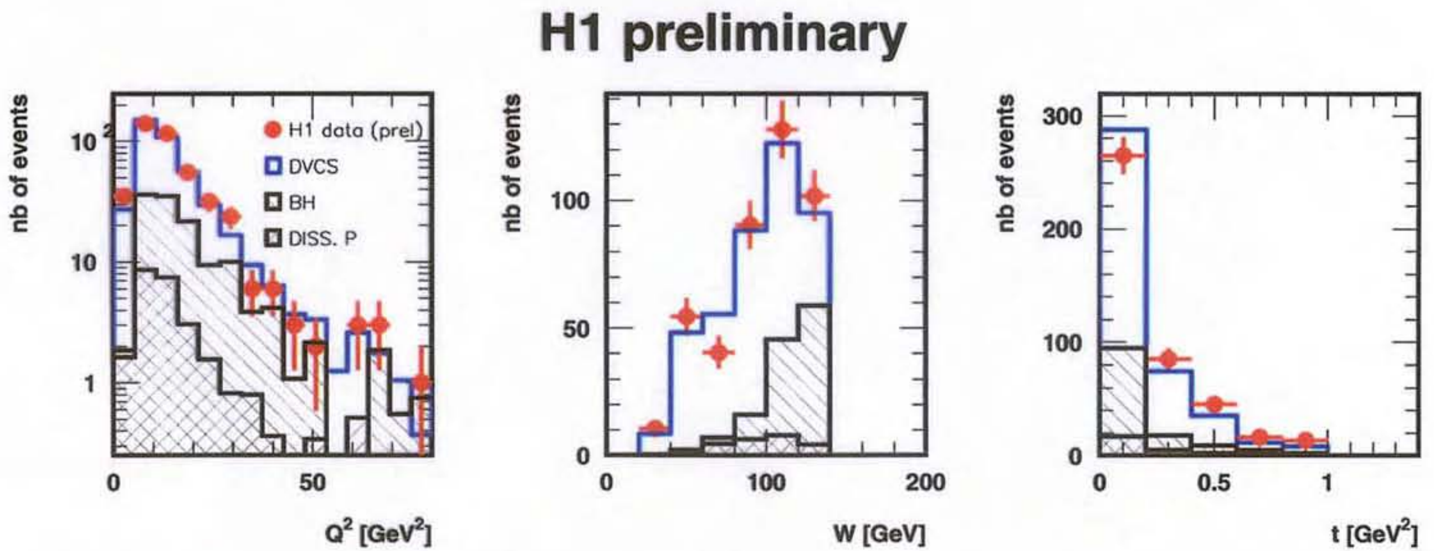
→ use MC to subtract BH in enriched DVCS sample

DVCS Analysis

- $e^+ \longrightarrow$

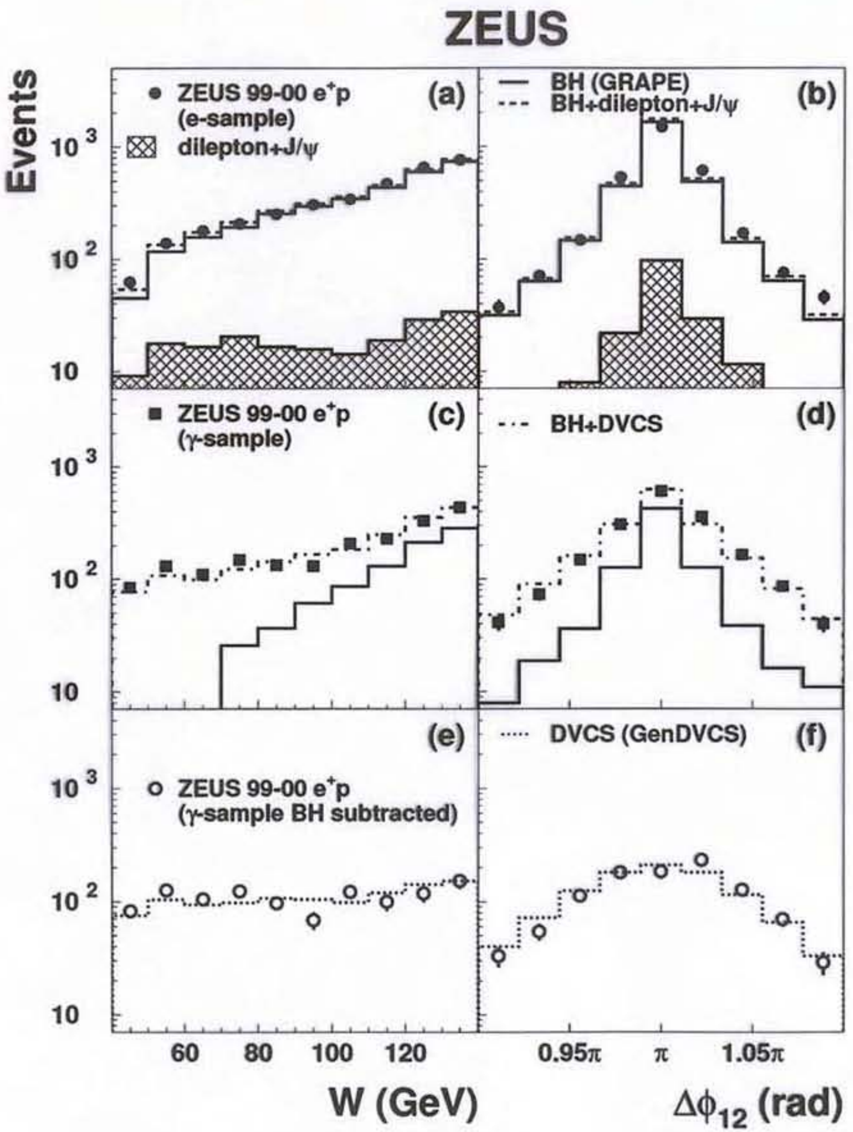


H1 data 2000	$\int \mathcal{L} = 26$ pb^{-1}
$E_e >$	15 GeV
$E_\gamma >$	2 GeV
$E_3 <$	0.5 GeV
elast.	no track, Fwd



$4 < Q^2 < 80\,\mathrm{GeV}^2 \quad 30 < W < 140\,\mathrm{GeV} \quad |t| < 1\,\mathrm{GeV}^2$

DVCS - control plots



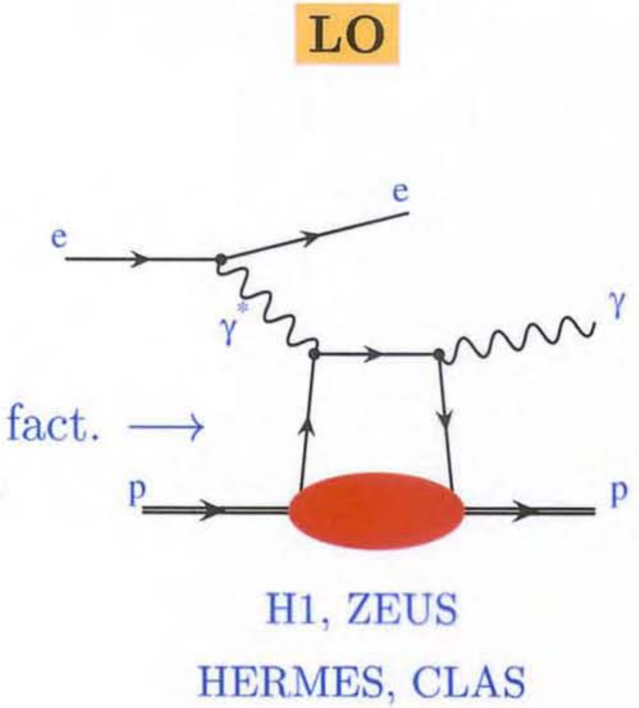
e^+ sample — BH control sample

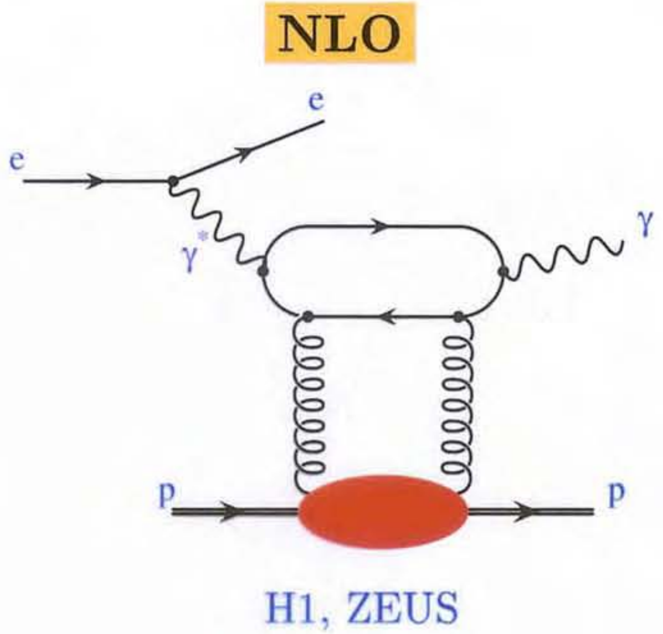
γ sample — DVCS + BH

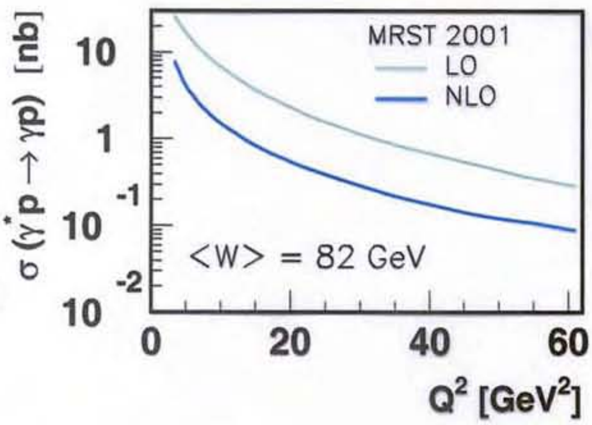
γ sample after BH subtraction — DVCS

DVCS Introduction

QCD







NLO leading twist calc. by A. Freund and M. McDermott

Eur.Phys.J. **C23** (2002) 651

Input: GPD

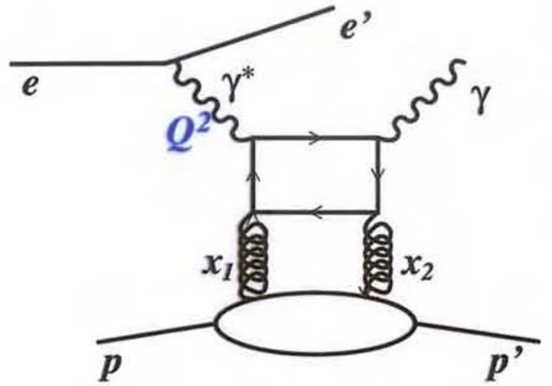
GPD modeling Freund [hep-ph/0306012]

$$GPD(x,\xi,Q^2,t) \sim \frac{PDF(\frac{x-\xi/2}{1-\xi/2},Q^2)}{1-\xi/2} \times e^{-b\,|t|}$$

PDF: MRST2001 and CTEQ6

$b = b_0(1 - 0.15\log(Q^2/2))\ \mathrm{GeV}^{-2}$

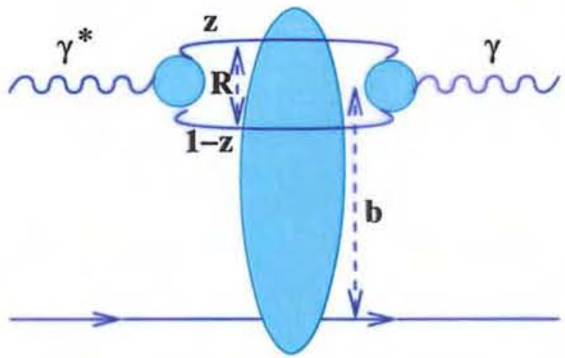
QCD Models for DVCS



QCD-based Model - Frankfurt, Freund and Strikman (FFS):

$$\frac{d^3\sigma_{\rm DVCS}}{dx dQ^2 dt} = \frac{\pi^2\alpha^3}{2xR^2Q^6}[1+(1-y)^2]e^{bt}F_2^2(x,Q^2)(1+\rho^2)$$

NLO calculation Freund, McDermott



Colour Dipole Model - Donnachie and Dosch (DD), Forshaw, Kerley and Shaw (FKS), McDermott, Frankfurt, Guzey and Strikman (MFGS)

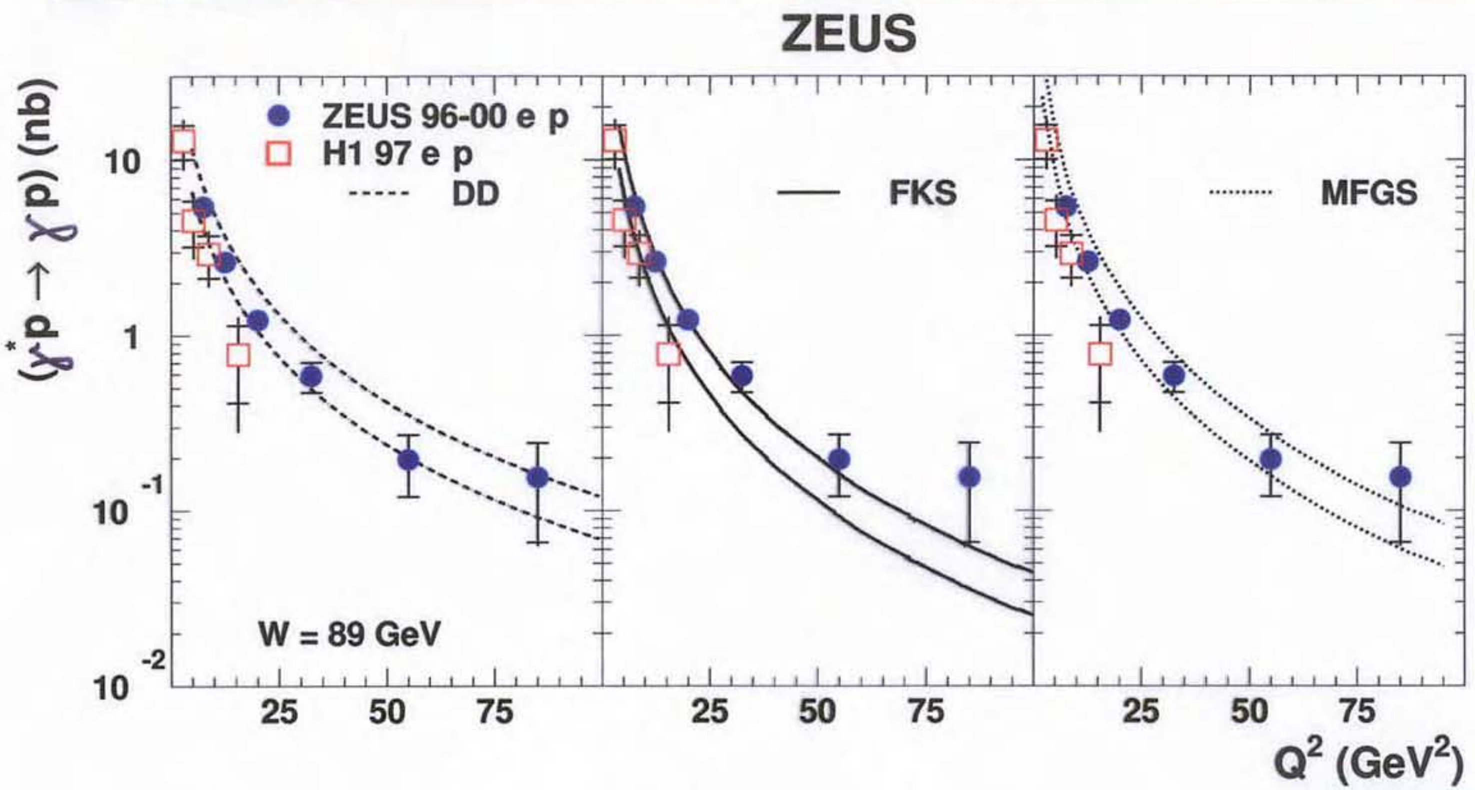
$$\mathcal{A} \sim \int_{R,z} \psi_{in}^{\gamma^*}\sigma_D\psi_{out}^{\gamma}$$

σ_D - dipole-p cross section

$\psi_{in}^{\gamma^*}$ - light-cone wave function of the incoming photon

ψ_{out}^{γ} - light-cone wave function of the outgoing photon

Comparison with Colour Dipole Models



upper curves $b = 4\,\mathrm{GeV}^{-2}$

lower curves $b = 7\,\mathrm{GeV}^{-2}$

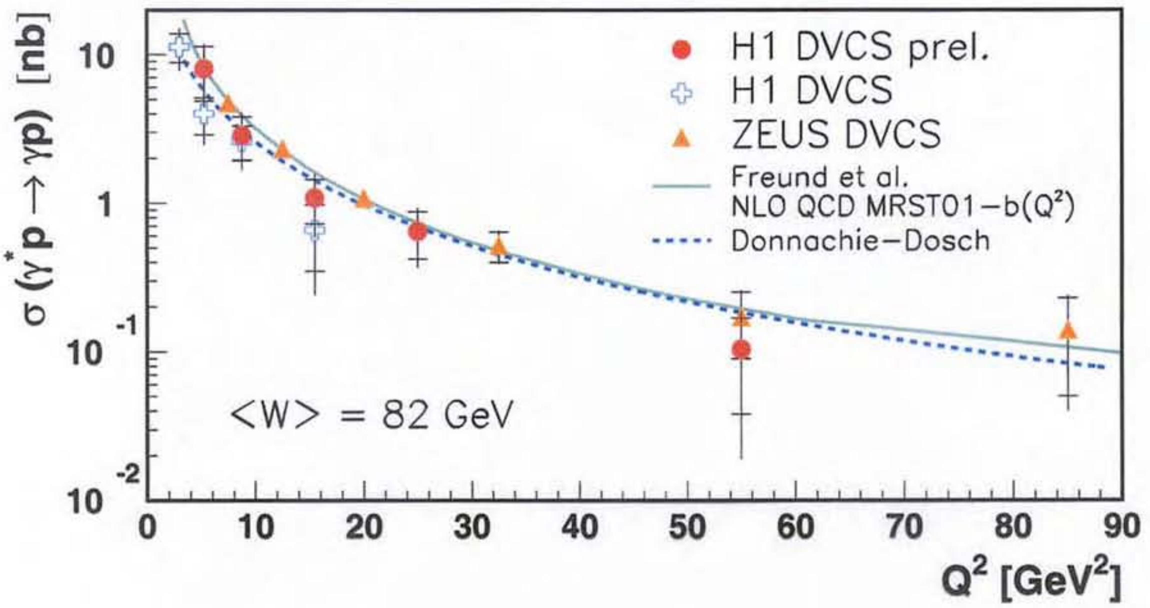
DD (Donnachie and Dosh) - perturbative + Regge

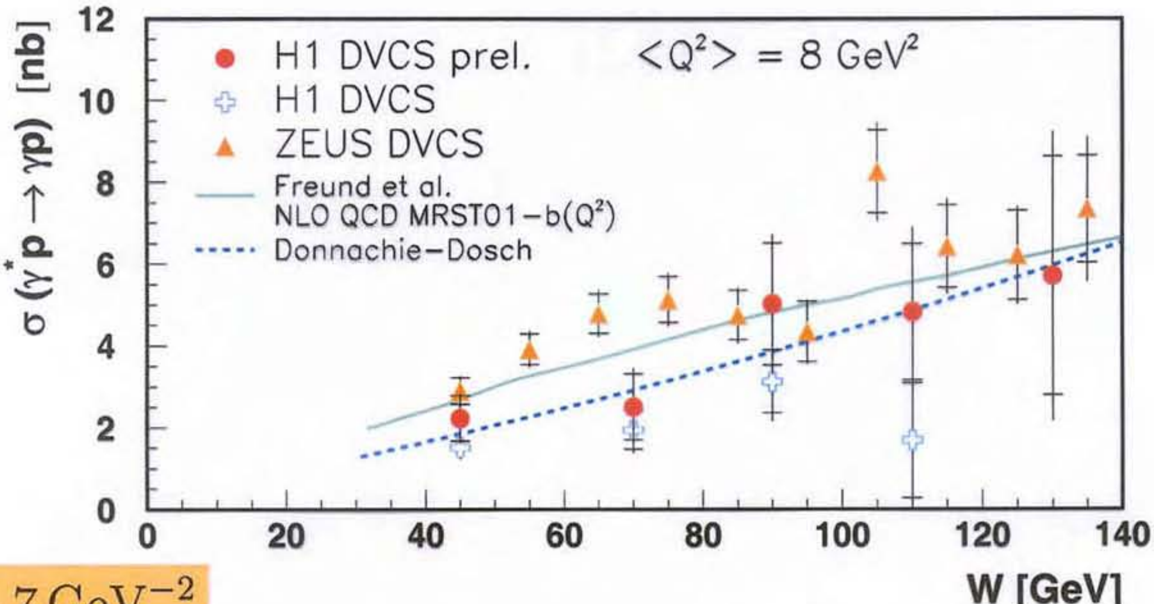
FKS (Forshaw,Kerley and Shaw) - Regge approach

MFGS(McDermott,Frankfurt,Guzey and Strikman)- QCD colour transparency

Very different models
give similar predictions in the
measured kinematical region

All H1 and ZEUS Results





$b = 7\,\mathrm{GeV}^{-2}$

$\Longrightarrow$ Good agreement between H1 results

$\Longrightarrow$ Fair agreement between H1-prel and ZEUS results except for $W \sim 70$ GeV: H1 lower by 2σ

Future Prospects: DVCS at HERA II

- HERA
  - spin rotators around H1 and ZEUS
- H1
  - VFPS in 2003 ⇒ measurement of t at small W
  - BST ⇒ precise measurement of ϑ_e, φ_e, z_{vrtx}, φ_γ
  - measurement of azimuthal asymmetries
- ZEUS
  - microvertex detector ⇒ measurement of ϑ_e, φ_e, z_{vrtx}, φ_γ
  - polarization/charge differences
- HERMES
  - large acceptance recoil detector in 2005
    - Improved exclusivity
    - Improved t-resolution

Hall A DVCS at 6 GeV -Projected Results

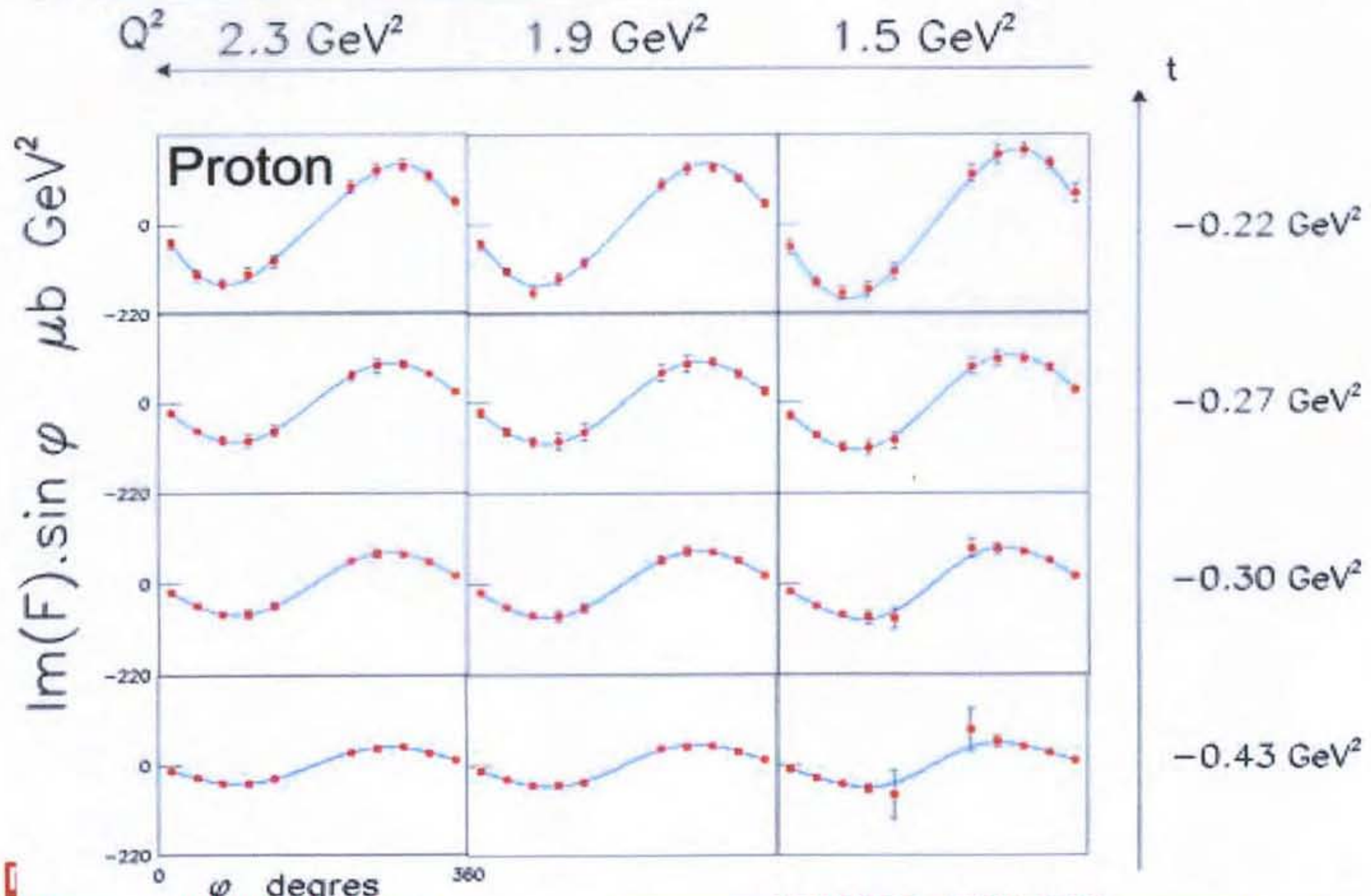
Unique characteristics:

- Very high luminosity (10^{37} cm^{-2}s^{-1})
- Well defined kinematics (high resolution)

➡ High precision for Q^2 up to 2.5 GeV^2 at fixed x_B=0.35

Method:

Measure *weighted cross-section differences* (rather than asymmetries) as function of φ angle. Deduce Q^2 dependence and relative importance of twist-2 and higher twists.



Goals:

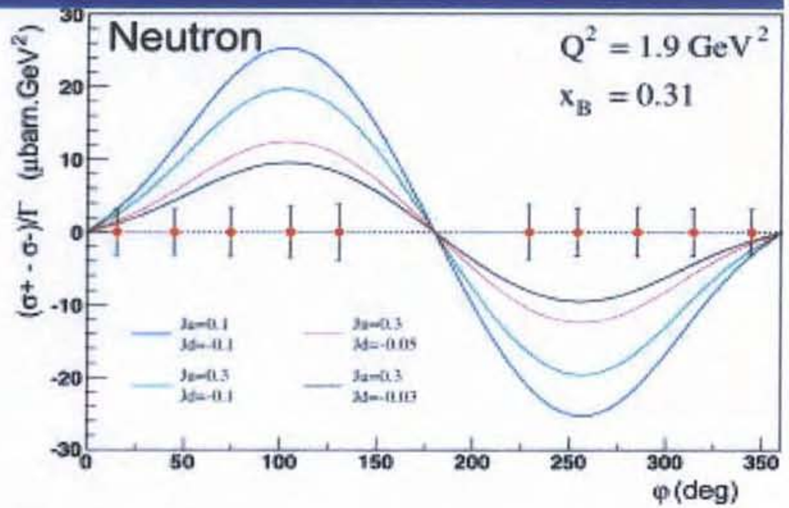
Test of handbag mechanism dominance in this Q^2 range.

Measure linear combinations of GPD's

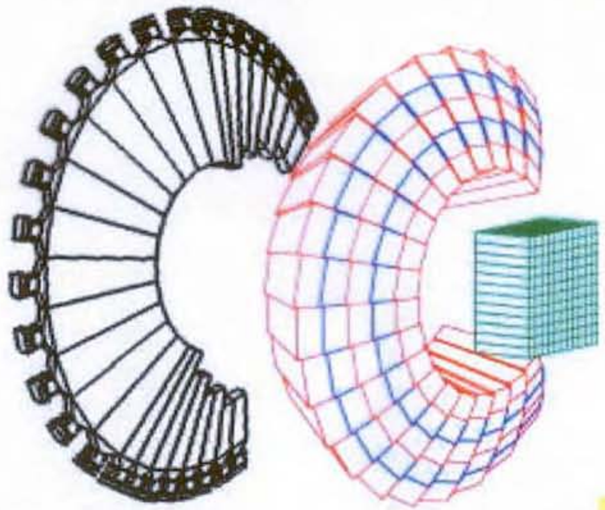
Neutron DVCS in Hall A at 6 GeV - E03-106

P. Bertin, C.E. Hyde-Wright, F. Sabatié and E. Voutier

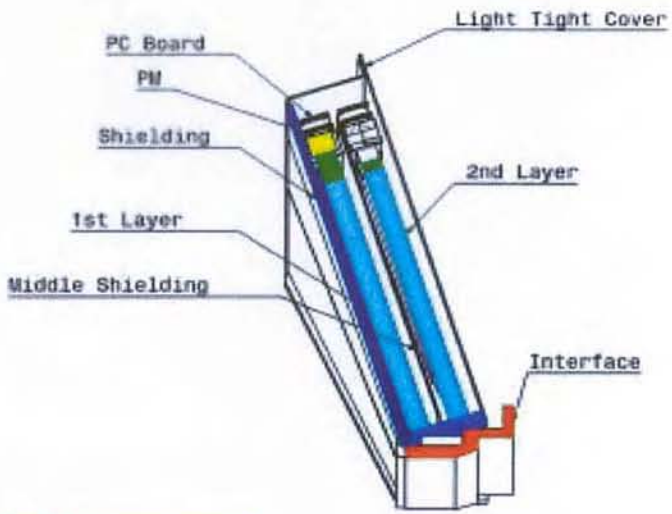
- Use of a deuterium target
- Proton DVCS is veto-ed by new detector
- Mostly sensitive to GPD E (unknown !)
- Information about quark orbital angular momentum through models and Ji's sum rule



Addition of a charged particle veto in front of the plastic scintillator array



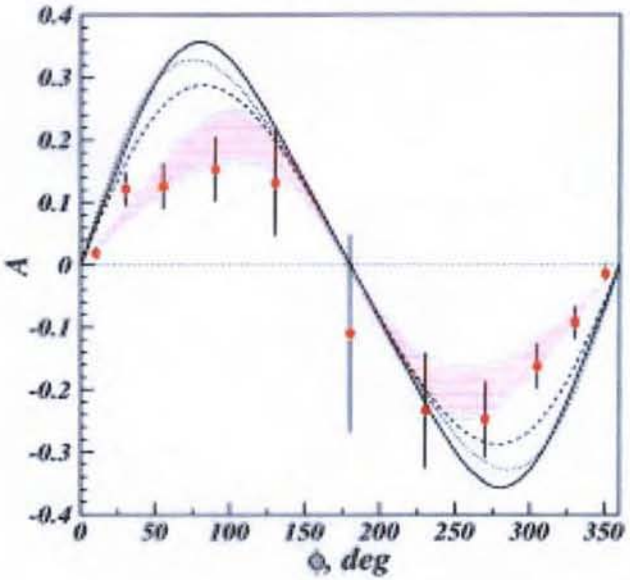
The veto counter consists in 2 layers of 2cm-thick scintillator paddles



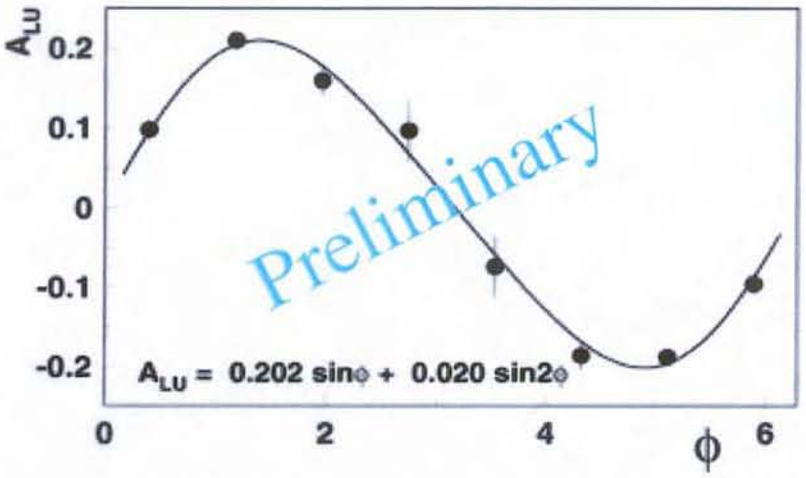
Z.-E. Meziani

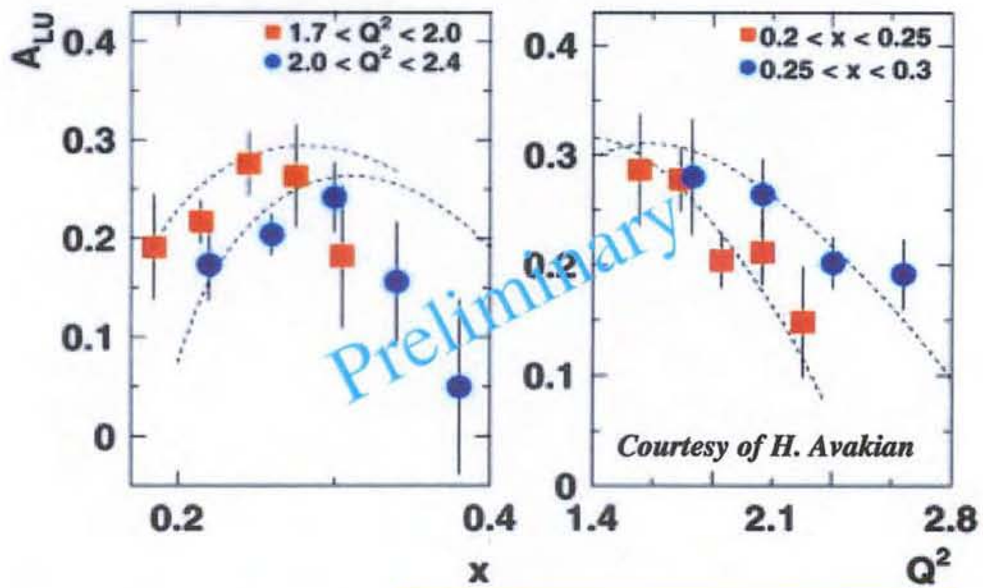
Hall B (non-dedicated) DVCS measurements

ep-->epX
Missing mass Mx=0



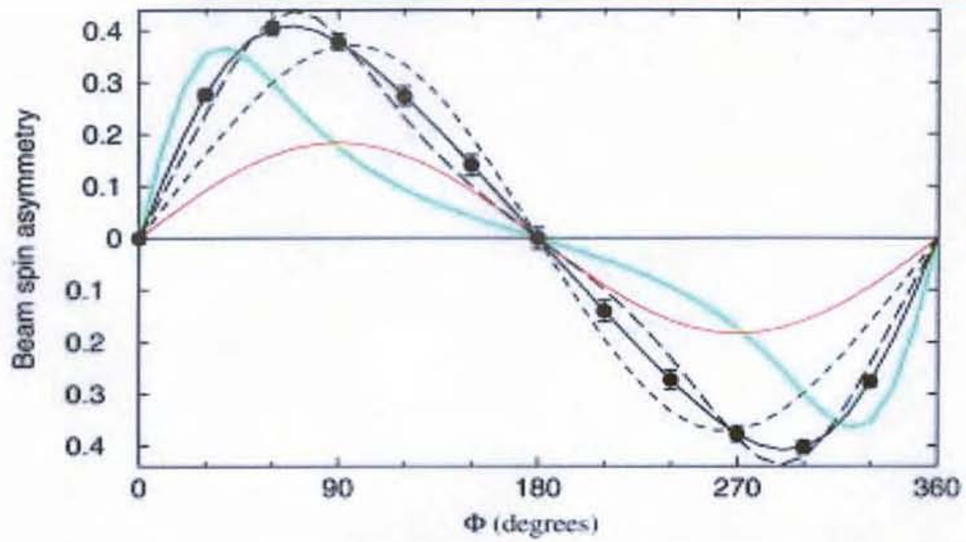
Published measurement at 4.2 GeV
Phys.Rev.Lett.87:182002,2001



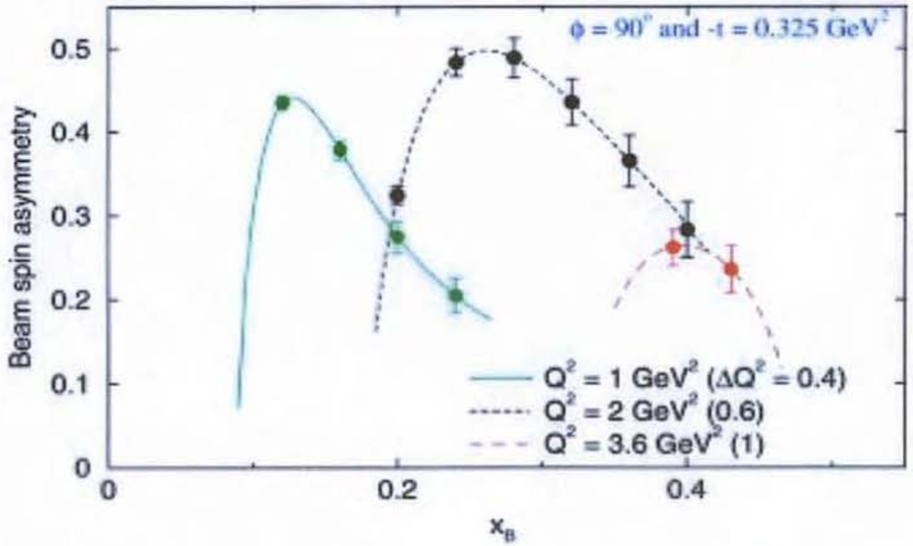


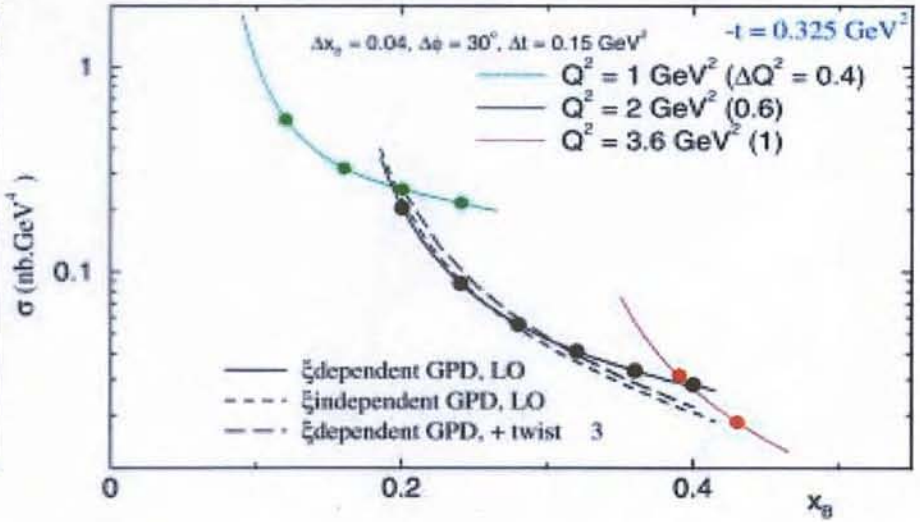
New measurement at 6 GeV

DVCS with CLAS at 6 GeV

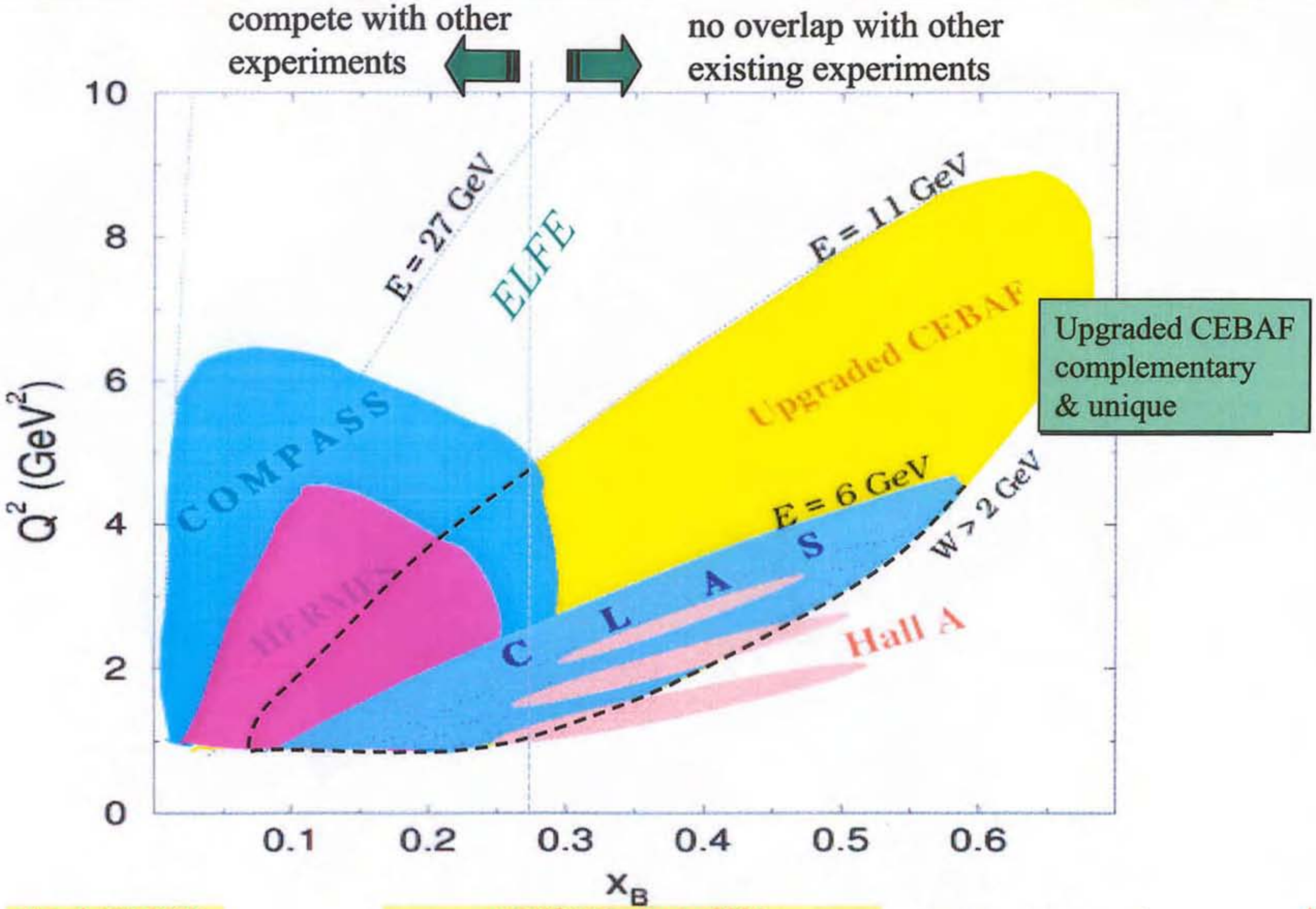


Dependence of φ asymmetry and total cross-section as a function of x_B, t, Q^2, φ (372 bins)





Kinematics coverage for deeply exclusive experiments



The JLab GPD Program @ 12 GeV

DVCS:

- DVCS/BH interference with polarized beam
  - ⇨ twist-2/3, Q^2 evolution
  - ⇨ linear combination of GPDs
- Differential cross section
  - ⇨ moments of GPDs
- DVCS/BH interference with polarized targets
  - ⇨ access different combinations of GPDs

DVMP:

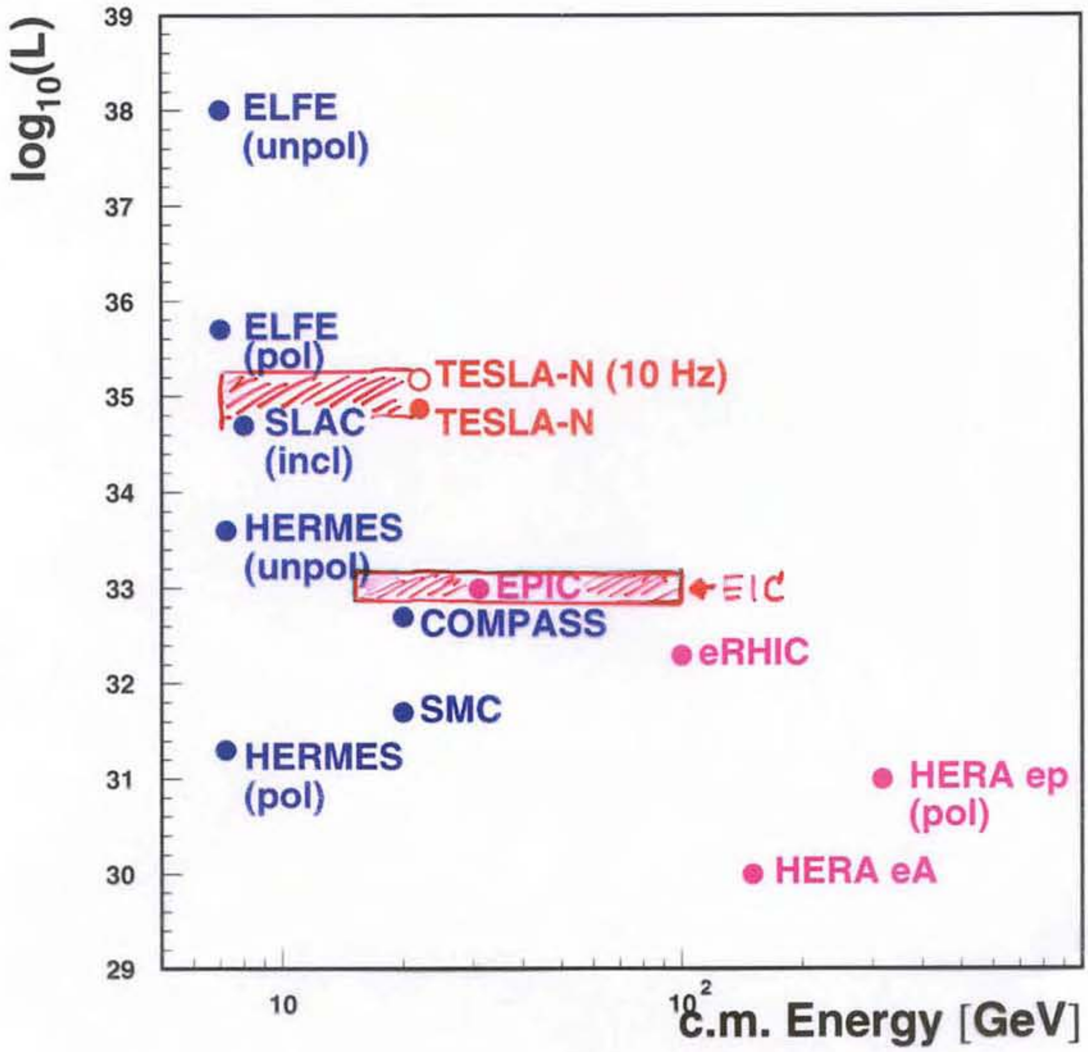
- Establish kinematics range where theory is tractable (if not known)
- Separation of flavor- and spin-dependent GPDs (ρ^o, ω, π^0, η, $K^{+,0}$)
- Access J^q contributions at $x_B > 0.15$

➡ **Quark distributions in transverse coordinates**

DDVCS: Allows access to $x \neq \xi$ kinematics $ep \rightarrow ep\gamma^* \rightarrow e^+e^-$

ΔDVCS: Hard baryon spectroscopy $ep \rightarrow e\gamma\Delta$, $(e\gamma N^*)$

LUMINOSITY (II)



THE EFFECTIVE POLARIZED LUMINOSITY FOR A SOLID-STATE FIXED-TARGET EXPERIMENT IS A FACTOR OF ABOUT 25 LOWER THAN FOR POLARIZED ep-COLLIDERS.

2001:

TESLA-TDR/Appendices :

2 Proposals

TESLA-N

- Use one (positron) arm of TESLA for polarized fixed target experiment
- Beam energy varied between 30 - 250 GeV
- Use large kinematic domain for Q^2 evolution studies

- Transversity distribution
- Gluon polarization

HERMES → COMPASS kinematics

⇒ still a viable proposal for any LC with high repetition rate (cold LC) !

ELFE

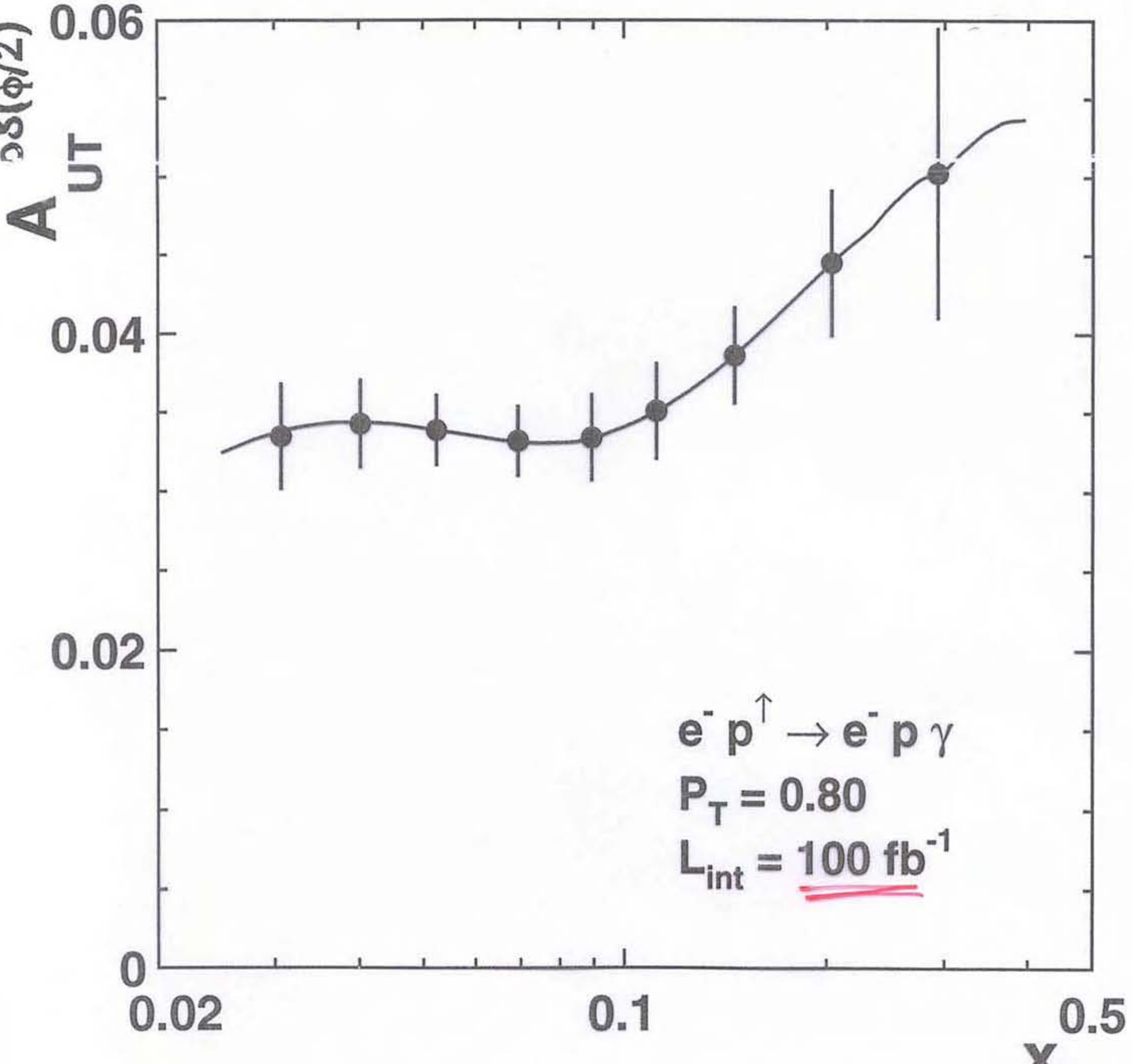
- Inject electron beam @ 30 GeV in modified HERA-e
- Use HERA as stretcher ring ⇒ extract high dutyfactor beam
- Fully exploit high resolution for exclusive reactions

- Skewed Parton Distributions
- High precision exclusive reactions

HERMES kinematics

→ HERA will definitely stop ≤ middle 2007

High Luminosity
TESLA-N / ELFE - type exp.
w/ transv. pol. target



[Korotkov]

SUMMARY

- ▷ GENERALIZED PARTON DISTRIBUTIONS BEAR A FASCINATING POTENTIAL TO FULLY DESCRIBE THE MOMENTUM AND ANGULAR MOMENTUM STRUCTURE OF THE NUCLEON

- ▷ HERA:
  THE NEW HERMES RECOIL DETECTOR, COMBINED WITH AN UNPOLARIZED PROTON TARGET, WILL LEAD TO SIGNIFICANT IMPROVEMENTS IN RESOLUTION AND STATISTICS FOR MEASUREMENTS OF AZIMUTHAL ASYMMETRIES IN HARD EXCLUSIVE REACTIONS (DVCS, PSEUDOSCALAR AND VECTOR MESON PRODUCTION).
  H1, ZEUS AND ALSO HERMES WILL CONTRIBUTE BY IMPORTANT CROSS SECTION MEASUREMENTS.

- ▷ KINEMATICALLY COMPLEMENTARY HIGH STATISTICS MEASUREMENTS WILL BE CARRIED OUT AT JLAB.

- ▷ THE WORLD-WIDE EFFORT TO MEASURE EXCLUSIVE REACTIONS WILL HAVE TO BE FOLLOWED BY A GLOBAL ANALYSIS TO SORT OUT THE BEST MODELS FOR GENERALIZED PARTON DISTRIBUTIONS.