results and future on DVCS and DVES

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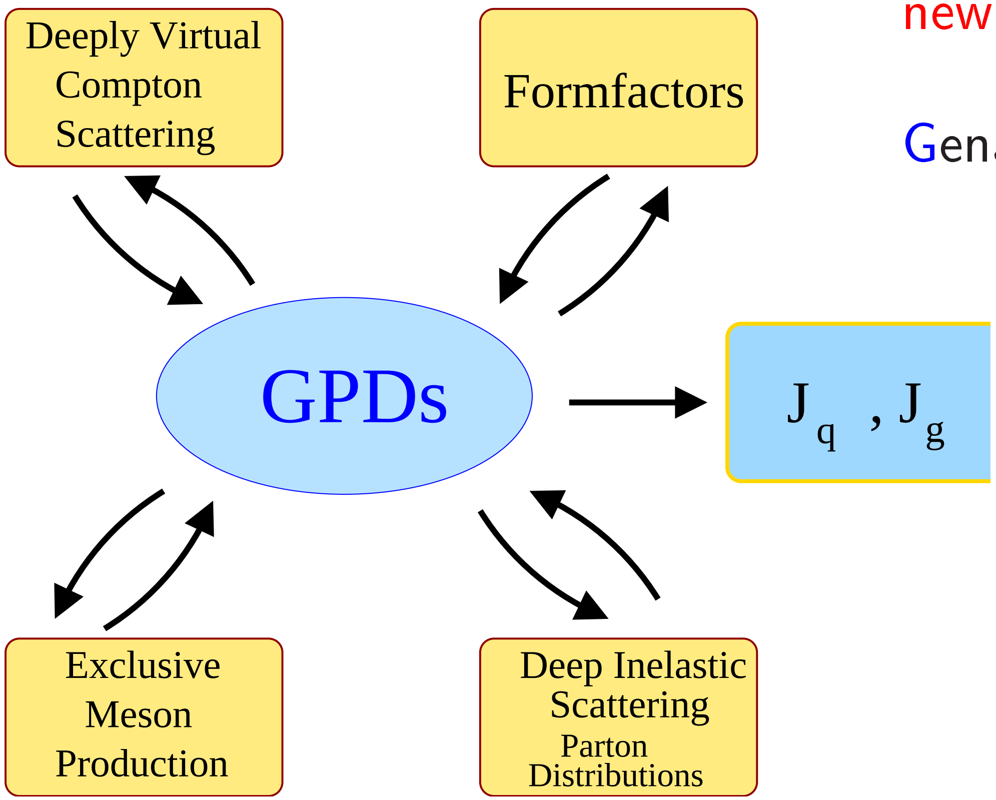
on behalf of the HERMES collaboration

European workshop on the QCD structure of the Nucleon - QCD-N^{02}
April 3-6, 2002, Ferrara, Italy

- exclusive photons (dvcs)
- exclusive vector mesons (ρ, ω, ϕ)
- exclusive pseudoscalar mesons (π^+, π^0)



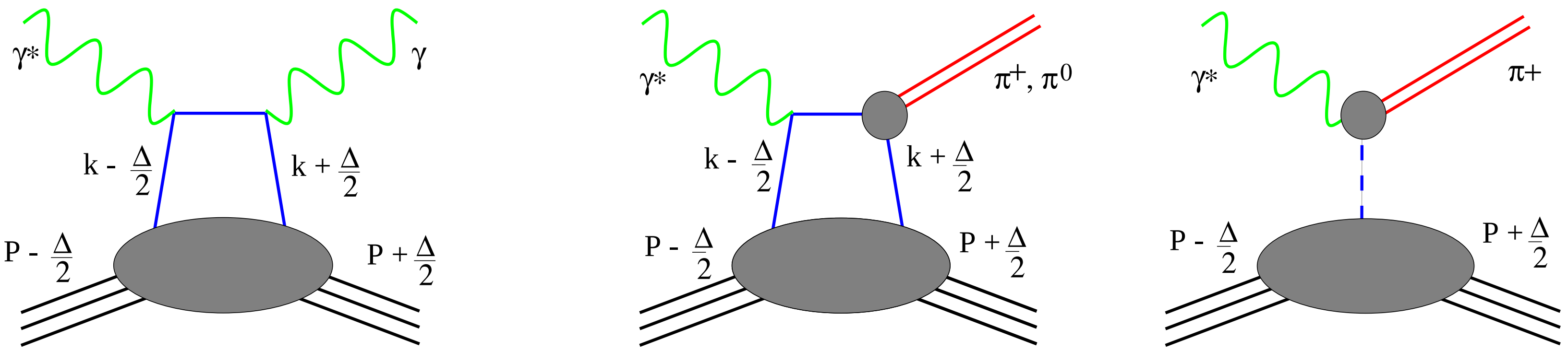
new observables in hard exclusive processes:

Genaralised Parton Distributions ($H, E, \tilde{H}, \tilde{E}$)

$\Rightarrow$ access to orbital angular momentum:

$$\boxed{\int x \mathrm{d}x \, (H + E) = J_q}$$

GPDs introduction - cont'd



quantum numbers of final state $\rightarrow$ select different GPDs

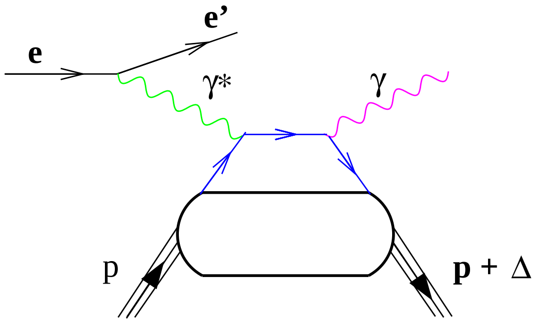
DVCS: $H, E, \tilde{H}, \tilde{E}$
vector mesons: H, E
pseudoscalar mesons: $\tilde{H}, \tilde{E}$

quadratic combination of GPDs appear in unpolarised cross section
$\rightarrow$ **polarisation** provide **new observable**

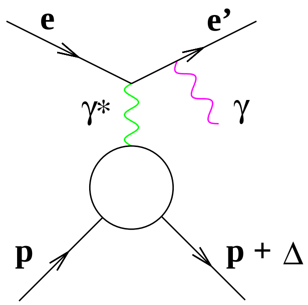
dvcs

$\mathbf{ep \rightarrow e' \, \gamma \, p}$

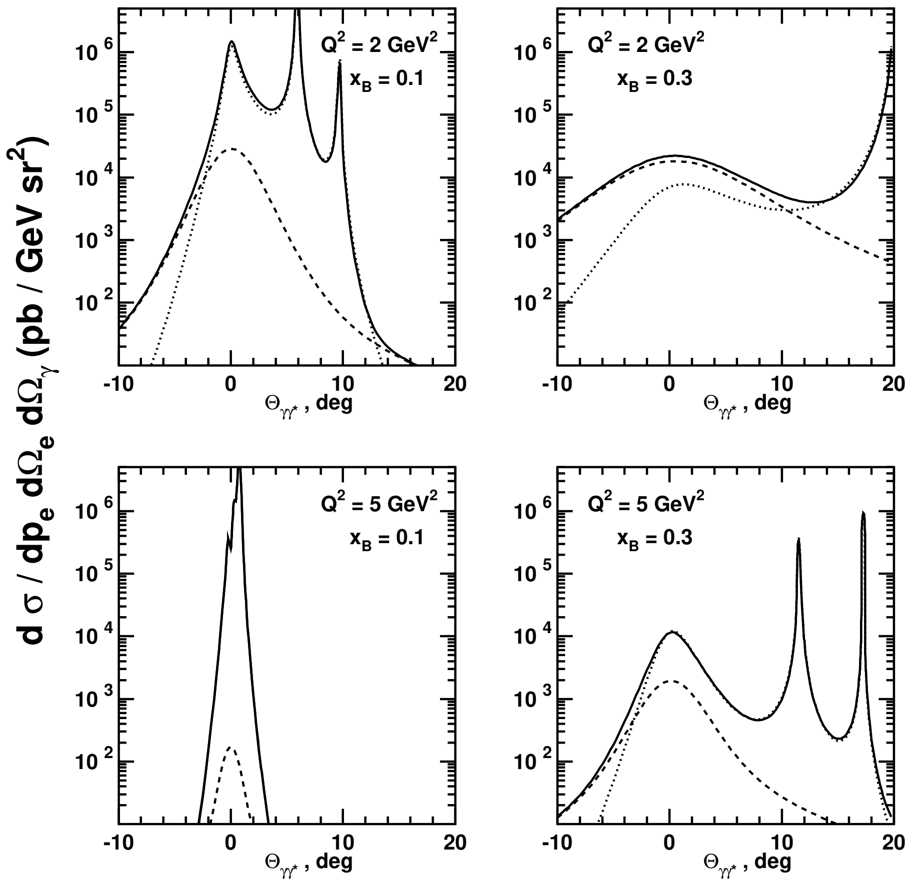
BH process larger than DVCS in HERMES kinematics:



DVCS



Bethe-Heitler (BH)

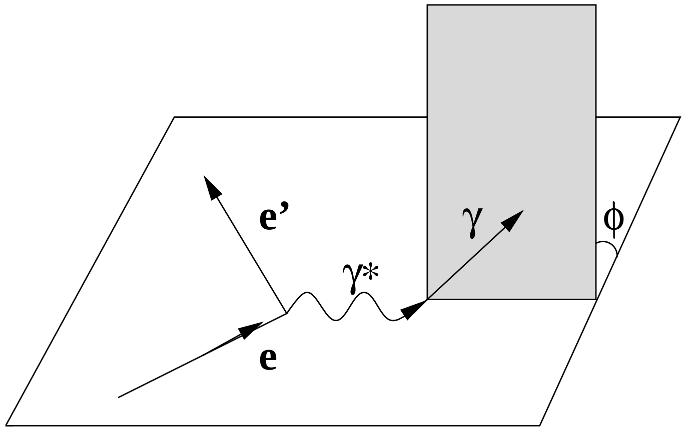


[Korotkov, Nowak, hep-ph/0108077]

$$
\begin{aligned}
d\sigma \quad &\propto \quad |\mathcal{T}_{BH}|^2 + |\mathcal{T}_{DVCS}|^2 \\
&+ \quad (\mathcal{T}^*_{BH}\mathcal{T}_{DVCS} + \mathcal{T}^*_{DVCS}\mathcal{T}_{BH})
\end{aligned}
$$

DVCS-BH interference:

$\rightarrow$ use BH as a vehicle to study DVCS



ϕ: azimuthal angle between lepton scattering plane and the $\gamma^* \gamma$ - plane

isolate BH-DVCS interference term:

- imaginary part $\propto$ beam helicity asymmetry:

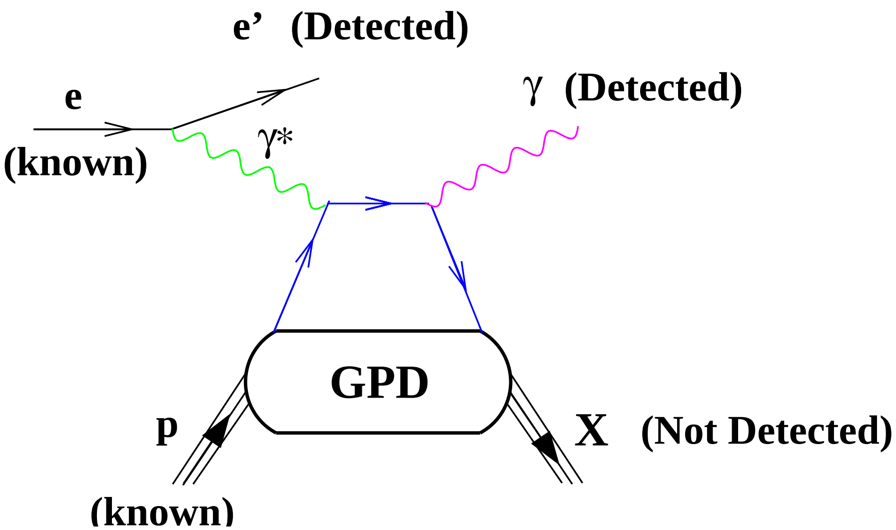
$$d\sigma_{\overleftarrow{e^+}} - d\sigma_{\overrightarrow{e^+}} \propto \mathrm{Im}\,(\mathcal{T}_{BH}\mathcal{T}_{DVCS})$$
$$\propto \sin\phi \qquad \text{(leading twist)}$$

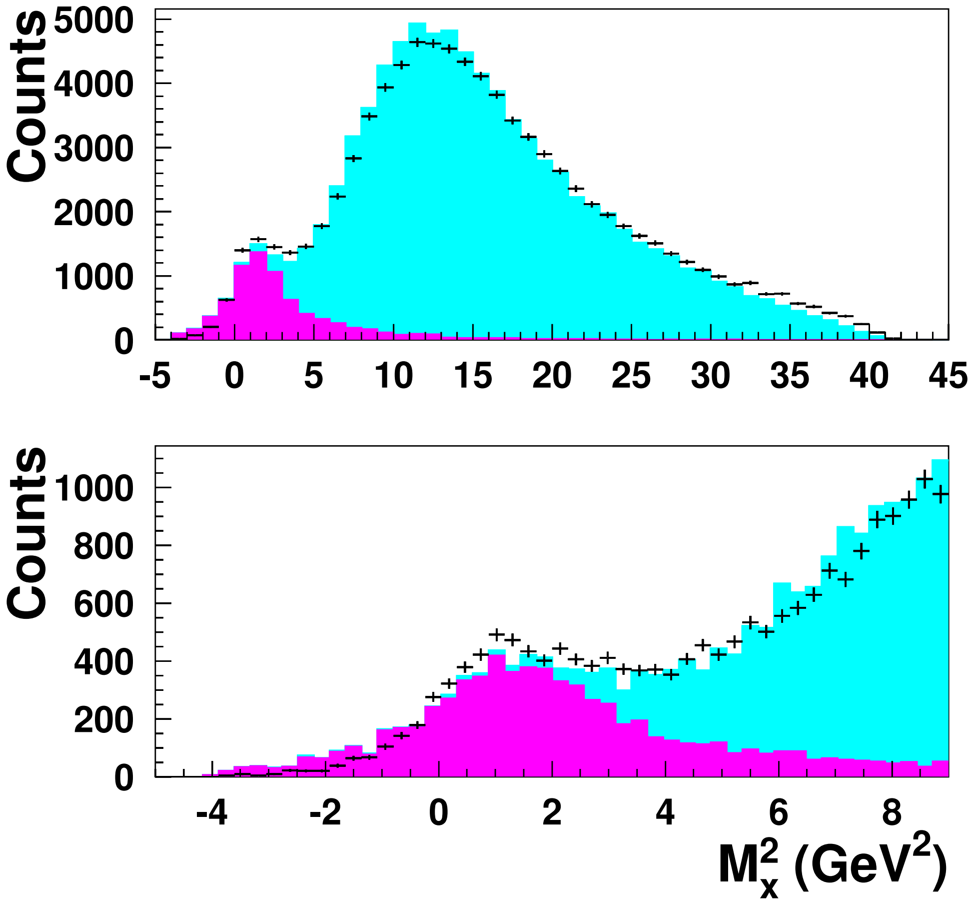
- real part $\propto$ beam charge asymmetry:

$$d\sigma_{e^+} - d\sigma_{e^-} \propto \mathrm{Re}\,(\mathcal{T}_{BH}\mathcal{T}_{DVCS})$$
$$\propto \cos\phi \qquad \text{(leading twist)}$$

$\Rightarrow$ both asymmetries measured by HERMES

dvcs photon spectrum

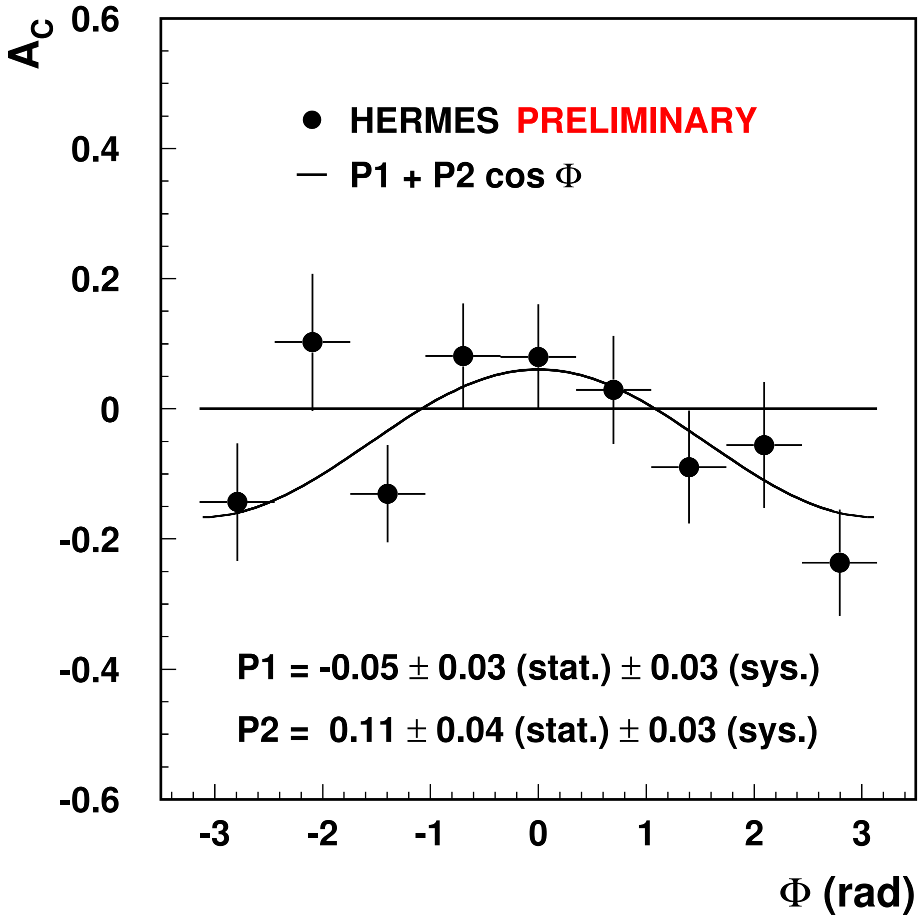




- calo energy resolution in exclusive region:
  $\langle E_\gamma \rangle \approx 12$ GeV $\rightarrow$ $\sigma(E_\gamma) \approx 0.5$ GeV
- background $\pi^0 \rightarrow \gamma\gamma$ estimated with preshower

$$\mathrm{M}_x^2 = (p + q - cl)^2, \quad \sigma(\mathrm{M_x}) \approx 0.8 \text{ GeV}$$

dvcs — beam charge asymmetry (BCA)

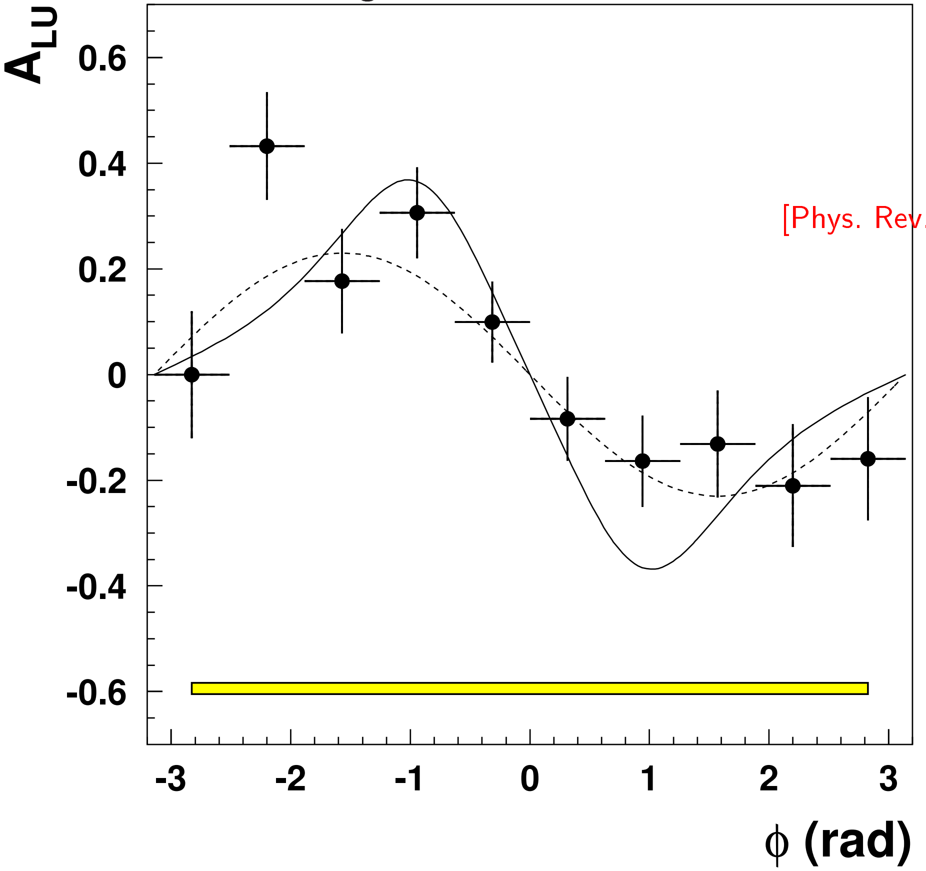


$$A_C(\phi) = \frac{N_{e^+}(\phi) - N_{e^-}(\phi)}{N_{e^+}(\phi) + N_{e^-}(\phi)}$$

exclusive region: $-1.5 < M_x < 1.7$ GeV

$\Rightarrow$ see talk of Frank Ellinghaus

dvcs — single beam-spin asymmetry (SSA)



$$A_{\mathrm{LU}}(\phi) = \frac{1}{\langle |P_l| \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

[Phys. Rev. Lett. 87 (2001), 182001]

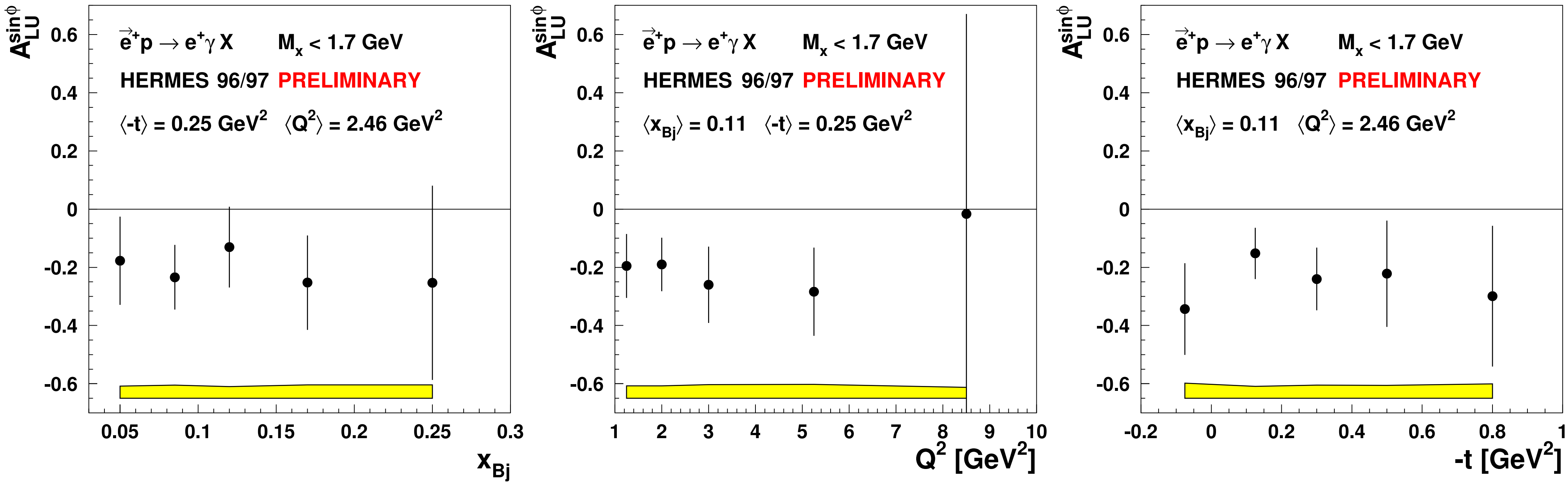
$$A_{\mathrm{LU}}^{\sin\phi}(\phi) = -0.23 \pm 0.04 \pm 0.03$$

at $\langle x \rangle = 0.11$, $\langle Q^2 \rangle = 2.5$ GeV^2, $\langle -t \rangle = 0.27$ GeV^2

—— GPD expectation including twist-3 contribution

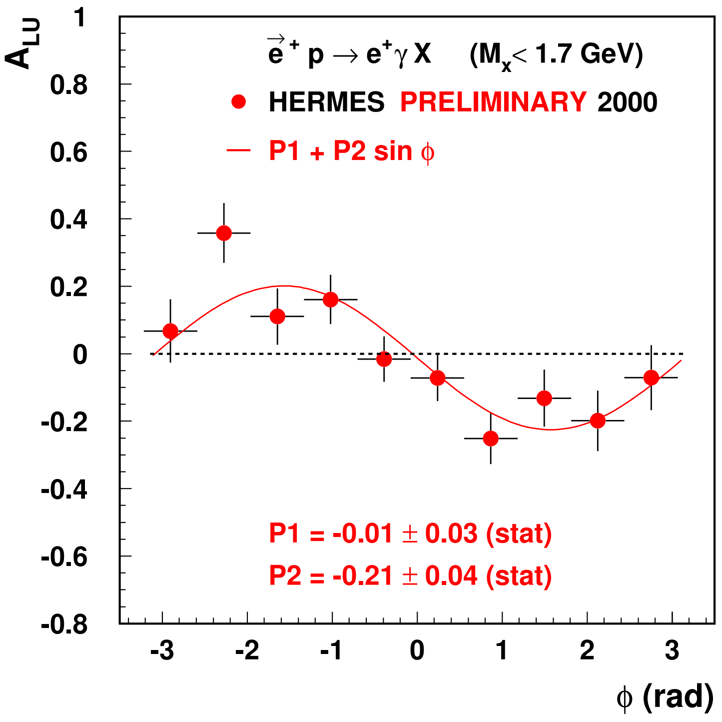
[Kivel, Polyakov, Vanderhaegen, Phys. Rev. D 63 (2001), 114014]

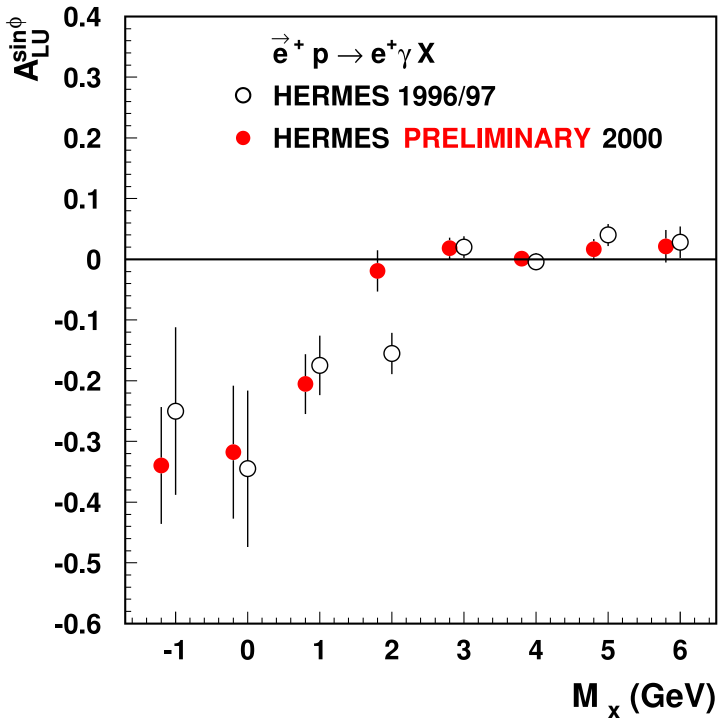
dvcs SSA kinematic dependences



dependences on x, Q^2, and $-t$ consistent with a Monte Carlo simulation based on twist-2 GPD model [Guichon, Guidal, Vanderhaegen, Phys. Rev. D 60 (1999), 094017]

dvcs ongoing analyses 2000 data





$\longrightarrow$ combined 96/97 + 2000 data set :
needs MC studies (known resolution difference due to different spectrometer setups)

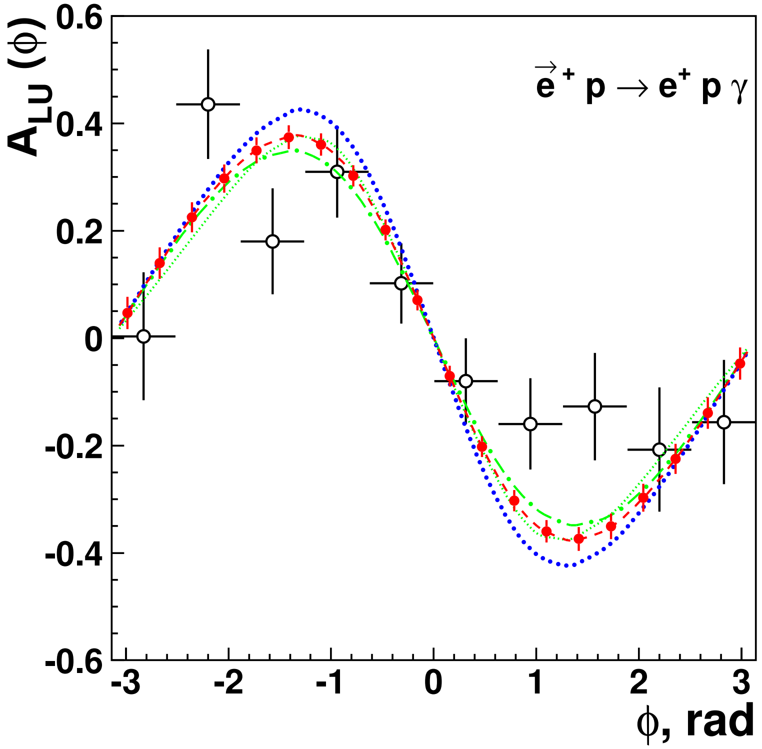
$\longrightarrow$ SSA from 2000 deuterium data

$\longrightarrow$ target-spin asymmetry from 96/97 hydrogen and 2000 deuterium

future — HERMES run II — upgrade: recoil detector

$2\ fb^{-1}$ projections for one year of data taking

→ high density unpol. runs planned for 2002,3



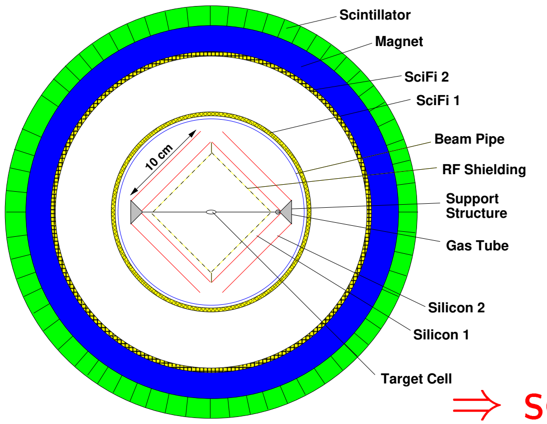
improvement in systematics:

→ beam polarisation measurement with new calorimeter

→ improved reconstruction of the forward photon in the calorimeter (energy resolution and impact position)

→ improved $\gamma - \pi^0$ separation

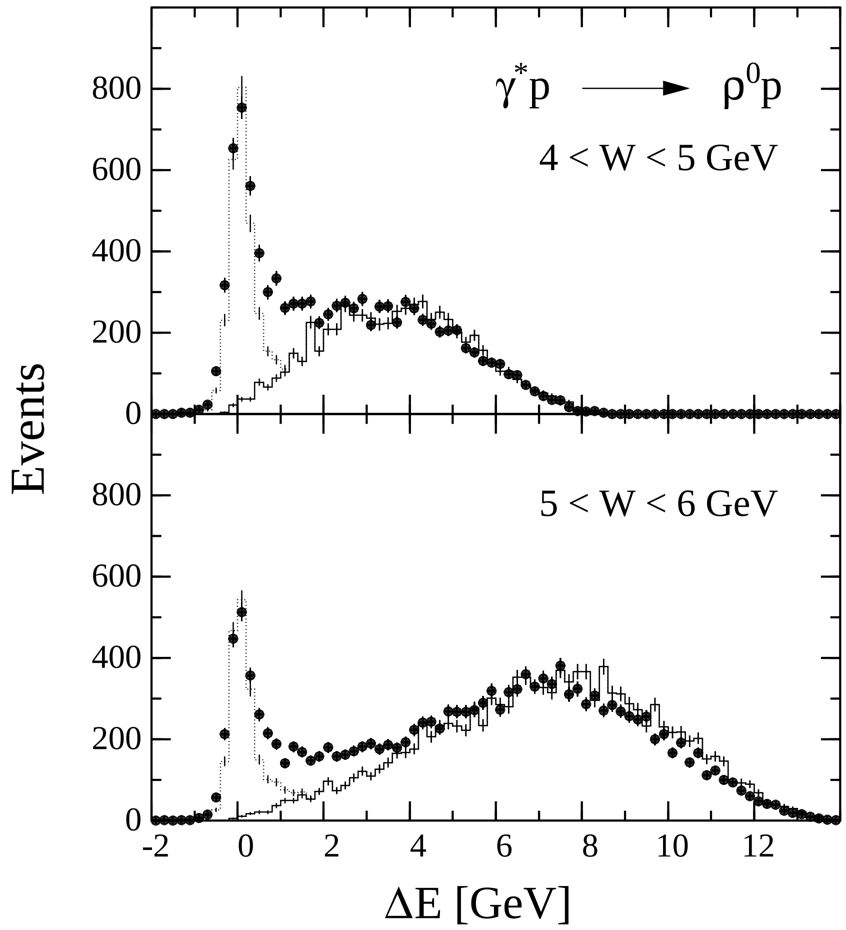
→ detection of the recoiling proton:



⇒ see talk of K. Rith

exclusive VM-production

$$\boxed{\mathbf{e\ p} \rightarrow \mathbf{e}'\ \rho^0(\phi,\omega)\ \mathbf{p}}$$



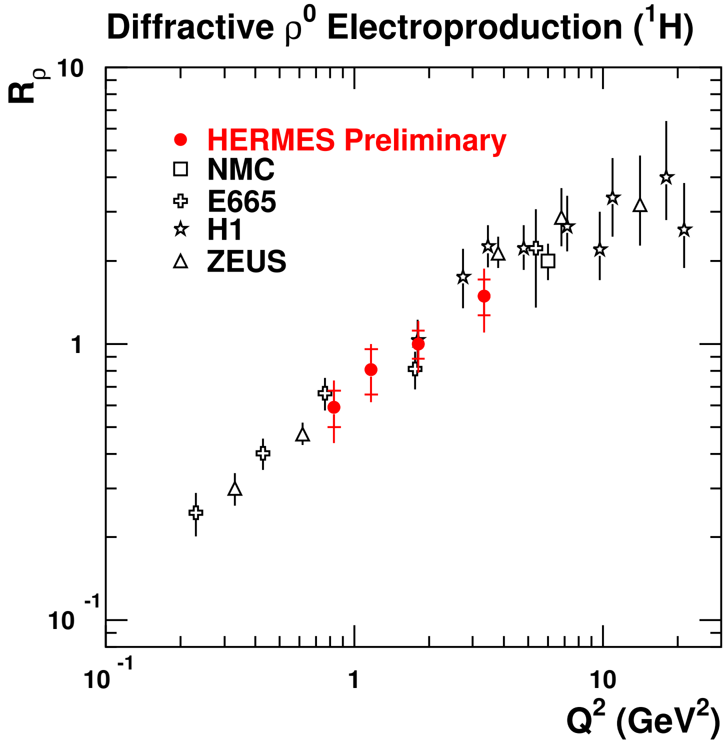
$$\rho^0 \rightarrow \pi^+\pi^-$$
$$\phi \rightarrow K^+K-$$
$$\omega \rightarrow \pi^+\pi^-\pi^0$$

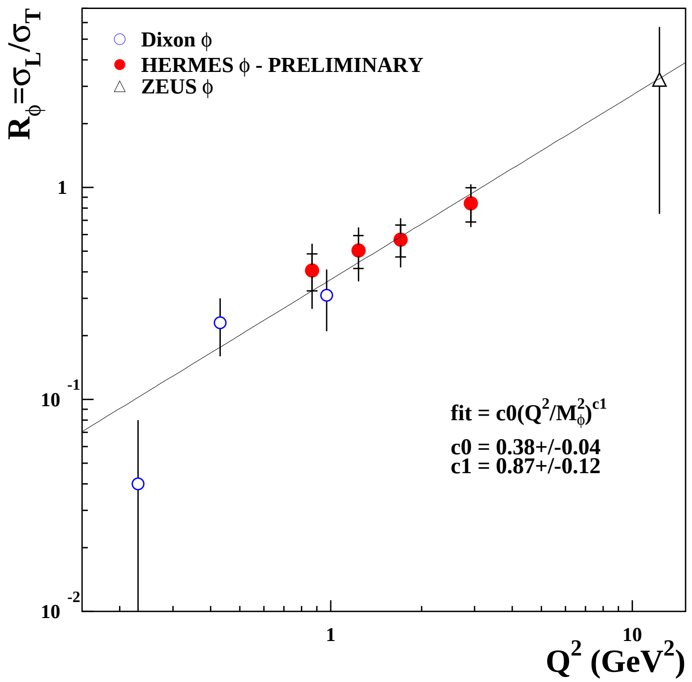
$\Rightarrow$ good determination of exclusive channel
$\rightarrow$ DIS-‘background‘ well described by Monte Carlo
$\rightarrow$ somewhat worse for ϕ and ω

$\Rightarrow$ deduce longitudinal cross section from decay angular distributions

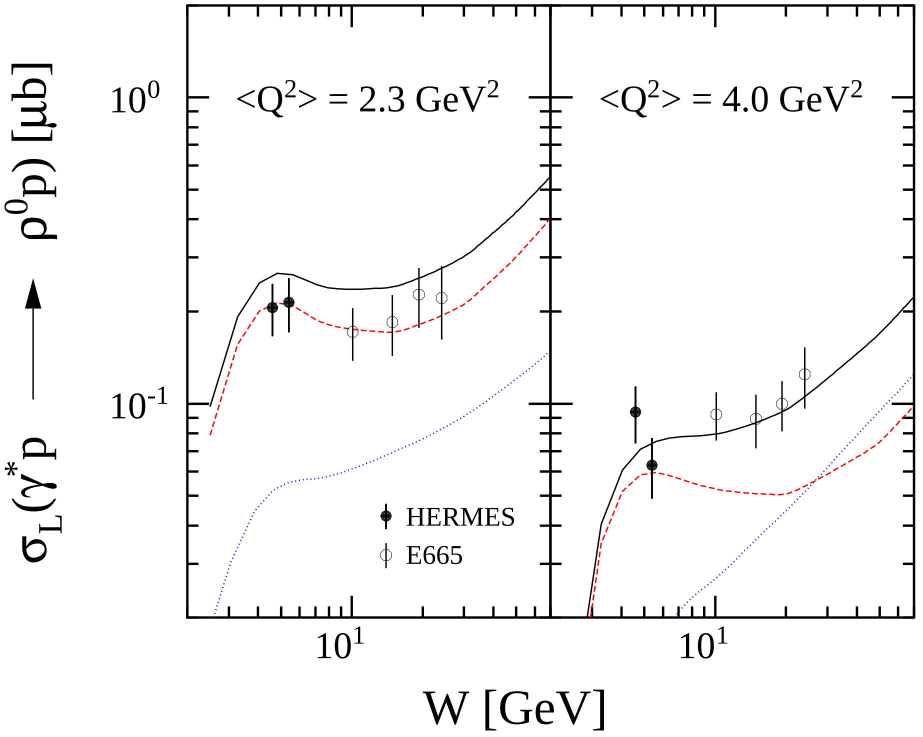
exclusive ρ^0, ϕ — σ_L/σ_T separation

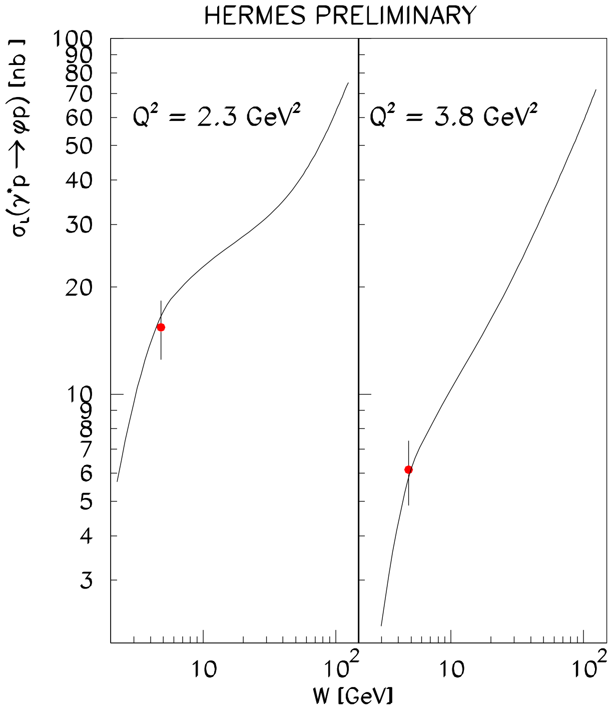
assuming SCHC + knowledge of γ^* polarisation: $R = \frac{\sigma_L}{\sigma_T} = \frac{1}{\epsilon} \frac{r^{04}_{00}}{1 - r^{04}_{00}}$





exclusive ρ^0, ϕ $\boxed{\sigma_L}$



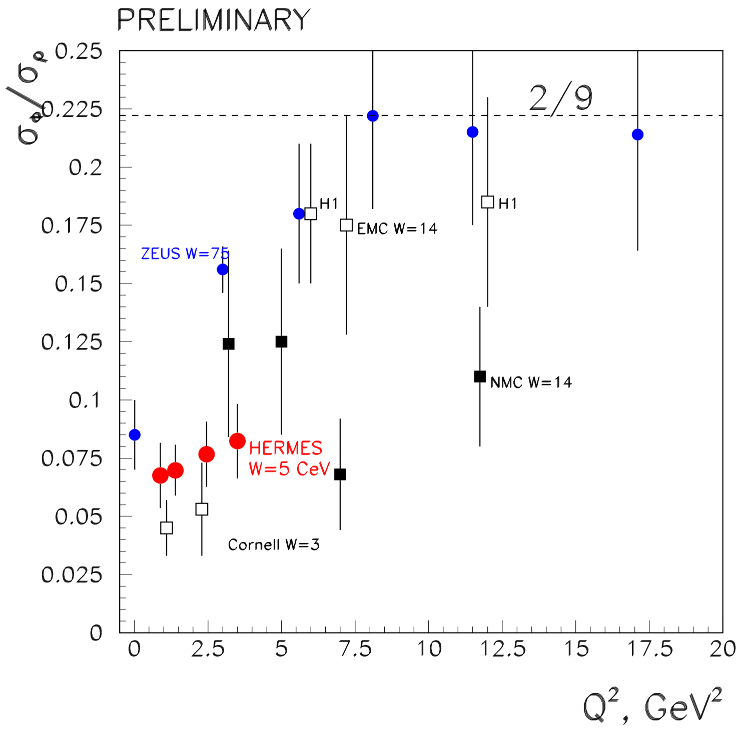


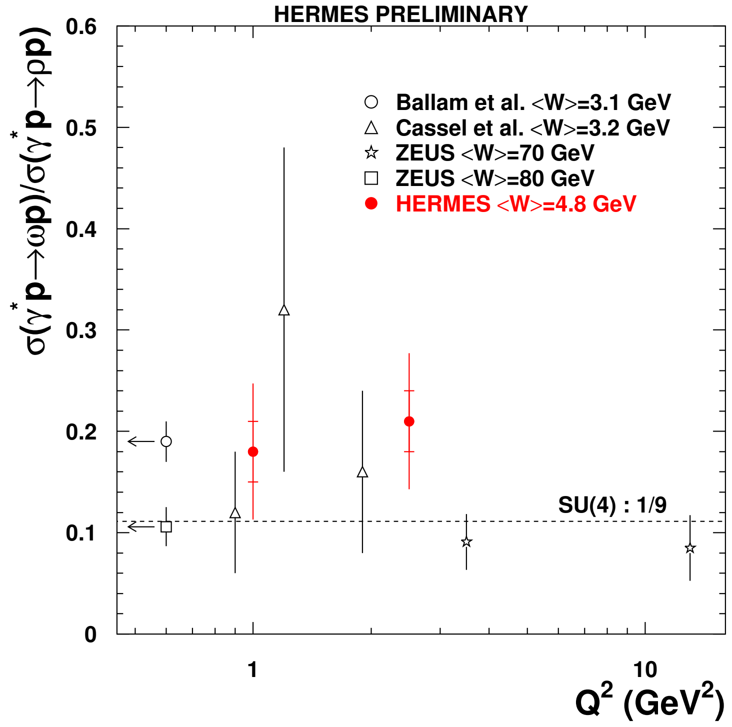
[Guichon, Guidal, Vanderhaegen, Phys. Rev. D 60 (1999), 094017; private communication 2001]

GPD calculations: ◦ quark exchange mechanism dominates $\sigma_L(\gamma^* p \to \rho^0 p)$
◦ 2-gluon exchange mechanism dominates $\sigma_L(\gamma^* p \to \phi\, p)$

model dependent higher-twist effects mostly cancel in cross section ratios

$\Rightarrow$ precocious scaling for ϕ/ρ and ω/ρ



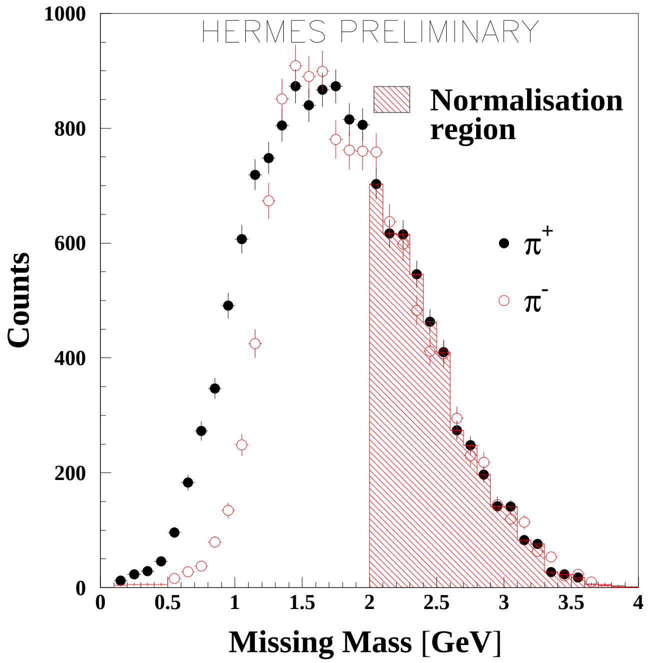


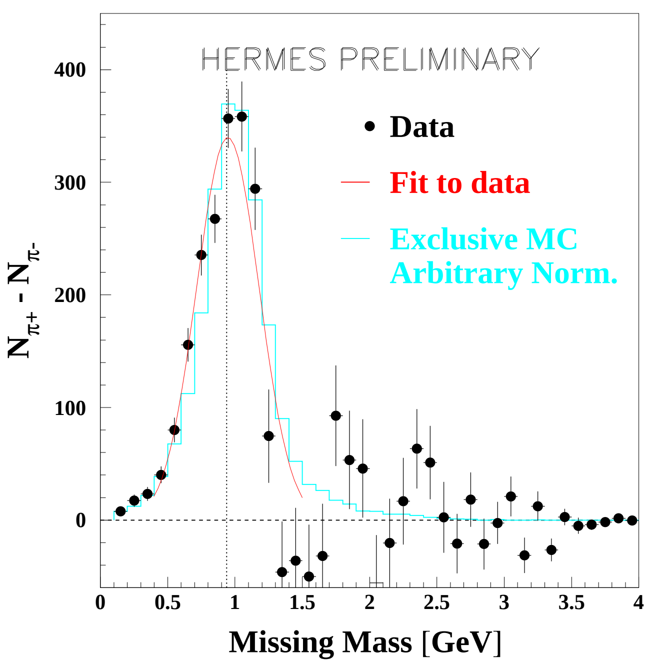
SU(4) prediction: 2/9 for σ_ϕ/σ_ρ

SU(4): 1/9 for $\sigma_\omega/\sigma_\rho$

$\rightarrow$ GPD expectation: 1/5

exclusive PS meson production $\boxed{e\ \vec{p} \rightarrow e'\ n\ \pi^+}$





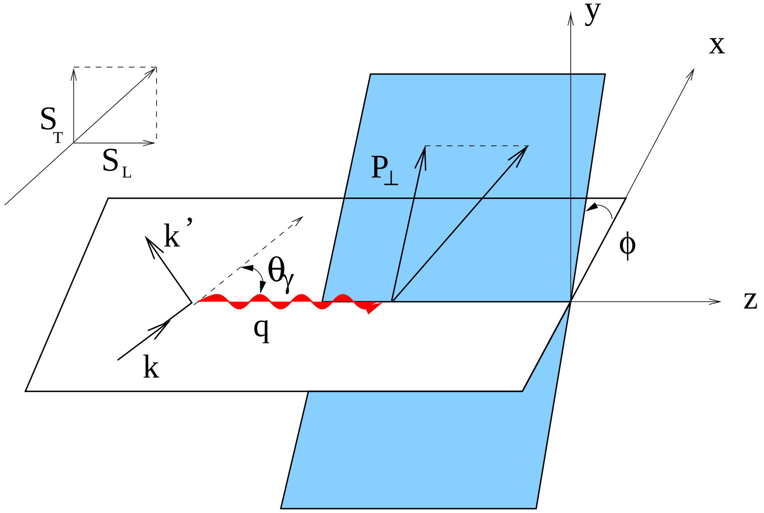
clear peak at missing mass $\approx \mathrm{M_n}$

position and width in agreement with Monte Carlo based on GPD model for $\sigma_L(Q^2, x, t)$

[Mankiewicz, Piller, Radyushkin, Eur. Phys. J. C10 (1999), 307]

$\longrightarrow$ deficit: difference in relative contribution of resonant and non-resonant channels to π^+, π^- yield
$\longrightarrow$ no σ_L/σ_T (Rosenbluth) separation foreseen for the moment

exclusive π^+ target - SSA



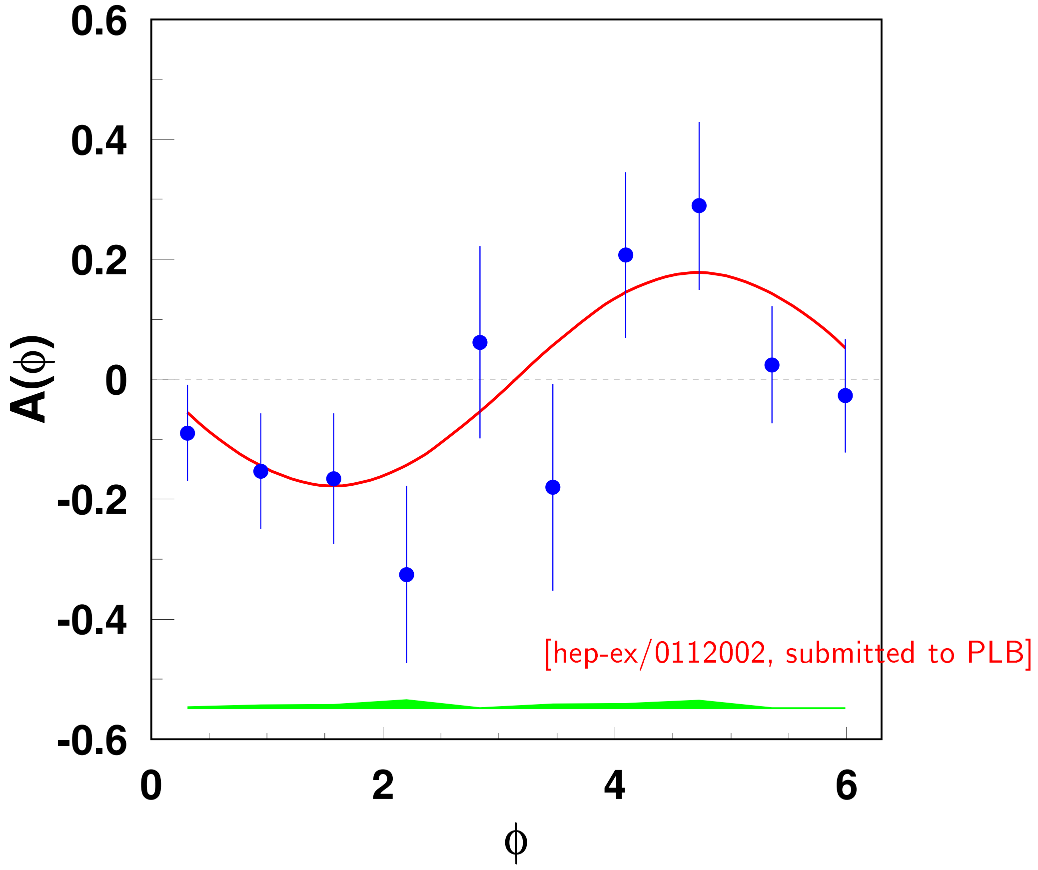
transverse component in γ^* frame:

$$\boxed{\sigma_S \sim [S_\perp \sigma_L + S_\parallel \sigma_{LT}] \cdot A_{UL}^{\sin\phi} \sin\phi}$$

σ_{LT} suppressed by $1/Q \cdots$ but $S_\parallel > S_\perp$

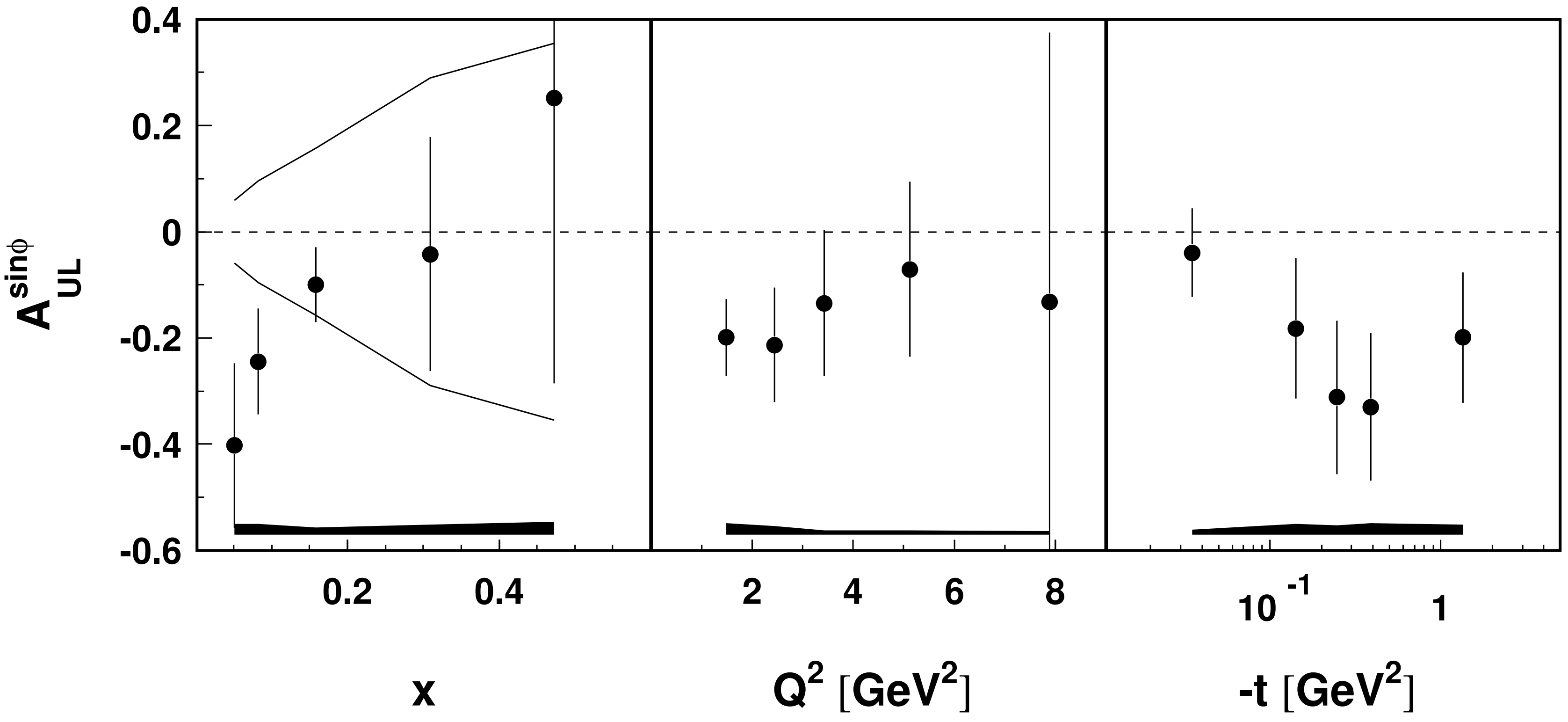
HERMES in 1997: $\boxed{S_\perp / S \sim 0.17}$

$$A_{UL}(\phi) = \frac{1}{\langle|P_t|\rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$



$$A_{UL}^{\sin\phi} = -0.18 \pm 0.05 \pm 0.02$$

exclusive π^+ target - SSA

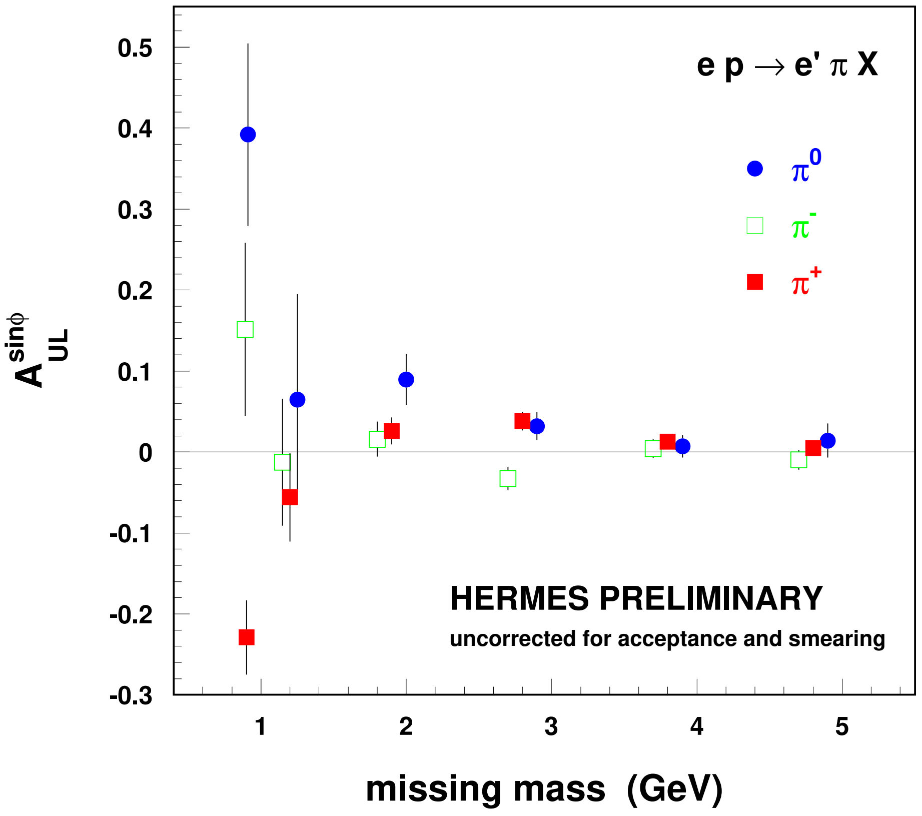


$$\boxed{\sigma_{\mathrm{P}} \sim [S_\perp(x,Q^2)\sigma_{\mathrm{L}} + S_\parallel(x,Q^2)\sigma_{\mathrm{LT}}]}$$

——— lines indicate limits for any asymmetry arising from *transverse* target component

$\Rightarrow$ asymmetry at low x arises from *longitudinal* target component $S_\parallel$ independently of any model

exclusive π^0 ongoing analyses + future



target-SSA for ep$\rightarrow$ e$'\pi^0$p

pseudoscalar ratios:

ep $\rightarrow$ e$'\pi^+$ n / ep $\rightarrow$ e$'\pi^0$p

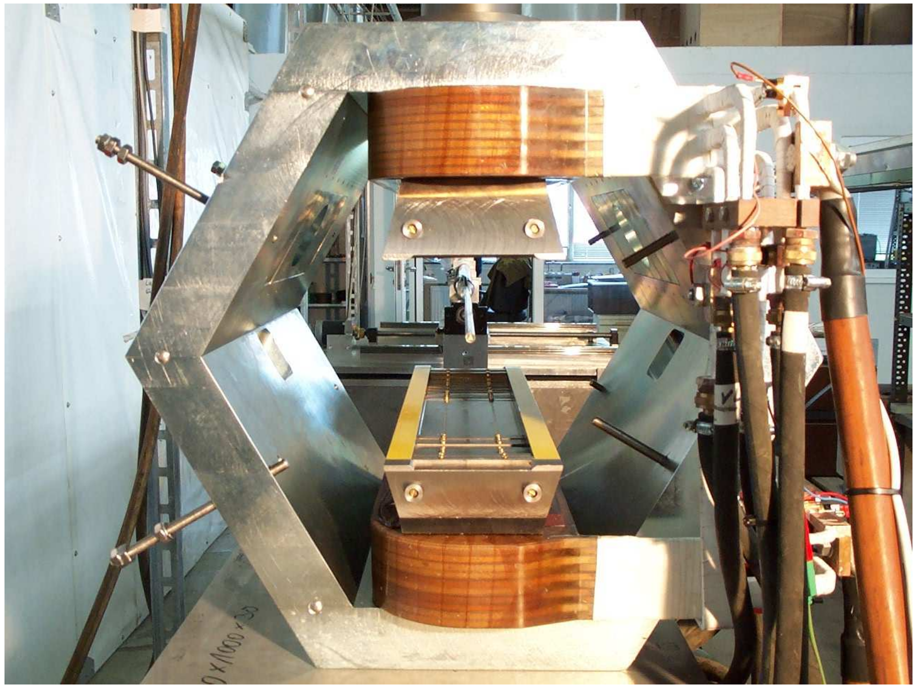
ep $\rightarrow$ e$'\eta$ p / ep $\rightarrow$ e$'\pi^0$p

ep $\rightarrow$ e$'\pi^0$p / en $\rightarrow$ e$'\pi^0$n

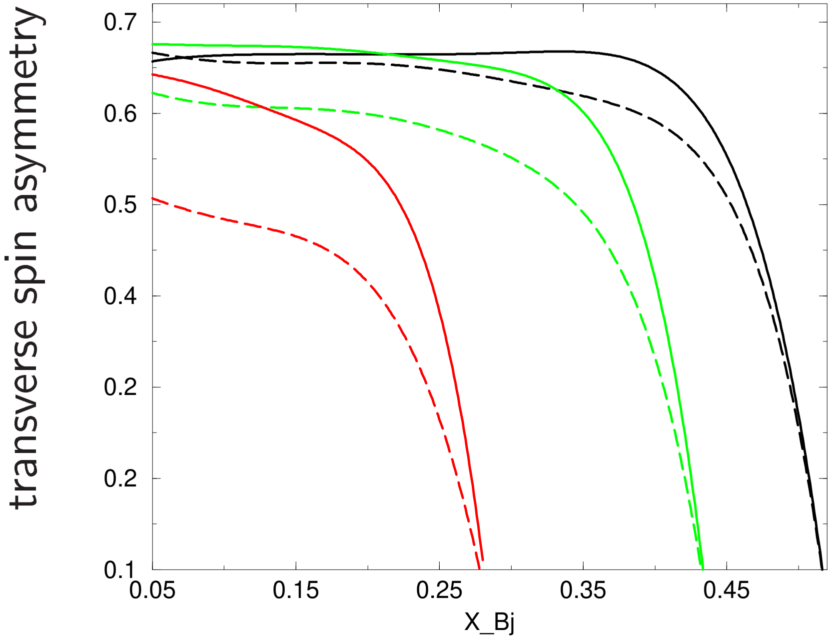
$\rightarrow$ detection of the recoiling proton

future ___ HERMES run II _________ transverse target ___

large transverse π^+ SSA expected due to interference between pole and non-pole amplitudes: $\sigma \propto |S_\mathrm{T}| \sin\phi \; \tilde{E} \cdot \tilde{H}$



target polarisation above 80 %



[Frankfurt,Pobylitsa,Polyakov,Strikman PRD60(1999),014010]

size of asymmetry depends on pion ff.:

1- asymptotic pion distribution amplitude

2- Chernyak-Zhitnitsky pion DA

summary & outlook

- DVCS: single beam-spin and beam charge azimuthal asymmetries extracted
  $\rightarrow$ more data from proton and deuteron targets
  $\rightarrow$ more data with electron beam

- DVES: first promising results from exclusive production of vector mesons ρ, ω, ϕ and pseudoscalar mesons π^+
  $\rightarrow$ ongoing analyses for π^0, η, K

$\Rightarrow$ comparison to GPD predictions
$\Rightarrow$ polarisation variables (target/beam) for single spin azimuthal asymmetries
$\Rightarrow$ beam charge variable for lepton charge azimuthal asymmetries

$\Rightarrow$ start of measurements with transversely polarised target
$\Rightarrow$ detector upgrades: recoil detector