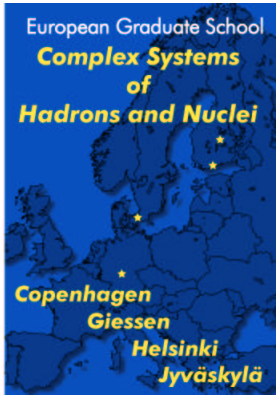


Workshop on In-Medium Hadron Physics

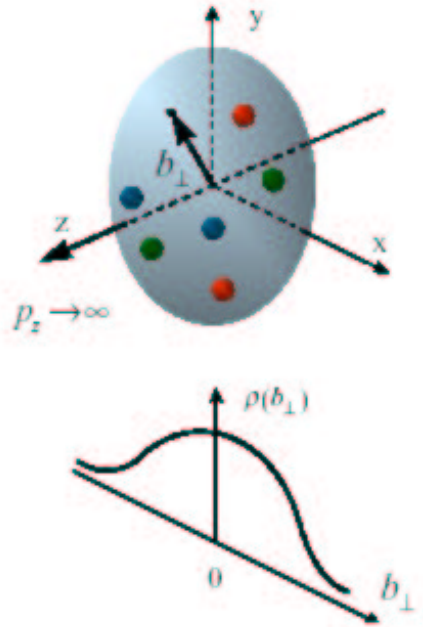
First Measurements of DVCS off Nuclei

Matthias Hoek

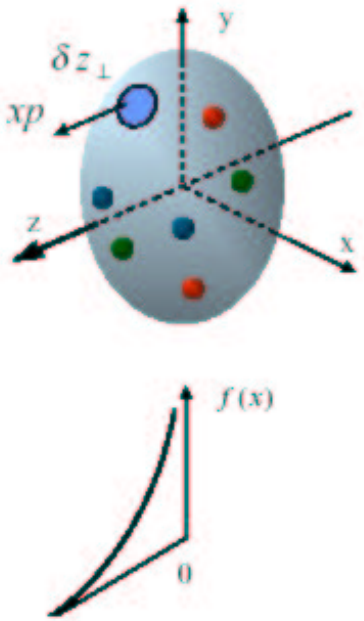
II. Physikalisches Institut, JLU Gießen

Generalized Parton Distributions

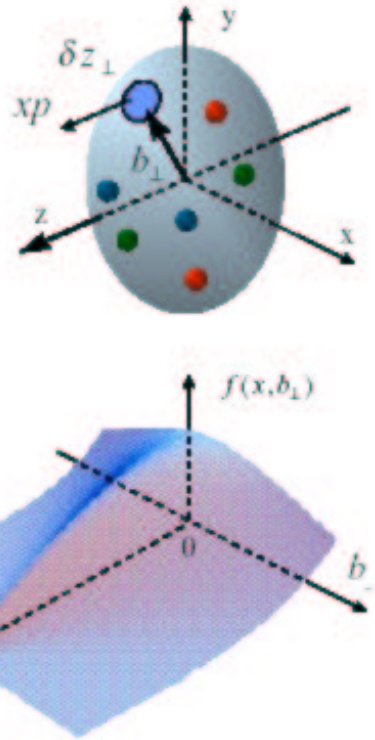
Form Factor



Parton Distribution



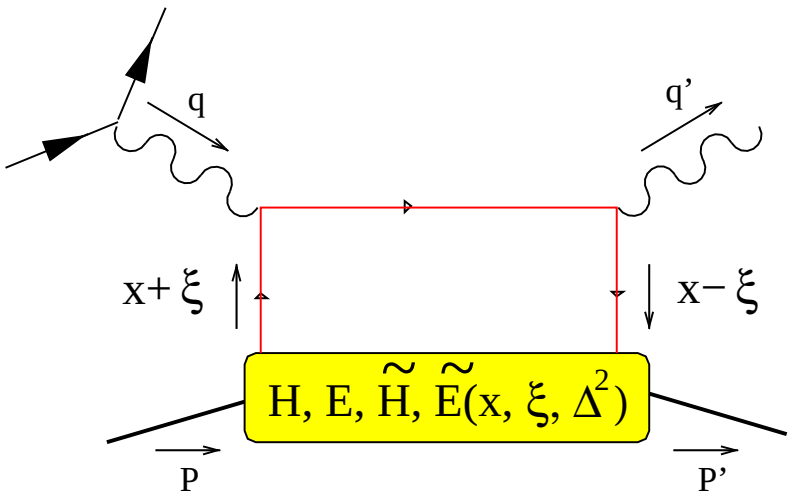
GPD



$\longrightarrow$ study **G**eneralized **P**arton **D**istributions via

Deeply **V**irtual **C**ompton **S**cattering

DVCS Handbag Approximation



$\Rightarrow$ DVCS process factorizes into

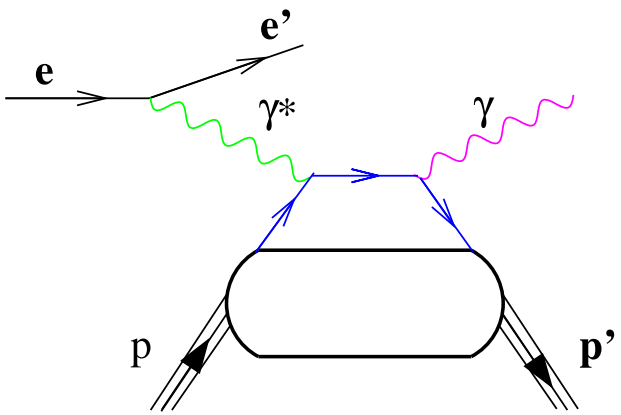
$\longrightarrow$ hard scattering part (pQCD)

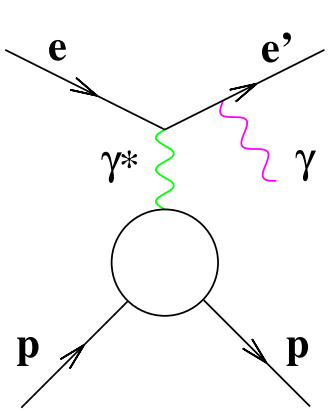
$\longrightarrow$ non-perturbative part (GPD)

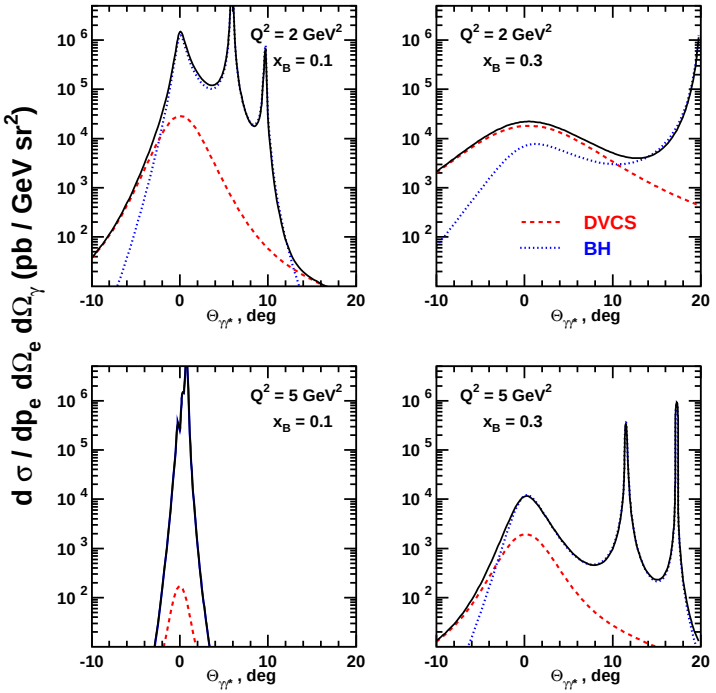
(Collins et al., Phys Rev D59, 1999)

- GPDs depend on three variables
  - x, $\xi \longrightarrow$ light-cone momentum fractions
  - $\xi \longrightarrow \frac{x_B}{2-x_B}$ in Bjorken limit
  - $\Delta^2 = \left(p_\gamma^* - p_\gamma\right)^2 = -t$

DVCS-Bethe Heitler Interference



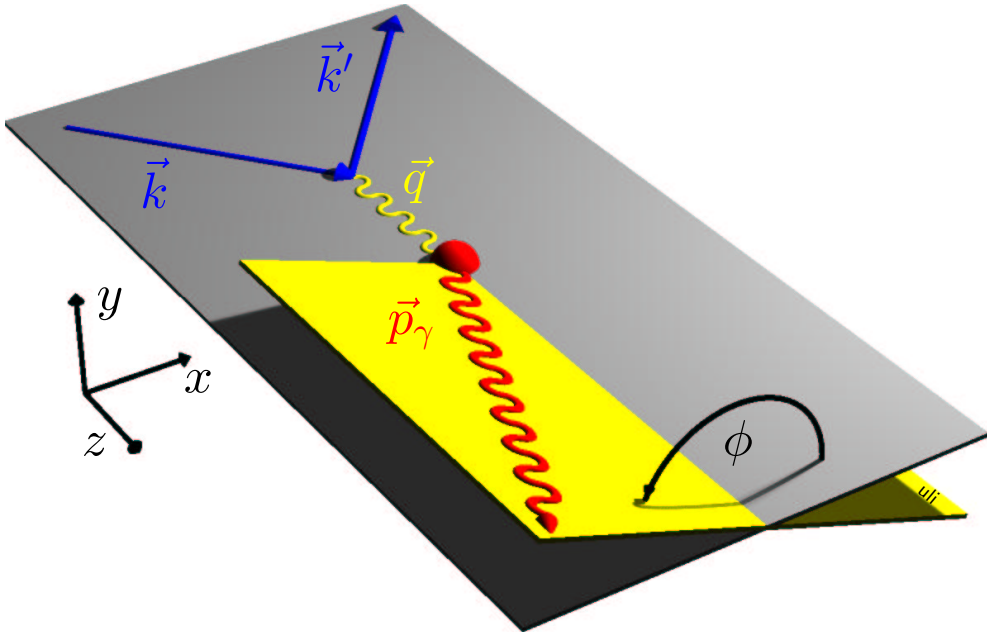




DVCS & BH $\rightarrow$ same final state

$$\frac{d\sigma}{d\,x_B\;d\,Q^2\;d|t|d\,\phi} = x_B\;y^2\,\frac{|\tau_{BH}|^2+|\tau_{DVCS}|^2+\overbrace{\tau_{DVCS}\,\tau^*_{BH}+\tau^*_{DVCS}\,\tau_{BH}}^{\mathcal{I}}}{32(2\,\pi)^4 Q^4\sqrt{1+4x_B^2M_p^2/Q^2}}$$

Measuring DVCS Asymmetries



- DVCS-BH interference gives direct access to amplitudes
- Decompose $\mathcal{I}$ in sum of Fourier harmonics

  (Belitsky et al. hep-ph/0112108)
- Beam Charge Asymmetry

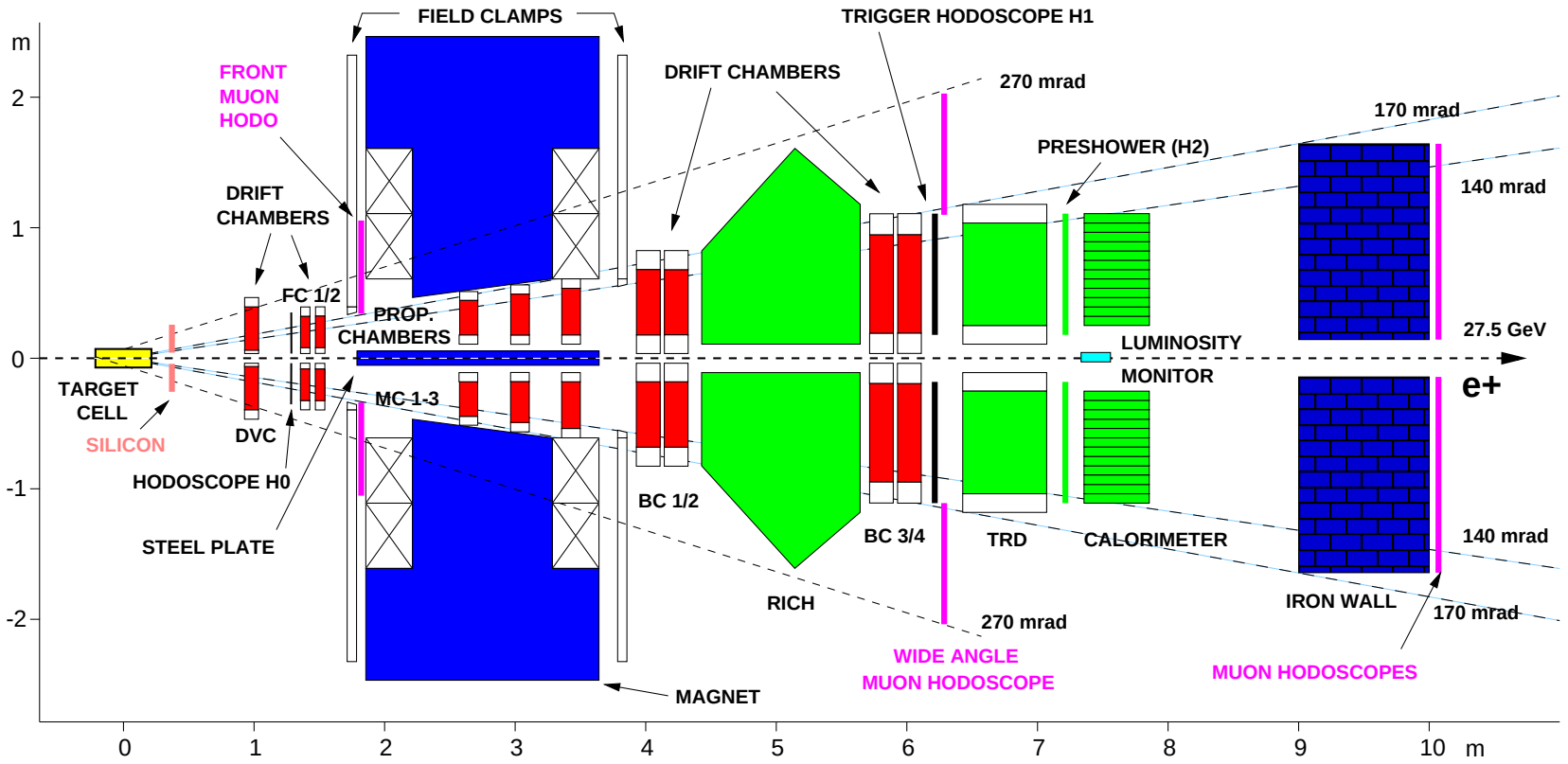
  $\rightarrow$ real part
- Beam Spin Asymmetry

  $\rightarrow$ imaginary part

$$\mathcal{I} = \pm \frac{4\sqrt{2}\, m\, e^6}{t\, Q\, x_B} \frac{1}{\sqrt{1-x_B}} \cdot \cos\phi \frac{1}{\epsilon\,(\epsilon-1)} \Re M^{1,1} - P_l \sin\phi \sqrt{\frac{1+\epsilon}{\epsilon}} \Im M^{1,1}$$

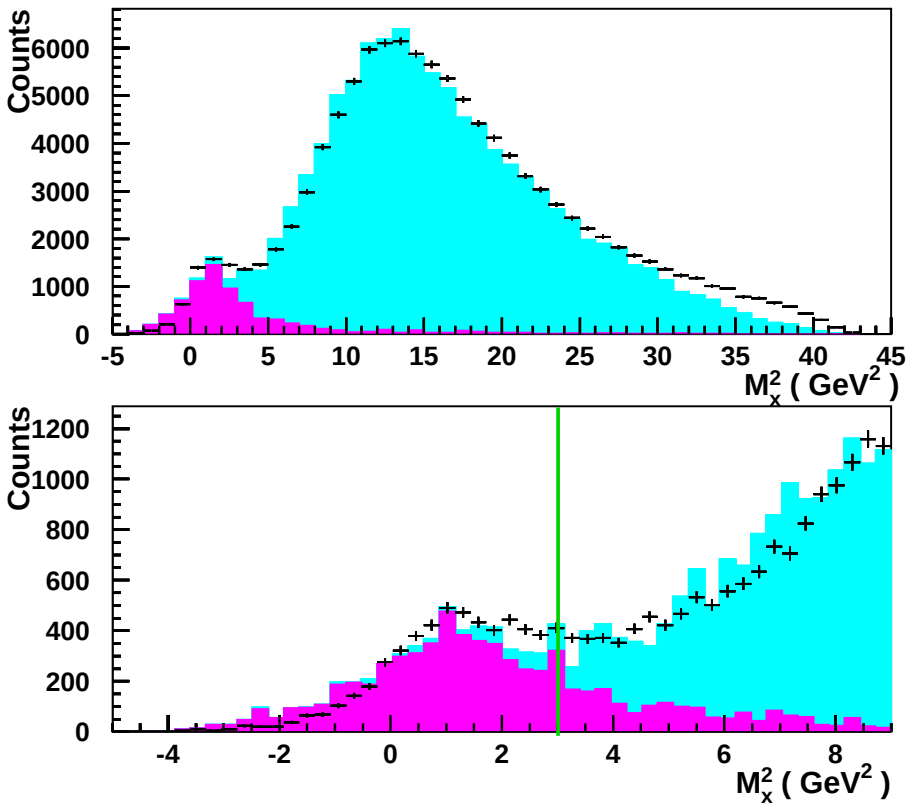
$\rightarrow M^{1,1}$ is a combination of GPDs

The HERMES experiment



- Internal gas targets: $\vec{H}, \vec{D}, H_2, D_2, {}^{20}Ne, {}^{84}Kr$
- Beam: 27.6 GeV positrons or electrons, $\langle P_B \rangle \approx 0.55$
- Reconstruction: $\frac{\Delta P}{P}$ < 1.6%, $\epsilon_{e^\pm} \geq 97\%$

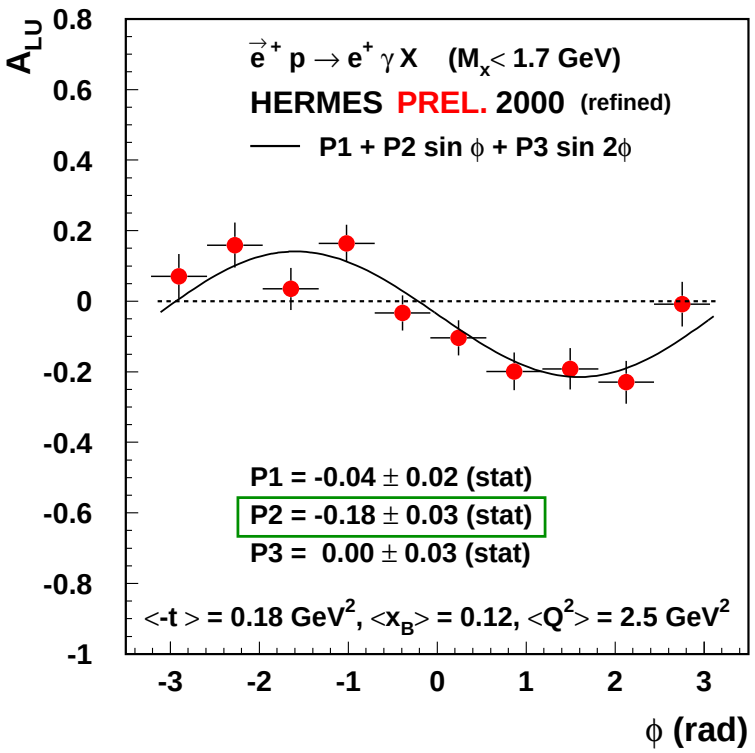
Establish Exclusivity

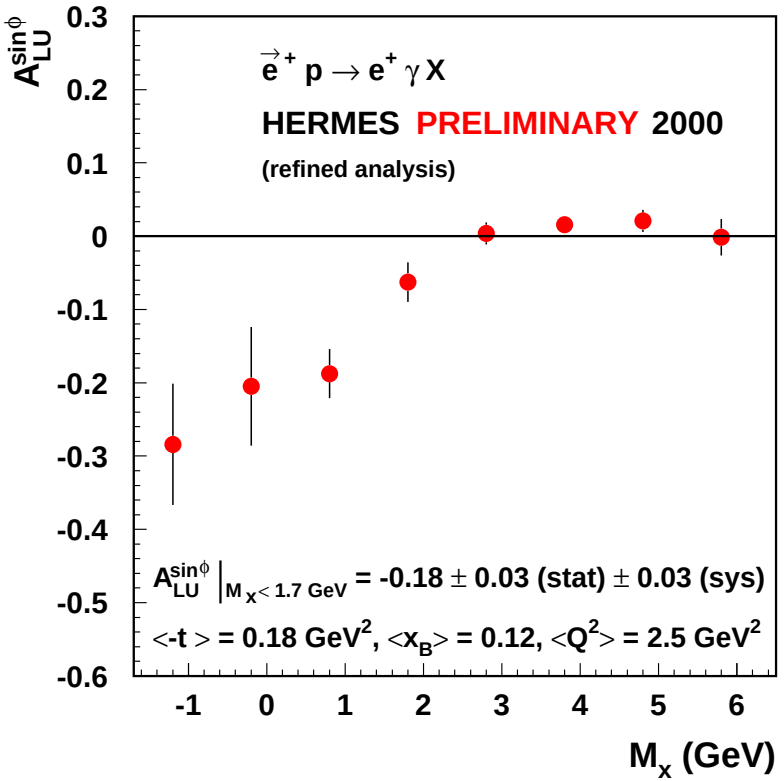


$$M_x^2 = m_p^2 + 2\,m_p\,(\nu - E_\gamma) + t$$

- Detect photon
  $\rightarrow$ calorimeter
- Detect lepton
  $\rightarrow$ spectrometer
- Identify reaction by missing mass cut
  $M_X^2 < 3\,\mathrm{GeV}$
- Kinematic requirements
  $\rightarrow$ $Q^2 > 1\,\mathrm{GeV}^2$
  $\rightarrow$ $W^2 > 4\,\mathrm{GeV}^2$

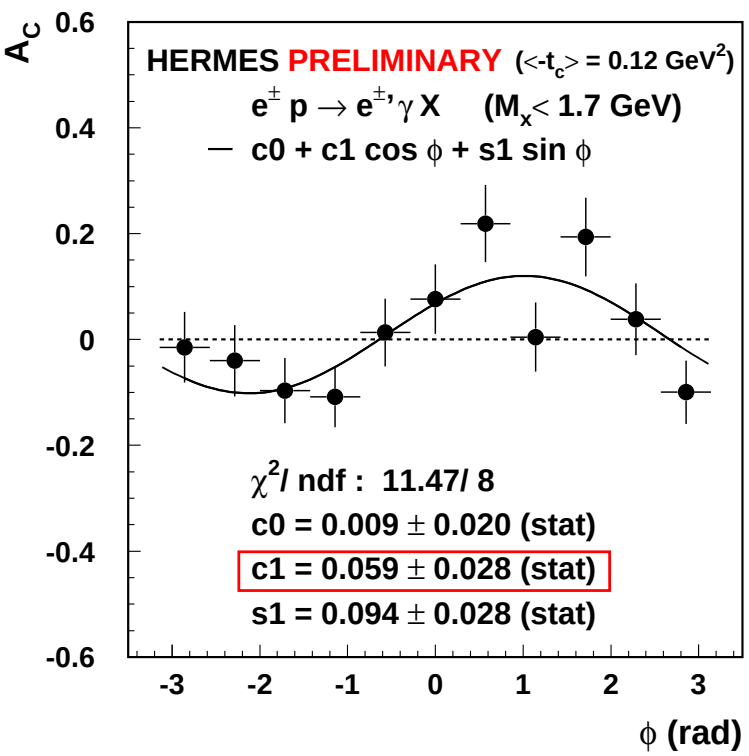
BSA on Proton

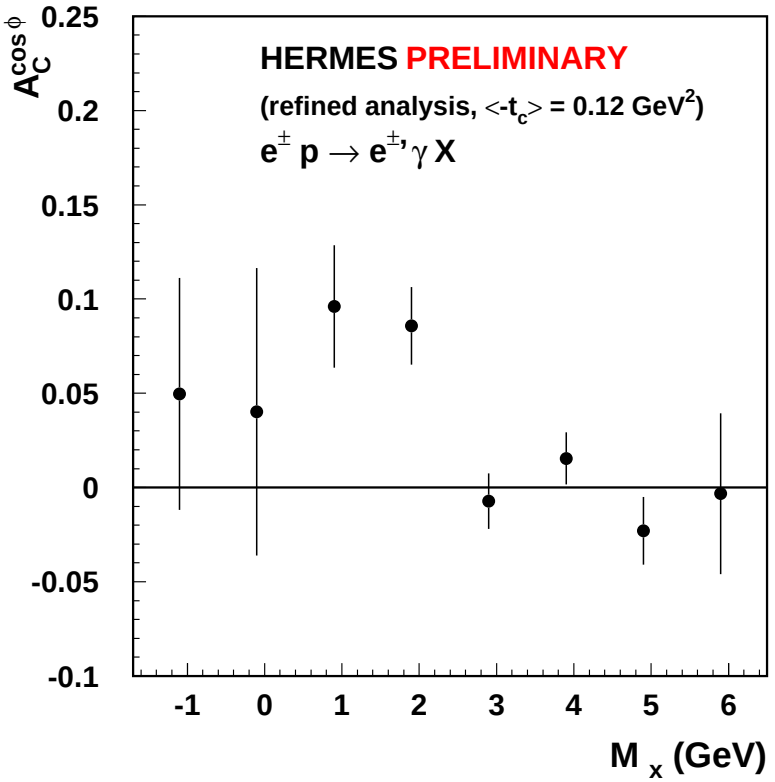




$$A_{LU}(\phi) = \frac{1}{\langle |P_B| \rangle} \frac{\overrightarrow{N}(\phi) - \overleftarrow{N}(\phi)}{\overrightarrow{N}(\phi) + \overleftarrow{N}(\phi)}$$

BCA on Proton





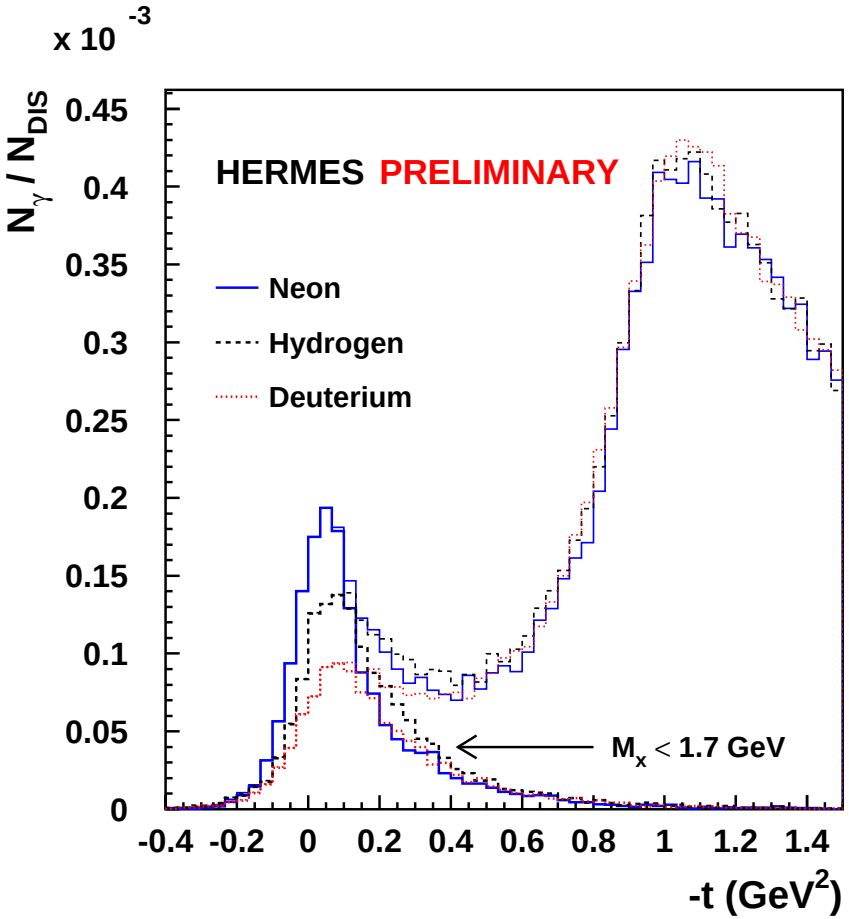
$$A_C(\phi) = \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

From Nucleons to Nuclei

- Apply GPD formalism to nuclei
  - 3D distributions of quarks and gluons inside nucleus
  - Link partonic and nuclear degrees of freedom
  - Study binding effects from a new perspective
  - Access to forces inside the nucleus

    (Polyakov, Physics Letters B555, 2003)
- Adapt kinematical variables
  - $M_N \rightarrow M_A$
  - $x_B \rightarrow x_A \approx x_B \frac{M_N}{M_A}$

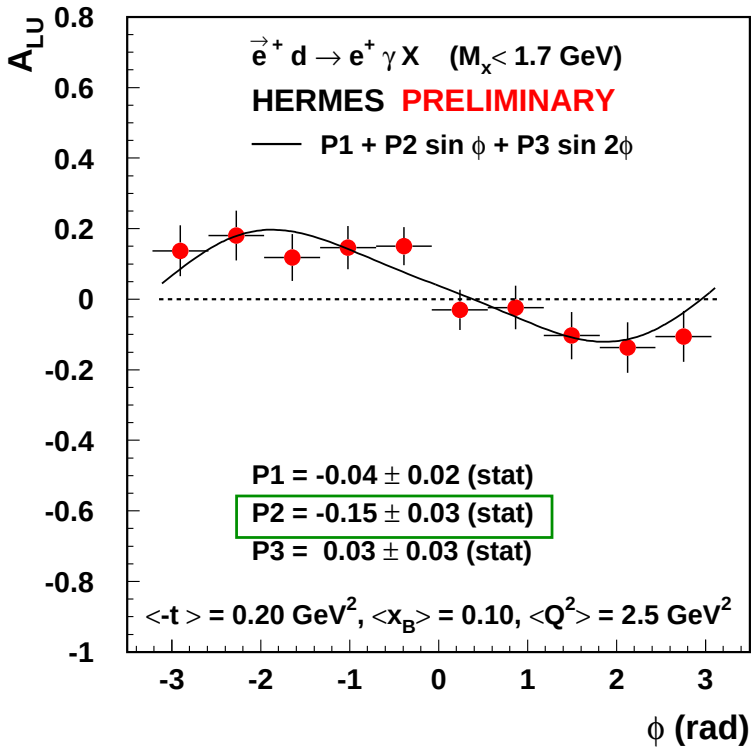
Nuclear Targets

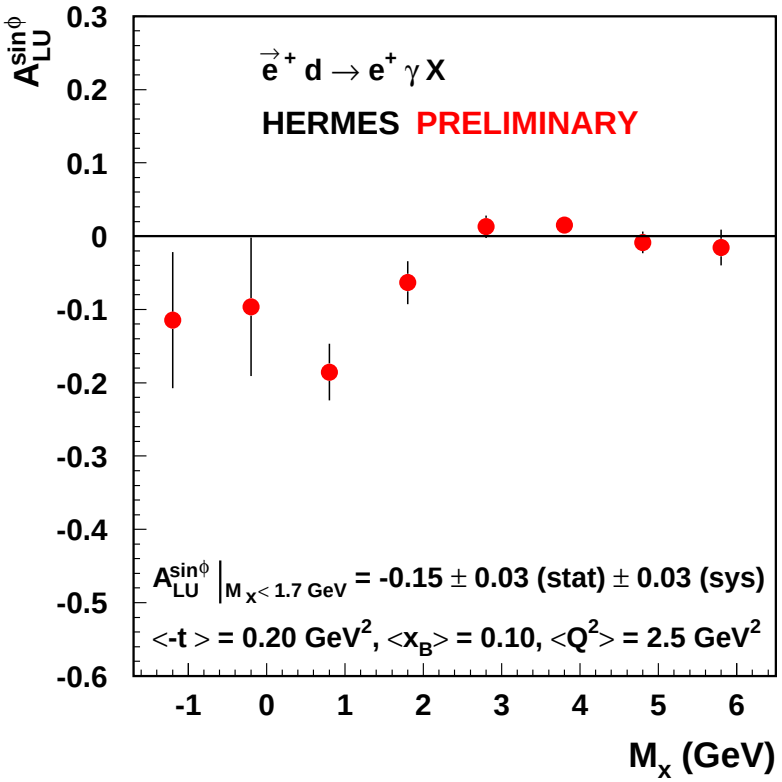


- Deuteron
  - Spin-1 nucleus
  - described by 9 GPDs $\rightarrow$ $H_{1,2,3,4,5}\left(x,\xi,t\right), \tilde{H}_{1,2,3,4}\left(x,\xi,t\right)$
  - study bound-state effects
- Neon
  - 90.9% $^{20}_{10}$Ne + 8.8% $^{22}_{10}$Ne $\rightarrow$ Spin-0 nucleus
  - only 1 GPD $\rightarrow$ $H\left(x,\xi,t\right)$
- Start from nucleon GPD to model nuclear GPD

  (Kirchner et al., Eur. Phys. J. C 32, 2004)

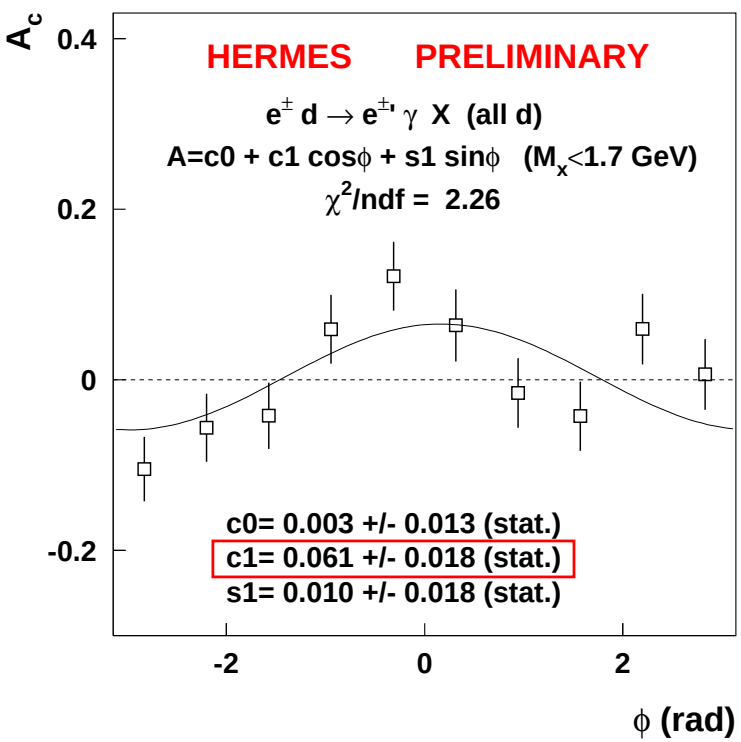
BSA on Deuteron

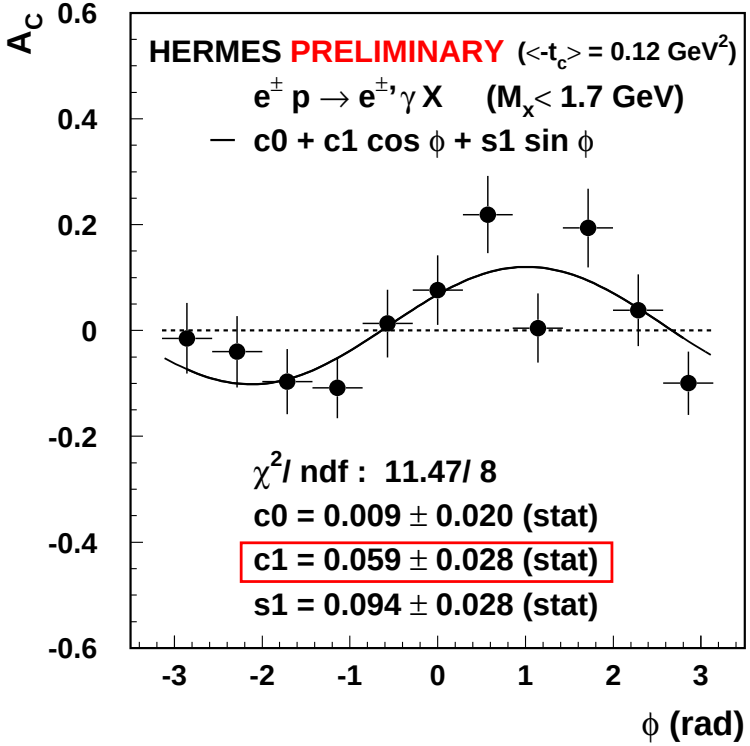




$$\frac{A_{LU}^d}{A_{LU}^p} = \frac{-0.15 \pm 0.03}{-0.18 \pm 0.03} \rightarrow$$ consistent with calculations by Kirchner et al.

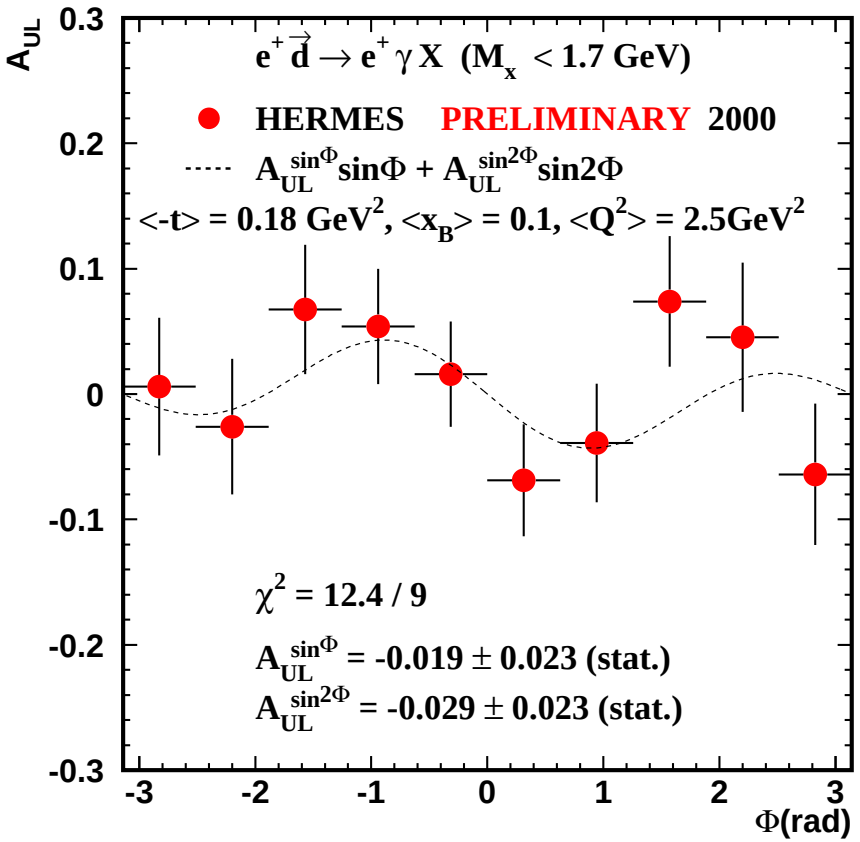
BCA on Deuteron





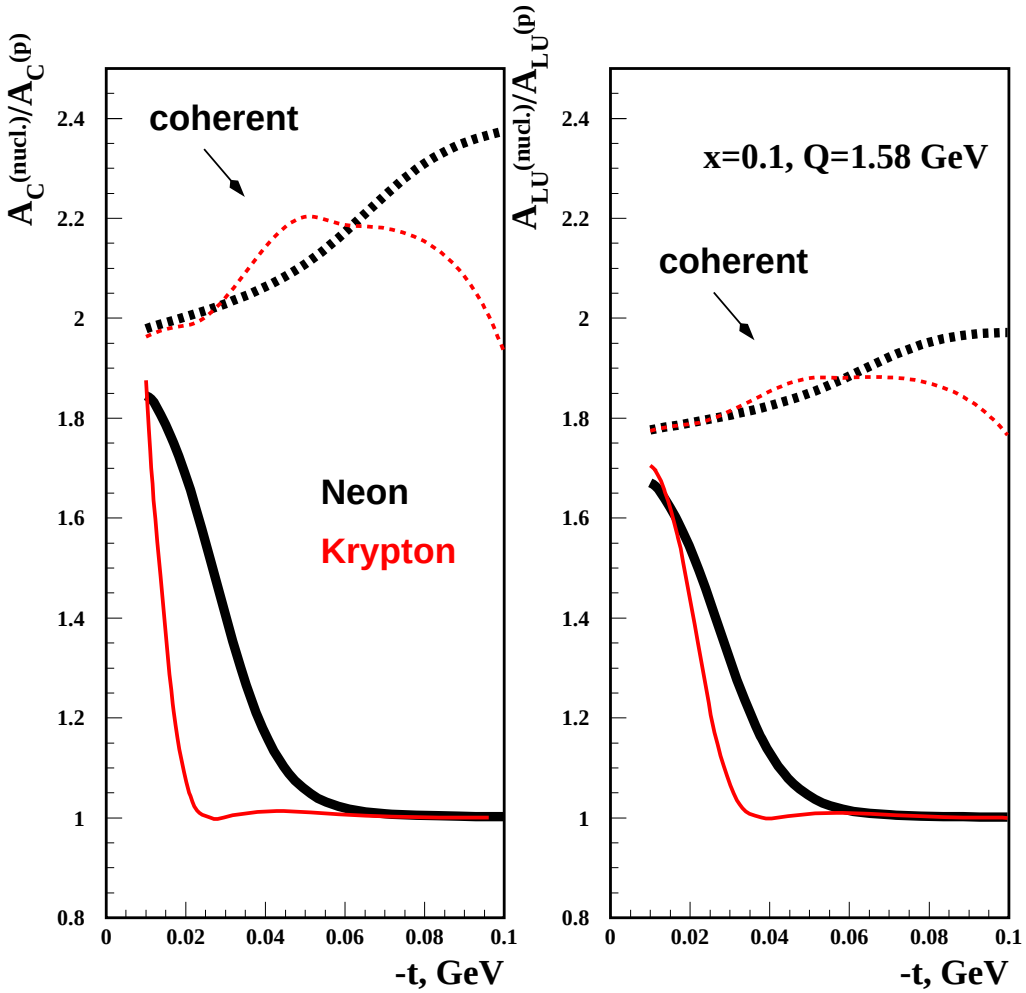
$A_C^d \sim A_C^p \longrightarrow$ incoherent scattering on p is dominant process

Target Spin Asymmetry on Deuteron



- first experimental observation of TSA
- sizeable $\sin(\phi)$ and $\sin(2\phi)$ contributions
- access to $\tilde{H}$

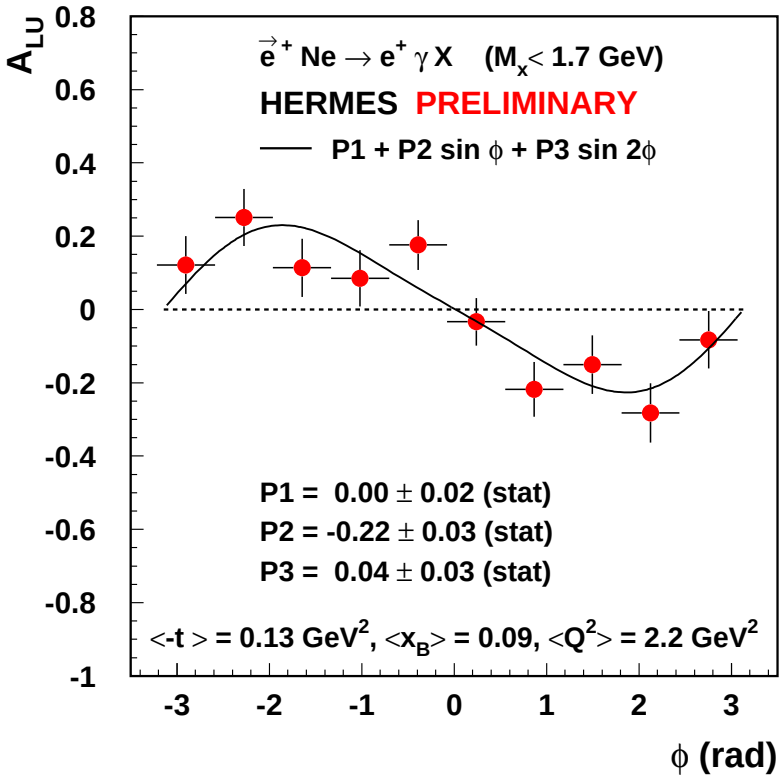
Predictions for BSA & BCA on heavy nuclei

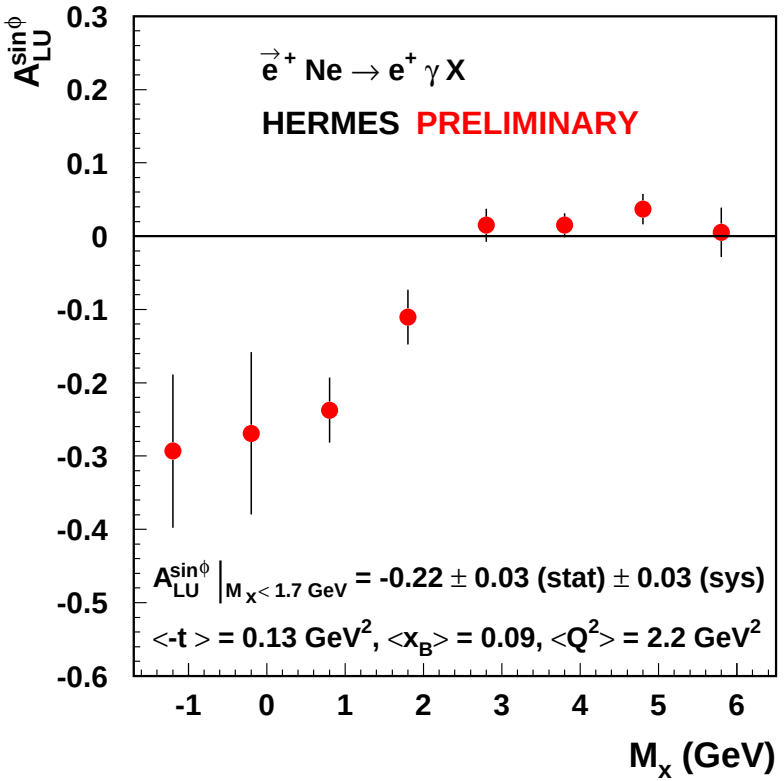


- for coherent process
  → nuclear asymmetry clearly enhanced
- incoherent contribution
  → ratio of asymmetries is decreased

(Strikman hep-ph/0301216)

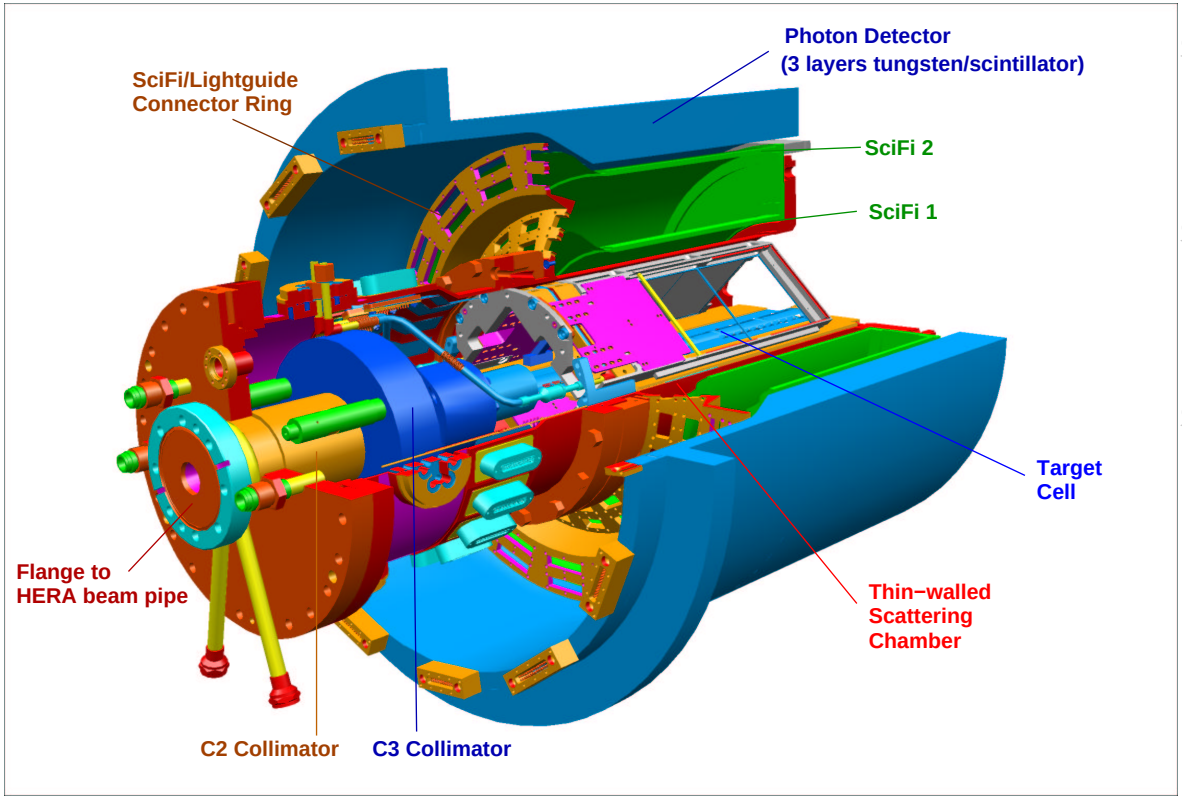
BSA on Neon





$$\frac{A_{LU}^{Ne}}{A_{LU}^{p}} = \frac{-0.22 \pm 0.03}{-0.18 \pm 0.03} \rightarrow \text{sum over coherent and incoherent contributions}$$

The HERMES Recoil Detector



- Surround target area
  $\Rightarrow$ detect recoiling nucleon
- Improve background suppression
- High statistics on unpolarized targets
  $\rightarrow$ $2\,\mathrm{fb}^{-1}$
  $\rightarrow$ proton and nuclear targets

Conclusions

- DVCS observed on p, d, Ne
- HERMES measures Beam Spin-, Beam Charge- and Target Spin-Asymmetries
- Analysis on Neon in progress
- Data on Krypton and Xenon taken in 2004
  $\longrightarrow$ study A-dependence of asymmetries
- Install Recoil Detector in 2005