Nuclear DVCS at HERMES

Analysis Status Report

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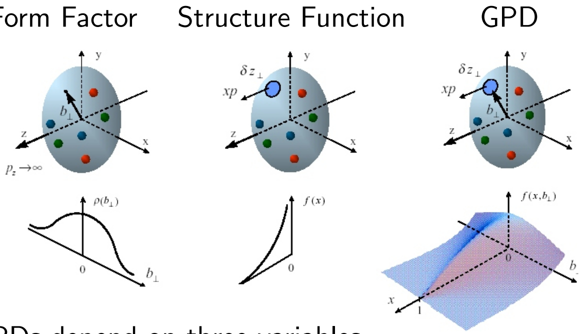
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Outline

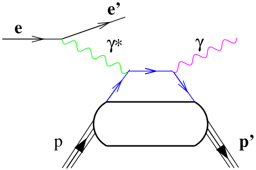
1. Motivation
2. HERA & HERMES Detector
3. DVCS Analysis
4. Conclusions & Outlook

Generalised Parton Distributions

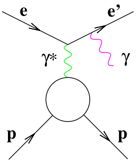


- GPDs depend on three variables
  - x, $\xi \to$ light-cone momentum fractions
  - $\xi \to \frac{x_B}{2-x_B}$ in Bjorken limit
  - $\Delta^2 = (p_\gamma^* - p_\gamma)^2 = -t$
- GPDs constraint by FF & Structure Function

Deeply Virtual Compton Scattering



DVCS



Bethe-Heitler

- DVCS process factorizes
  - → hard scattering part (pQCD)
  - → non-perturbative part (GPD)

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

- Interference $\mathcal{I}$ with **B**ethe-**H**eitler

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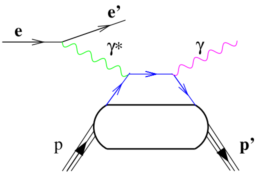
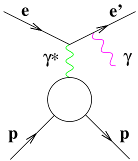


DVCS



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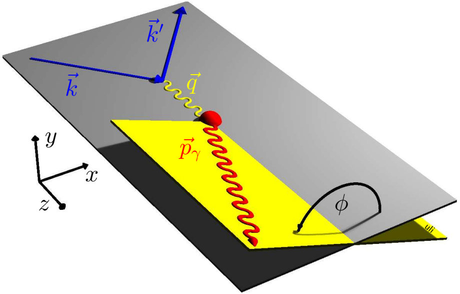
$$\frac{d\sigma}{dx_B\ dQ^2\ d\,|t|\ d\phi} = x_B\ y^2 \frac{|\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \overbrace{\tau_{DVCS}\,\tau_{BH}^* + \tau_{DVCS}^*\,\tau_{BH}}^{\mathcal{I}}}{32\,(2\,\pi)^4\ Q^4 \sqrt{1+4x_B^2 M_p^2/Q^2}}$$

Beam Spin Asymmetry (BSA)



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

  (Belitsky et al. hep-ph/0112108)
- Beam Spin Asymmetry
  $\rightarrow$ $\sin\phi$ behaviour
  $\rightarrow$ beam polarisation P_l

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

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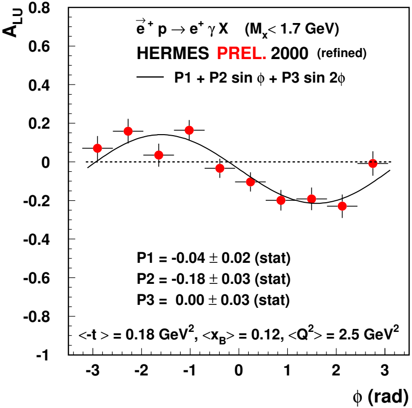

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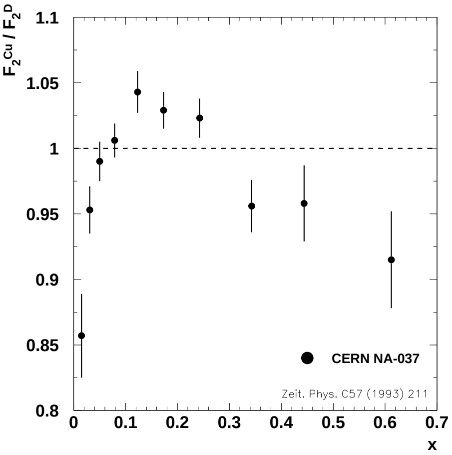
Supersize It – From Nucleons to Nuclei



- Modifications of Structure Functions observed (EMC Effect)
- Apply GPD formalism to nuclei
  - 3D distributions of quarks and gluons inside nucleus
  - Access to forces inside the nucleus

  (Polyakov, Physics Letters B555, 2003)
- No of GPDs depends on spin of nucleus
- Start from nucleon GPD to model nuclear GPD

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

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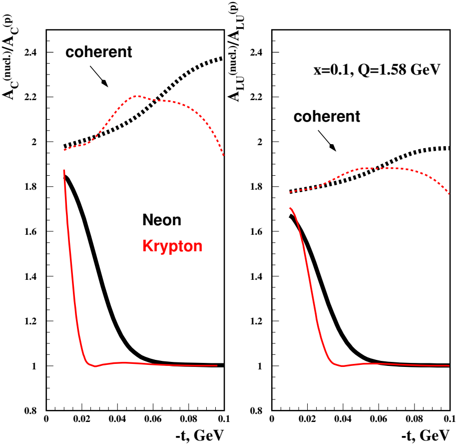

(Strikman hep-ph/0301216)

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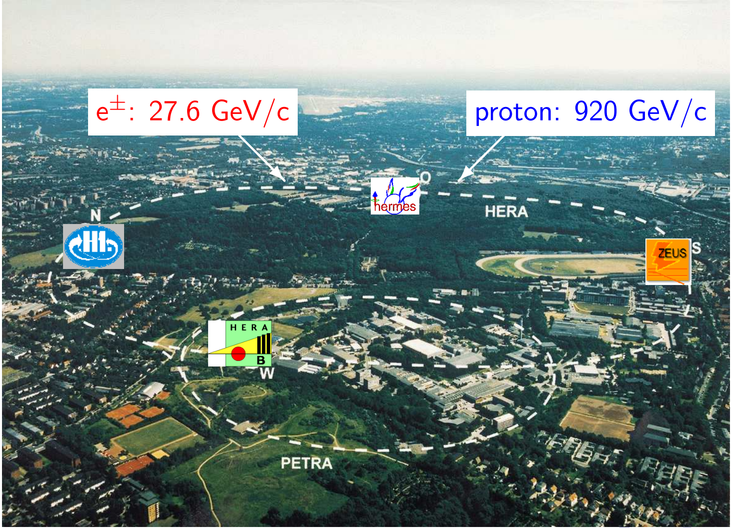

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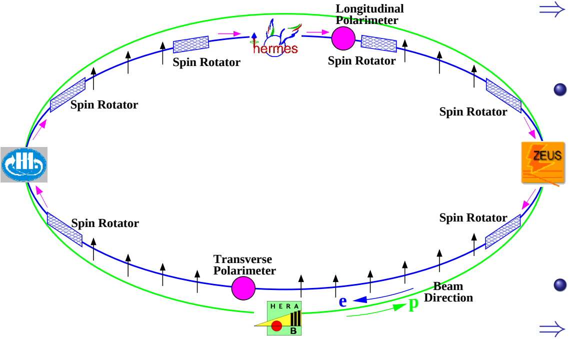

- Synchrotron Radiation

⇒ Transverse Polarisation (Sokolov-Ternov-Effect)

- Polarisation up to 60%

- Spin rotators

⇒ Longitudinal Polarisation

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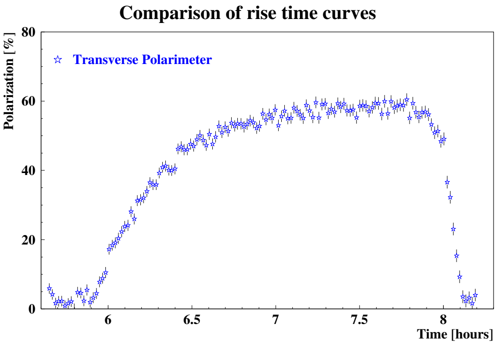

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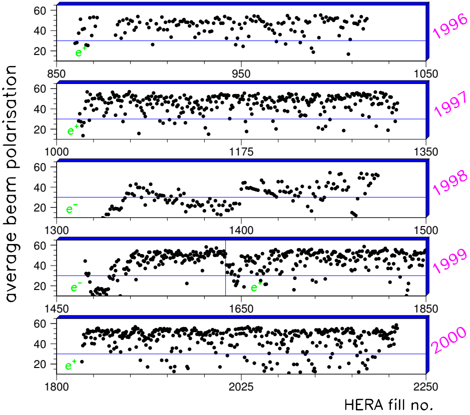

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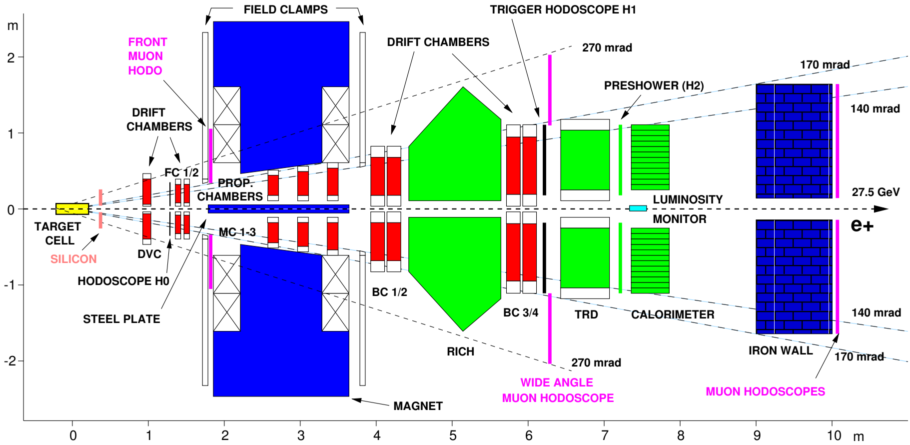
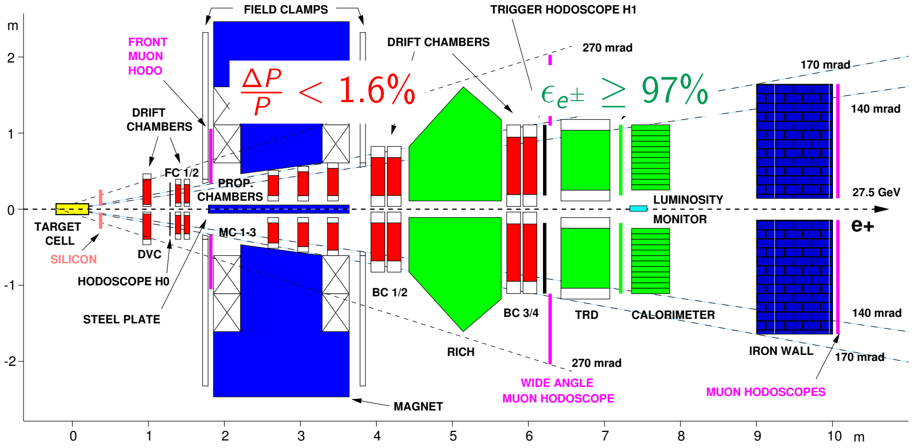
HERMES Detector



HERMES Detector



Targets

- Hydrogen
- Deuterium
- Helium
- Nitrogen
- Neon
- Krypton
- Xenon

even-even Nuclei $\Rightarrow$ Spin 0
odd Z or N $\Rightarrow$ Spin 1/2 – 9/2

$\hookrightarrow$ Spin: $\frac{1}{2}$

$\hookrightarrow$ Composition: ${}^1_1$H

$\hookrightarrow$ Statistics

1997	1.555 million DIS
1998	0.640 million DIS
1999	0.015 million DIS
2000	6.850 million DIS
2002	0.670 million DIS
2003	0.056 million DIS
2004	0.138 million DIS

Targets

- Hydrogen
- Deuterium
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- Neon
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- Xenon

even-even Nuclei ⇒ Spin 0
odd Z or N ⇒ Spin 1/2 – 9/2

↪ Spin: 1

↪ Composition: $^{1}_{2}$H

↪ Statistics

1997	2.427 million DIS
1998	1.177 million DIS
1999	0.341 million DIS
2000	1.707 million DIS
2002	0.497 million DIS
2004	3.312 million DIS

Targets

- Hydrogen
- Deuterium
- Helium
- Nitrogen
- Neon
- Krypton
- Xenon

even-even Nuclei ⇒ Spin 0
odd Z or N ⇒ Spin 1/2 – 9/2

↪ Spin: 0

↪ Composition: $^{2}_{4}$He

↪ Statistics

2000 1.454 million DIS

Targets

- Hydrogen
- Deuterium
- Helium
- Nitrogen
- Neon
- Krypton
- Xenon

even-even Nuclei ⇒ Spin 0
odd Z or N ⇒ Spin 1/2 – 9/2

↪ Spin: 1

↪ Composition: ${}^{7}_{14}N$

↪ Statistics

1997 1.919 million DIS
1999 0.086 million DIS

Targets

- Hydrogen
- Deuterium
- Helium
- Nitrogen
- Neon
- Krypton
- Xenon

even-even Nuclei ⇒ Spin 0
odd Z or N ⇒ Spin 1/2 – 9/2

↪ Spin: 0

↪ Composition: 90.9% $^{10}_{20}$Ne + 8.8% $^{10}_{22}$Ne

↪ Statistics

2000 3.800 million DIS

Targets

- Hydrogen
- Deuterium
- Helium
- Nitrogen
- Neon
- Krypton
- Xenon

even-even Nuclei ⇒ Spin 0
odd Z or N ⇒ Spin 1/2 – 9/2

↪ Spin: 0 (9/2)

↪ Composition: 57% $^{36}_{84}$Kr + 17% $^{36}_{86}$Kr +12% $^{36}_{82}$Kr + 12% $^{36}_{83}$Kr

↪ Statistics

1998	0.016 million DIS
1999	1.086 million DIS
2002	0.480 million DIS
2003	0.038 million DIS
2004	1.596 million DIS

Targets

- Hydrogen
- Deuterium
- Helium
- Nitrogen
- Neon
- Krypton
- Xenon

even-even Nuclei ⇒ Spin 0
odd Z or N ⇒ Spin 1/2 – 9/2

↪ Spin: 0(?)

↪ Composition: 27% $^{54}_{132}$Xe + 26% $^{54}_{129}$Xe +21% $^{54}_{131}$Xe + 10% $^{54}_{134}$Xe + 9% $^{54}_{136}$Xe + 4% $^{54}_{130}$Xe

↪ Statistics

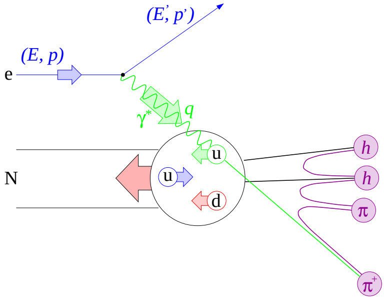
2004 1.086 million DIS

Data Quality

- Using Burstlist from DQ Cops
- Employing Bad Bit Pattern 0x503E13DC
  - ↪ Beam Polarisation $30 < |g1Beam.rPolFit| < 80$
  - ↪ Polarimeter working $|g1Beam.iPolFitGap| \leq 300$
  - ↪ Reasonable dead time
  - ↪ Burst Length $0 < g1DAQ.rLength < 11$
  - ↪ Beam Current $5 < g1Beam.rMdmCurr < 50$
  - ↪ Not the first burst of a run
  - ↪ No problem during μDST production
  - ↪ Unpolarised data
  - ↪ No dead calorimeter blocks
  - ↪ No dead blocks in H2 or Lumi
  - ↪ TRD was working properly
  - ↪ No HV trips in tracking chambers
- Dead time correction $0.8 < g1DAQ.rDeadCorr21 < 1.0$
- Luminosity rate $5. < g1Beam.rLumiRate < 3000.$

DIS Event selection

- Trigger 21 fired
- Same charge as beam
- Long track !(g1Track.iSelect & 0x300)



DIS Event selection

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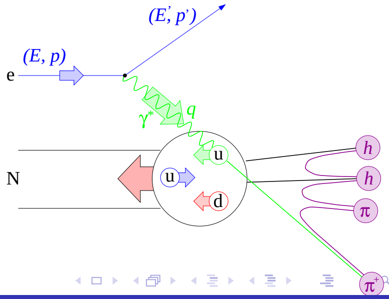
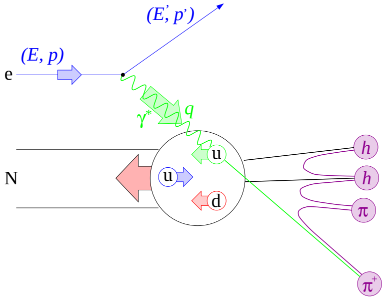
- PID $= \underbrace{g1Track.rPID2}_{Preshower+Calorimeter} + \underbrace{g1Track.rPID5}_{TRD} > 2$



DIS Event selection

- Trigger 21 fired
- Same charge as beam
- Long track !(g1Track.iSelect & 0x300)
- PID = g1Track.rPID2 + g1Track.rPID5 > 2
- Vertex cut
  - $|g1Track.rVertZ| < 18\text{cm}$
  - g1Track.rVertD $\leq$ 0.75cm
- Fiducial volume cut
  - $|x_{Calo}^{lepton}| < 175\text{cm}$
  - $30\text{cm} < |y_{Calo}^{lepton}| < 108\text{cm}$



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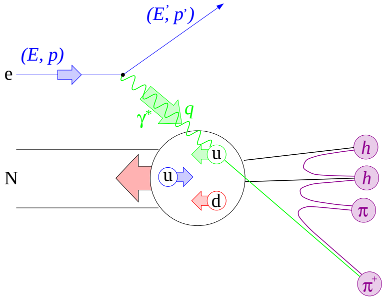
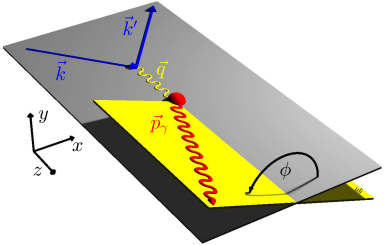
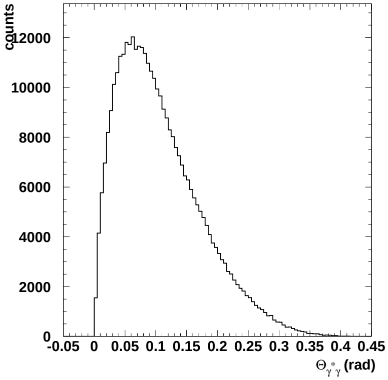
- Kinematic cut
  - $Q^2 > 1.0$ GeV^2
  - $W^2 > 9.0$ GeV^2
  - $\nu < 22.0$ GeV



Single Photon Events

- Only 1 track reconstructed and identified as DIS event
- 1 untracked cluster in Calorimeter
- Signal in Preshower > 1 MeV
- Fiducial volume cut
  - $|x_{Calo}^{photon}| < 125\text{cm}$
  - $33 < |y_{Calo}^{lepton}| < 105\text{cm}$
- Calculate add. variables ($\theta_{\gamma\gamma^*}$, ϕ, M_x)





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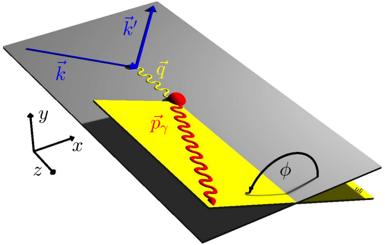

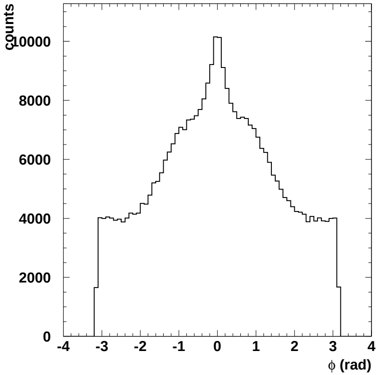

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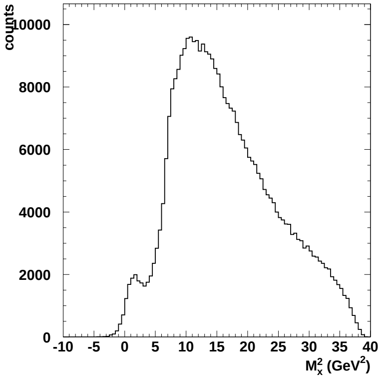
- Calculate add. variables ($\theta_{\gamma\gamma^*}$, ϕ, M_x)
- Using $M_{target} = M_{Proton}$

(Thesis S. Haan, Aug. 2005)

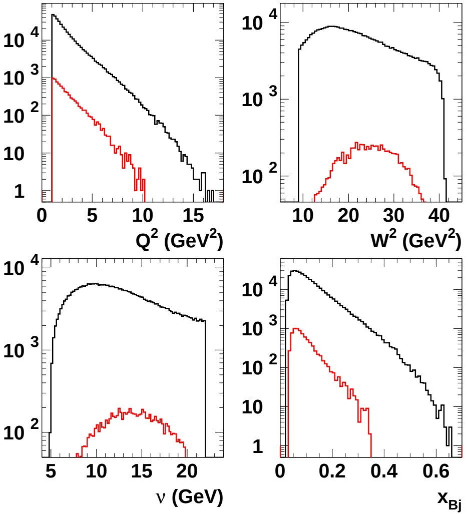
$$M_x^2 = M_{target}^2 + 2 \cdot M_{target} \cdot (\nu - E_\gamma) + t$$



Exclusive Events

- 3mrad $< \theta_{\gamma\gamma^*} <$ 45mrad
- Photon energy $E_\gamma > 1$ GeV
- Missing mass -2.25 $< M_x^2 < 2.89$ GeV^2
- Constraint t $(-t_c) <$ 0.7 GeV
- $0.03 < x_b < 0.35$

$$t_c = \frac{-Q^2 - 2\cdot\nu\left(\nu - \sqrt{\nu^2+Q^2}\cdot\cos\theta_{\gamma\gamma^*}\right)}{1+\frac{1}{M_{target}}\cdot\left(\nu-\sqrt{\nu^2+Q^2}\cdot\cos\theta_{\gamma\gamma^*}\right)}$$



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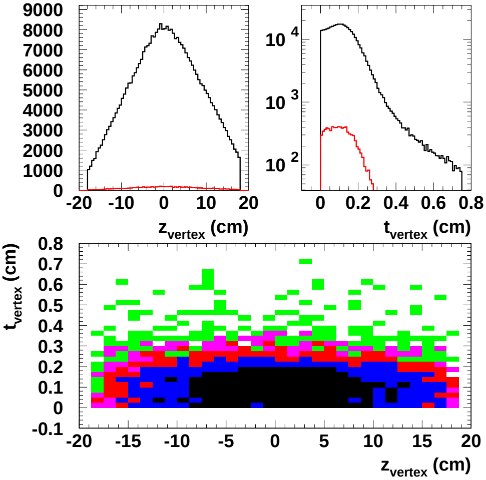

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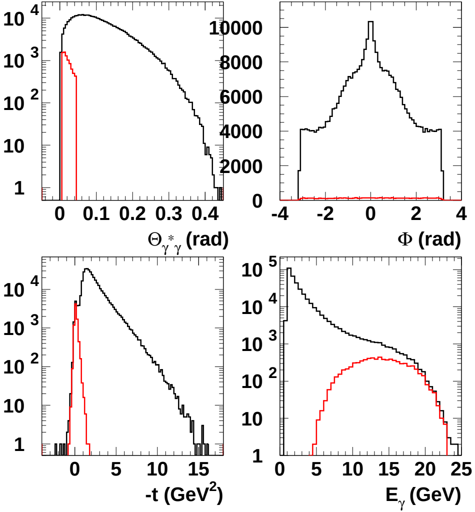
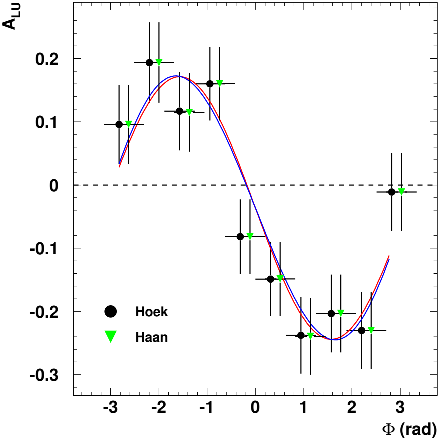


Crosscheck – Compare Neon Data



	S. Haan	M. Hoek
DIS_{total}	2.823.120	2.823.240
$\overrightarrow{DIS}$	1.326.798	1.326.821
$\overleftarrow{DIS}$	1.496.322	1.496.419
$DVCS_{total}$	4249	4239
$\overrightarrow{DVCS}$	2010	2003
$\overleftarrow{DVCS}$	2239	2236

- ✓ Differences understood
- ✓ Good agreement

Weighted Moment Method

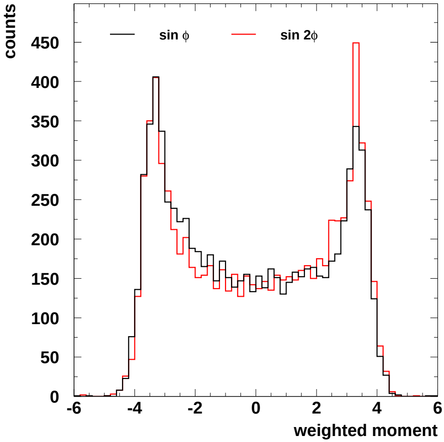
$$A_{LU}^{\sin\phi} = \frac{2}{N}\sum_i \frac{\sin\phi_i}{P_i}$$

- ✓ No Normalisation necessary
- ✓ Applicable for 1 helicity state
- x Acceptance effects

  (E. Thomas, 2001)

⇒ Discarded

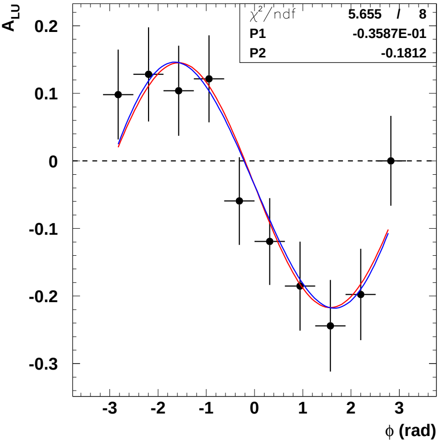
(Thesis B. Krauss, 2005)



Fitting Method - Standard

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

- ✓ Not sensitive to acceptance effects
- x Need normalisation to DIS/Lumi
- x Assumes constant polarisation
- x Both helicities necessary



Fitting Method - Antisymmetrisation

- map $[-\pi, 0] \rightarrow [0, \pi]$

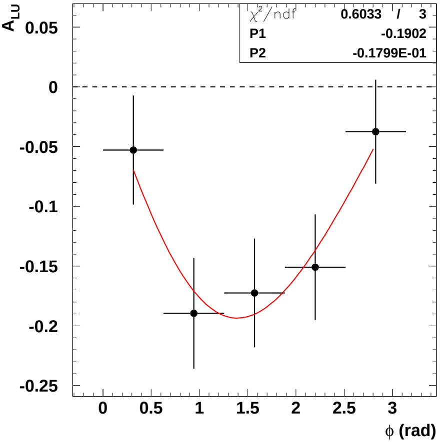
$\Rightarrow$ get ϕ-odd parts

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

$$A_{LU} = \frac{\sum_i \overrightarrow{w_i}\overrightarrow{A^i_{LU}} - \overleftarrow{w_i}\overleftarrow{A^i_{LU}}}{\sum_i \overrightarrow{w_i} + \overleftarrow{w_i}}$$

✓ Only 1 helicity state

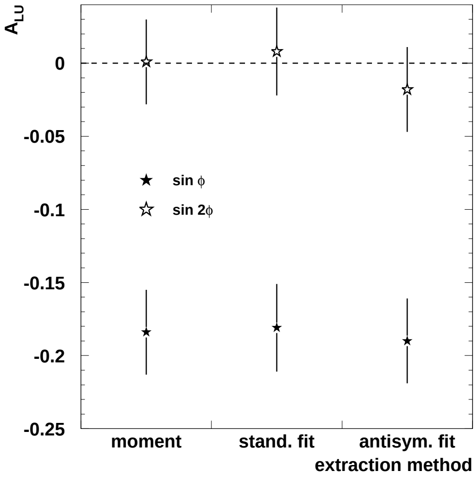
✓ Cancel acceptance and beam related effects



Comparing Extraction Methods

- No fit for Moment Method
- Standard fit:
  $P_0 + P_1 \sin\phi + P_2 \sin 2\phi$
- Antisym. fit:
  $P_0 \sin\phi + P_1 \sin 2\phi$

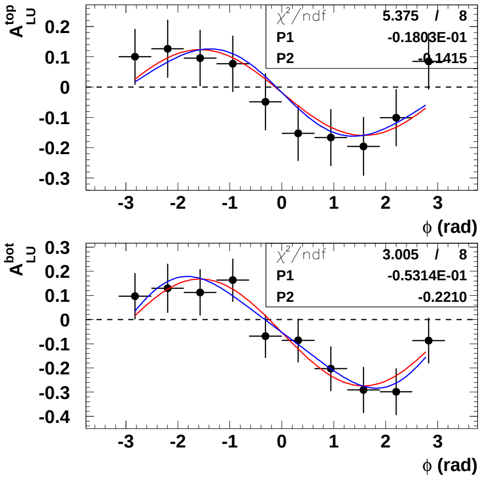
$\Rightarrow$ All methods agree on Hydrogen data from 2000



Top vs Bottom

- Study top/bottom detector separately
  - ⇒ Top/bottom defined by lepton position
- Sensitive on Acceptance effects
- Depends on Beam Parameters & Detector Alignment

⇒ (Substantial) Differences observed



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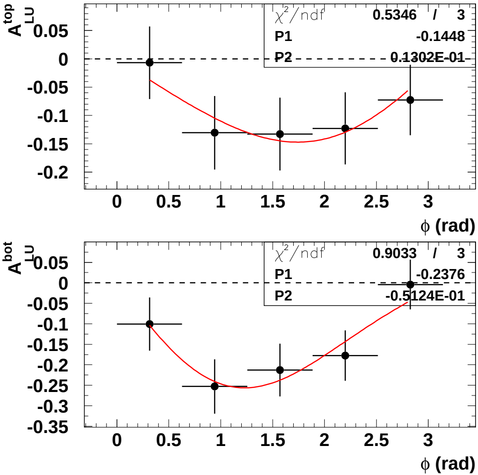
  - ⇒ Top/bottom defined by lepton position
- Sensitive on Acceptance effects
- Depends on Beam Parameters & Detector Alignment

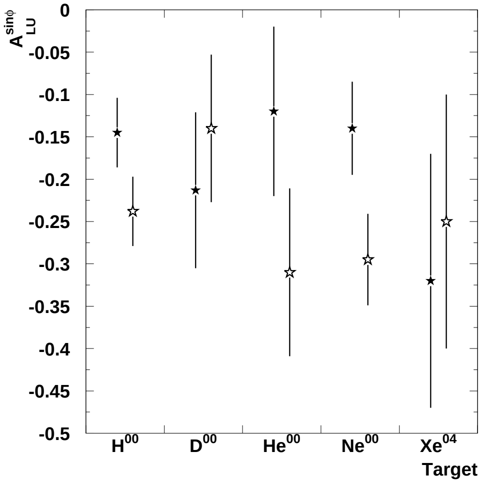
⇒ (Substantial) Differences observed



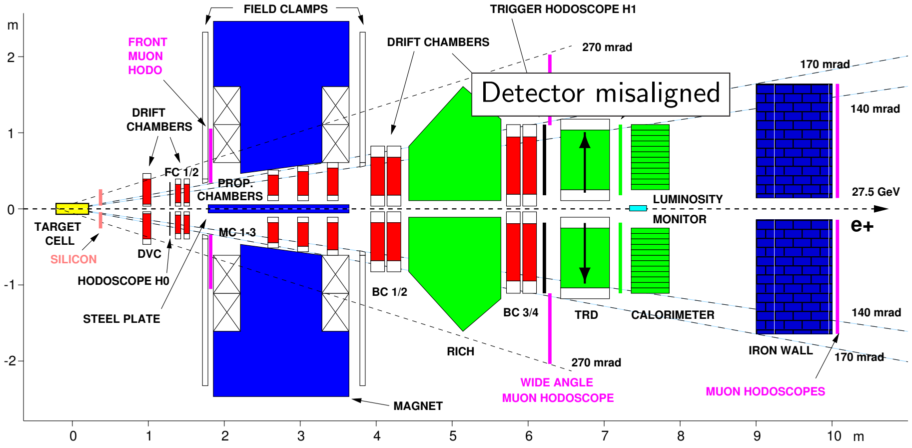
Top vs Bottom

- Study top/bottom detector separately
  - ⇒ Top/bottom defined by lepton position
- Sensitive on Acceptance effects
- Depends on Beam Parameters & Detector Alignment

⇒ (Substantial) Differences observed



Misalignment Effects



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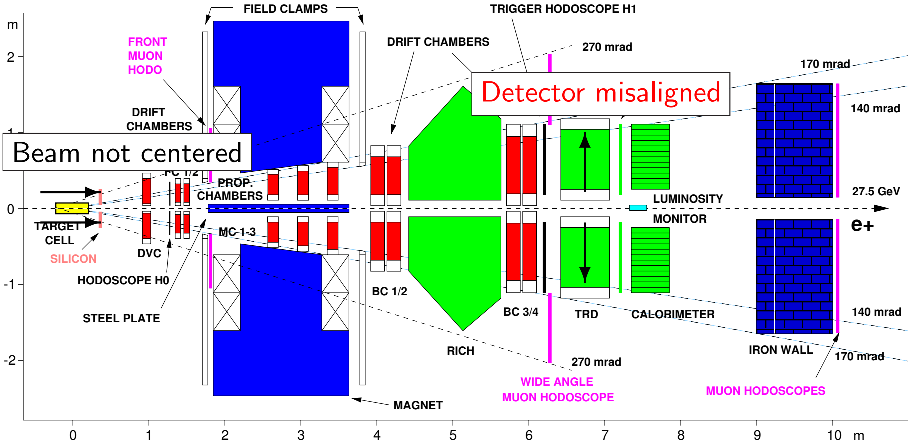

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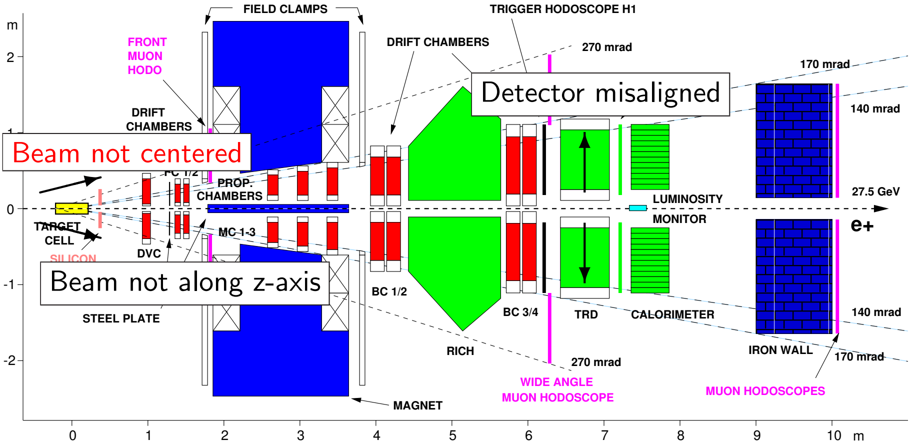
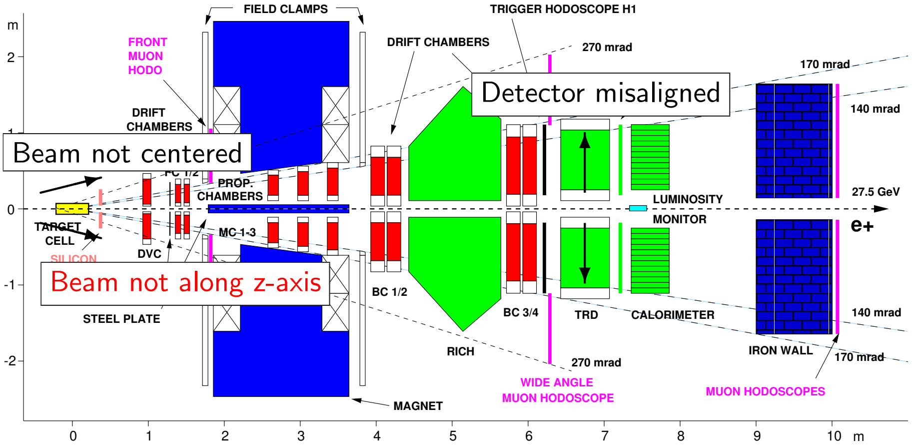


⇒ Changes acceptance of top and bottom part

Misalignment Effects

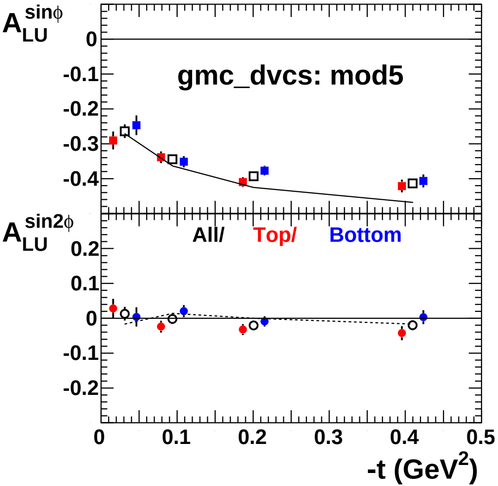


⇒ Changes acceptance of top and bottom part

Comparison with MC

- Study misalignment influence with MC

→ perfect conditions



Comparison with MC

- Study misalignment influence with MC

→ perfect conditions

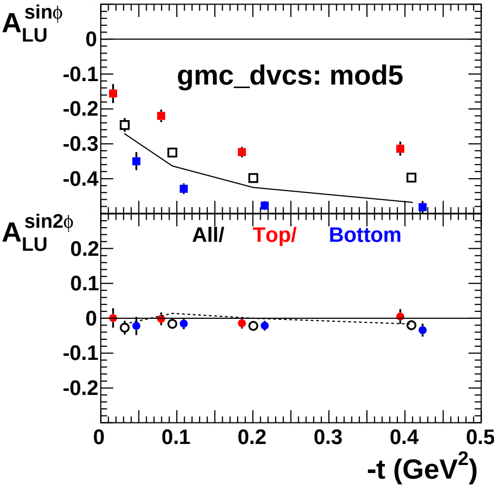
→ different parameters for helicity states

$\overrightarrow{P_{beam}}$

$$x_{slope} = y_{slope} = 1mrad$$
$$x_{shift} = y_{shift} = 0.2cm$$

$\overleftarrow{P_{beam}}$

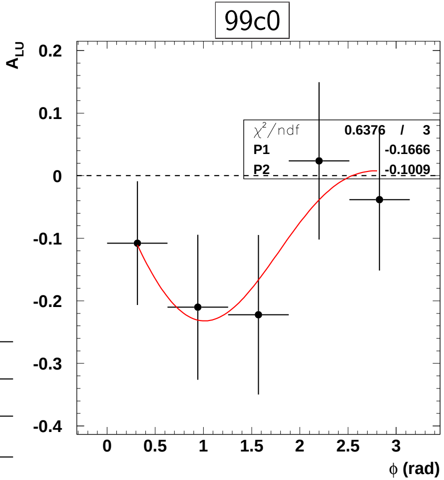
$$x_{slope} = y_{slope} = 0mrad$$
$$x_{shift} = y_{shift} = 0cm$$



The Krypton Puzzle

- Sizeable Asymmetry in 1999
- Asymmetry vanishes in 2004
- Regardless of fit method
- Statistics comparable

	1999	2004
DIS	845938	1008730
DVCS	1491	1735
$A_{LU}^{\sin\phi}$	-0.1667 ± 0.077	-0.065 ± 0.085



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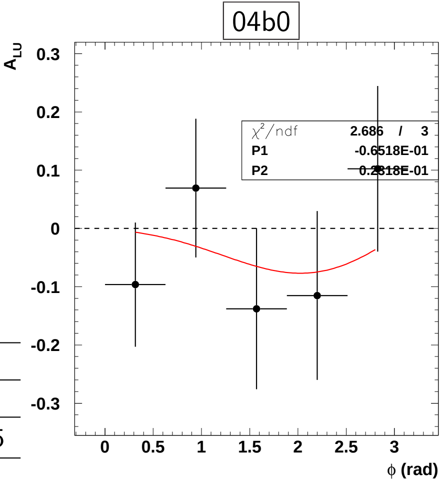

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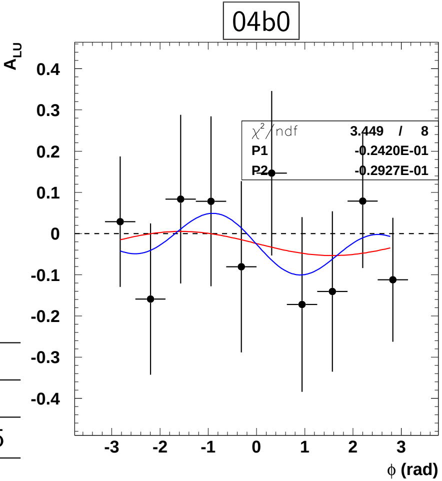

Conclusions & Outlook

- ✓ Analysis Code crosschecked
- ✓ Different Extraction Methods applied
- ✓ BSA for all heavy targets extracted
- ⇝ Distinguish coherent/incoherent contributions
- ⇝ Study BSA depending on Beam/Detector parameters
- ⇝ Solve Krypton-Puzzle