The Transverse Target Spin Asymmetry at Hermes and an outlook to the Recoil Detector

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T 27.3

The Composition of the Nucleon's Spin

$$\frac{1}{2} = \underbrace{J_{\mathrm{quarks}}}_{=\frac{1}{2}\Delta\Sigma + L_{\mathrm{q}}} + J_{\mathrm{gluons}}$$

- $\Delta\Sigma \approx 1/3$ from DIS and SIDIS

  Hermes: Phys. Rev. **D75** (2007) 012007

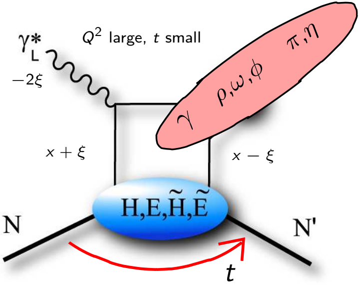
  $\Delta\Sigma = 0.330 \pm 0.011\ (\mathrm{theo}) \pm 0.025\ (\mathrm{exp}) \pm 0.028\ (\mathrm{evol})$

- $L_{\mathrm{q}} \rightarrow\ ?\ \rightarrow$ Ji's relation! $\leftarrow$ Generalized Parton Distributions

  Ji, PRL **78** (1997) 610

$$J_{\mathrm{q}} = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} \mathrm{d}x\, x \left[H_{\mathrm{q}}(x,\xi,t) + E_{\mathrm{q}}(x,\xi,t) \right]$$

GPDs: a unifying picture of nucleon structure



unpolarized	polarized	nucleon helicity
$H(x,\xi,t)$	$\widetilde{H}(x,\xi,t)$	conserved
$E(x,\xi,t)$	$\widetilde{E}(x,\xi,t)$	flipped

- PDFs: $H^{\mathrm{q}}(x,0,0)=q(x)$, $\widetilde{H}^{\mathrm{q}}(x,0,0)=\Delta q(x)$ forward limit
- Form Factors: $\int \mathrm{d}x\,[\mathrm{GPD}] = f(t)$, independent of ξ

$\Rightarrow$ GPDs: simultaneous description of transverse position (FF) and momentum distribution (PDF): "Nucleon Tomography"

Recent theoretical reviews: PPNP **47** (2001) 401; Phys. Rept. **388** (2003) 41; Phys. Rept. **418** (2005) 1

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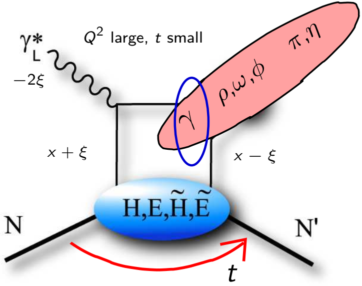

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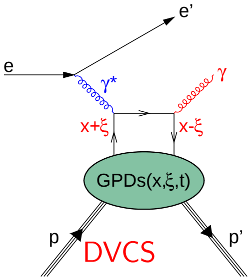
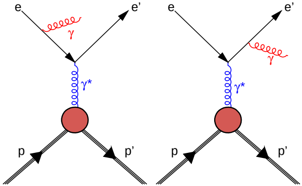
DVCS: the prime process to access GPDs

$\mathrm{eN} \rightarrow \mathrm{eN}\gamma$





Bethe-Heitler

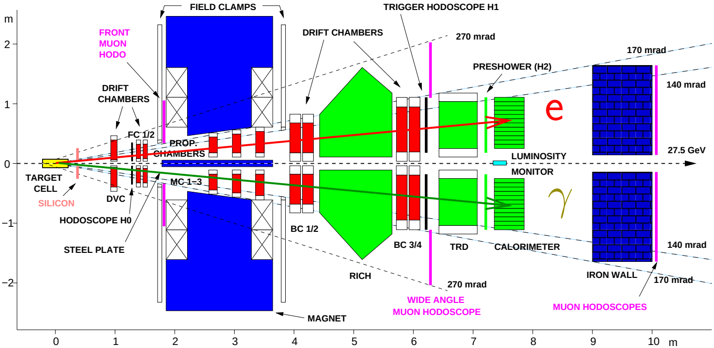
- $d\sigma \propto |\mathcal{T}|^2 = |\mathcal{T}_{\mathrm{DVCS}}|^2 + |\mathcal{T}_{\mathrm{BH}}|^2 + \mathcal{I}$
- Hermes kinematics: $|\mathcal{T}_{\mathrm{DVCS}}|^2 < |\mathcal{T}_{\mathrm{BH}}|^2$
- Interference: $\mathcal{I} = \mathcal{T}_{\mathrm{DVCS}}\mathcal{T}^*_{\mathrm{BH}} + \mathcal{T}^*_{\mathrm{DVCS}}\mathcal{T}_{\mathrm{BH}}$

- $\mathcal{I} \propto \pm(c_0 + \sum_n [c_n \cos(n\phi) + s_n \sin(n\phi)])$
  - c_n = Lin. Comb. (UU), (UT), (LL), (LT)
  - s_n = Lin. Comb. (LU), (UL), (UT), (LT)

(beam state, target state) **U**n-, **L**ong.-, **T**rans.-pol

Experimental access to GPDs through azimuthal asymmetries

DVCS with the Hermes forward spectrometer



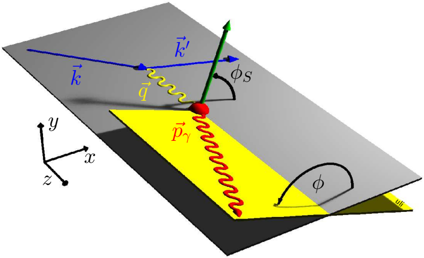
e^+: 70 pb$^-1$
e^-: 100 pb$^-1$

target 2002-2005: $H_2^{\uparrow}$

$$ep^{\uparrow} \rightarrow p'e'\gamma$$

Transverse Target Spin Asymmetries $A_{\mathrm{UT}}(\phi, \phi_s)$

BH-DVCS interference term in
$ep \longrightarrow e'p'\gamma$
induces azimuthal asymmetries
$\Rightarrow$ GPDs



$$A^{\mathcal{I}}_{\mathrm{UT}}(\phi, \phi_s) \propto \left[\mathrm{d}\sigma^+(\phi, \phi_s) - \mathrm{d}\sigma^-(\phi, \phi_s)\right] - \left[\mathrm{d}\sigma^+(\phi, \phi_s + \pi) - \mathrm{d}\sigma^-(\phi, \phi_s + \pi)\right]$$

$$\begin{aligned} A^{\mathcal{I}}_{\mathrm{UT}}(\phi, \phi_s) \;\; & \propto \;\; \mathrm{Im}\,(F_2\mathcal{H} - F_1\mathcal{E})\sin(\phi - \phi_s)\cos\phi \\ & + \;\; \mathrm{Im}\left(F_2\widetilde{\mathcal{H}} - (F_1 + \xi F_2)\widetilde{\mathcal{E}}\right)\cos(\phi - \phi_s)\sin\phi \end{aligned}$$

F_1, F_2: Pauli, Dirac form factors
$\mathcal{H}$, $\widetilde{\mathcal{H}}$, $\mathcal{E}$, $\widetilde{\mathcal{E}}$: Compton form factors
$=$ convolutions of hard scattering amplitude and twist-2 GPDs H, $\widetilde{H}$, E resp. $\widetilde{E}$

Transverse Target Spin Asymmetries $A_{\mathrm{UT}}(\phi, \phi_s)$

New Hermes publication (submitted to JHEP Feb. 2008)
Measurement of Azimuthal Asymmetries With Respect To Both Beam Charge and Transverse Target Polarization in Exclusive Electroproduction of Real Photons, A. Airapetian *et al.*

$$A^{\mathcal{I}}_{\mathrm{UT}}(\phi, \phi_s) \propto \left[\mathrm{d}\sigma^+(\phi, \phi_s) - \mathrm{d}\sigma^-(\phi, \phi_s)\right] - \left[\mathrm{d}\sigma^+(\phi, \phi_s + \pi) - \mathrm{d}\sigma^-(\phi, \phi_s + \pi)\right]$$

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F_1, F_2: Pauli, Dirac form factors
$\mathcal{H}$, $\widetilde{\mathcal{H}}$, $\mathcal{E}$, $\widetilde{\mathcal{E}}$: Compton form factors
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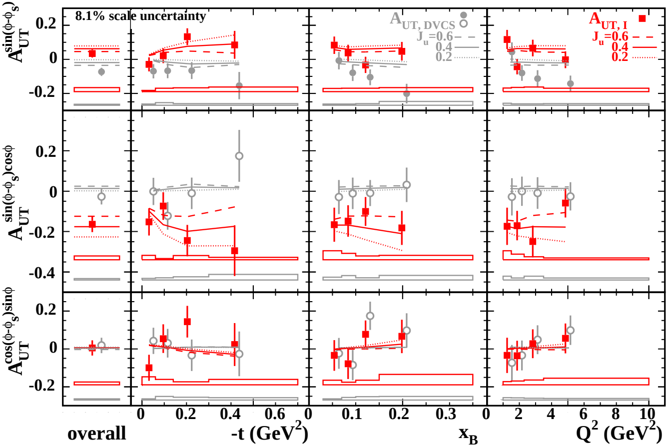
Hermes TTSA asymmetry amplitudes

Complete transversely polarized data set



sensitive to J_u:

$\mathrm{Im}(F_2\mathcal{H} - F_1\mathcal{E}) \cdot$

$\sin(\phi - \phi_s)\cos(n\phi)$

←NOT sensitive to J_u:

$\mathrm{Im}\left(F_2\widetilde{\mathcal{H}} - (F_1 + \xi F_2)\widetilde{\mathcal{E}}\right) \cdot$

$\cos(\phi - \phi_s)\sin\phi$

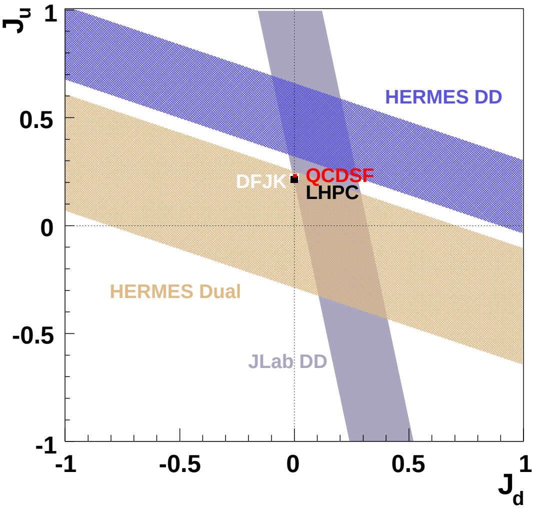
Sensitivity on J_u: GPD-model, assuming $J_d = 0$

(double distribution framework, DD)

Phys. Rev. **D60** (1999) 094017 and Prog. Part. Nucl. Phys. **47** (2001) 401

Model-Dependent Constraint on $J_u + k \cdot J_d$

$$\chi^2(J_u, J_d) = \left(A_{UT,\mathcal{I}}^{\sin(\phi-\phi_s)\cos n\phi}\big|_{exp} - A_{UT,\mathcal{I}}^{\sin(\phi-\phi_s)\cos n\phi}\big|_{theo}(J_u, J_d)\right)^2 / (\delta A^2_{stat} + \delta A^2_{sys})$$



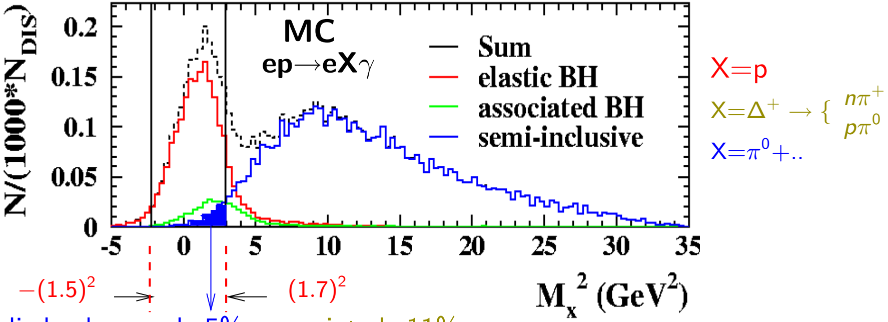
- Bands $\equiv$ 1–sigma constraint on J_u vs. J_d: $\chi^2(J_u, J_d) \leq \chi^2_{min} + 1$
- J_u and J_d free params in GPD models:
- Double distribution (DD) $J_u + J_d/2.8 = 0.48 \pm 0.17$
- Dual parameterization $J_u + J_d/2.8 = -0.02 \pm 0.27$

Dual model: hep-ph/0207153,

Phys. Rev. **D74** (2006) 054027

Exclusivity at Hermes

- Until now: **missing mass technique**

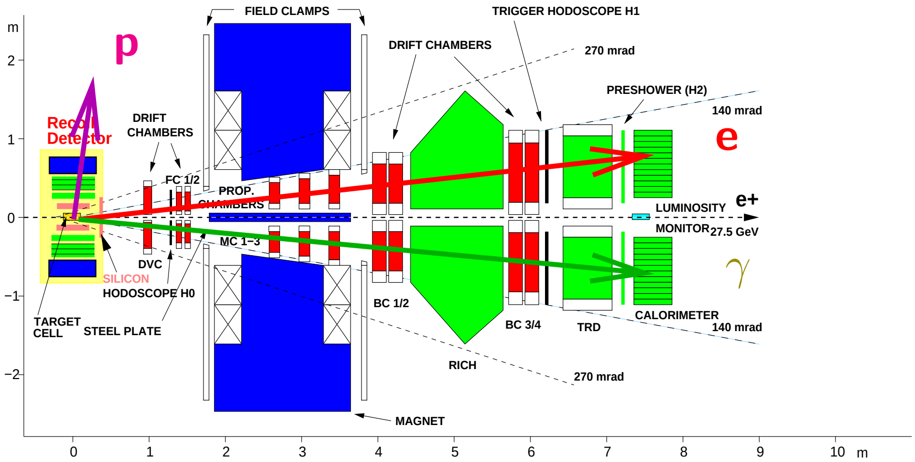


sidis background: 5%, associated: 11%

- With the **new Recoil detector**: genuine exclusivity
  - Identify recoiling protons
  - Identify particles from background processes

    $\Rightarrow$ sidis: 5% $\searrow \ll$ 1%, 11% $\searrow$ 1%

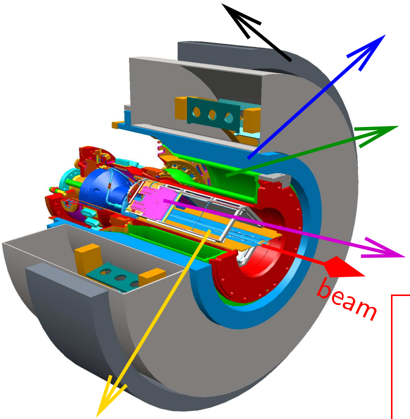
Recoil Detector installation: December 2005



Dedicated high lumi run 2006/07

The Hermes Recoil Detector

- SC Solenoid (1 Tesla)



- Target Cell with unpol. H_2 or D_2

- Photon Detector
  - 3 layers of Tungsten/Scintillator
- Scintillating Fiber Tracker
  - 2 Barrels
  - Each 2 parallel- & 2 stereo-layers
- Silicon Strip Detector
  - 2 Layers of 16 double-sided sensors
  - (10cm$\times$10cm) active area
  - Inside accelerator vacuum

Silicon & Fiber Tracker:

$p_\mathrm{p} \in [135, 1200]$MeV/c

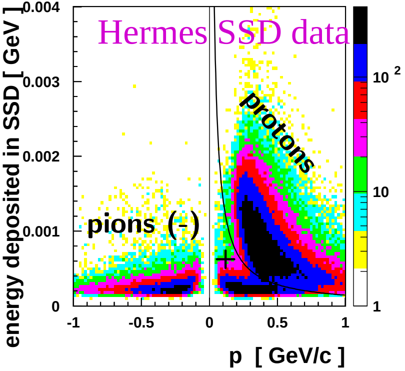
p/π **PID** for $p < 700$MeV/c

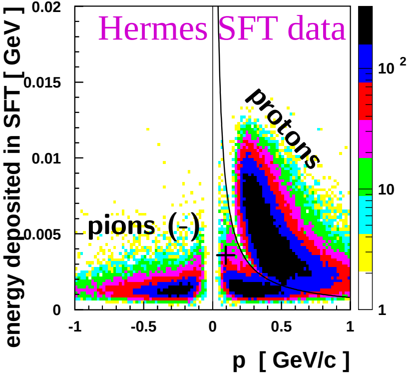
Photon Detector:

p/π **PID** for $p > 650$MeV/c

π^0 background supression

Status of Recoil PID and collected statistics



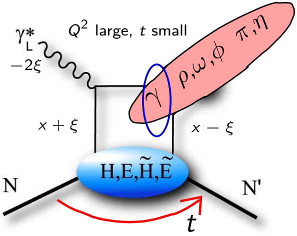


- H_2 unpol: **38 Mio DIS** (41.000 DVCS)
- D_2 unpol: **10 Mio DIS** (7.500 DVCS)
- **2 Beam helicities**, positron beam

(with fully operational recoil)

see also W. Yu **T 61.6**

Summary: Hermes TTSA and Recoil Detector



GPD access at Hermes:

unpolarized	**polarized**
photon: $J^{\mathcal{P}} = 1^-$ (DVCS)	
H: BCA, BSA, TTSA **E:** TTSA	$\widetilde{\mathbf{H}}$: LTSA , [TTSA] $\widetilde{\mathbf{E}}$: [TTSA]
$J^{\mathcal{P}} = 1^-$ mesons	$J^{\mathcal{P}} = 0^-$ mesons

- Extraction of azimuthal harmonics with respect to transverse target polarization in DVCS
- GPD models agree in general with measurements (J_u sensitivity)
- First model-dependent extraction of $J_\mathrm{u} + k \cdot J_\mathrm{d}$ possible
- Once background contributions are measured (recoil detector): refined analysis of pre-recoil DVCS and other exclusive data