DVCS measurements with nuclear targets at HERMES

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Generalised Parton Distributions

Form Factor

Structure Function

GPD

Generalised Parton Distributions

DVCS on proton target

- Accessible in exclusive reactions
- Simplest process : $\gamma^* p \rightarrow p' \gamma$
- Constrained by FF & Structure Function
- Depend on three variables
 - $x, \xi \rightarrow$ light-cone momentum fractions
 - $\xi \rightarrow \frac{x_B}{2-x_B}$ in Bjorken limit
 - $\Delta^2 = (p_\gamma^* - p_\gamma)^2 = -t$
- Nuclear spin determines number of GPDs
 - $I=0 \rightarrow 1$ GPD
 - $I=1/2 \rightarrow 4$ GPDs
 - $I=1 \rightarrow 9$ GPDs

Deeply Virtual Compton Scattering

DVCS

Bethe-Heitler

- DVCS-BH interference
- BH dominates at HERMES kinematics
- Decompose $\mathcal{I}$ in sum of Fourier harmonics
(Belitsky et al. hep-ph/0112108)
- **B**eam **C**harge **A**symmetry
→ $\cos \phi$ behaviour
- **B**eam **S**pin **A**symmetry
→ $\sin \phi$ behaviour
→ beam polarisation P_l

$$\text{Photon production } d\sigma \propto \underbrace{|\tau_{BH}|^2}_{\text{QED}} + |\tau_{DVCS}|^2 + \overbrace{\tau_{DVCS} \tau_{BH}^* + \tau_{DVCS}^* \tau_{BH}}^{\mathcal{I}}$$

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

The HERA Accelerator at DESY

$e^\pm$ beam: 27.6 GeV/c

- Collider experiments:
ZEUS & H1
- Fixed target experiments:
HERMES & HERA B
- Synchrotron Radiation

⇒ Transverse Polarisation
(Sokolov-Ternov-Effect)

- Polarisation up to 60%
- Spin rotators

⇒ Longitudinal Polarisation

The HERMES Spectrometer

Internal gas target $\bar{H}, \bar{D}, H_2, D_2, Ne, Kr, Xe$

Tracking $\frac{\Delta P}{P} < 1.6\%$

Particle Identification $\epsilon_{e^\pm} \geq 97\%$

Exclusive Event Selection

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

- Events with 1 DIS-Electron or -positron and one trackless cluster
- Kinematic requirements
 - $Q^2 > 1 \text{ GeV}^2$
 - $W^2 > 4 \text{ GeV}^2$
- Exclusivity via missing mass $-1.5 < M_x < 1.7 \text{ GeV}$
- Estimate background contribution from MC
 - Associated BH/DVCS ($e p \rightarrow e' \Delta^+ \gamma$)
 - Semi-Inclusive ($e p \rightarrow e' \pi^0 X$)
 - Overall background contribution $\approx 15\%$

Beam Charge Asymmetry on Deuterium

- Expected $\cos(\phi)$ dependence
- $\cos(\phi)$ -Moments vanishing at higher missing mass

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

Beam Spin Asymmetry on Nuclear Targets

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

- Expected $\sin(\phi)$ dependence
- $\sin(\phi)$ -Moments vanishing at higher missing mass
- Integrating over t
- **Deuterium**
 - Spin 1
- Neon
 - Spin 0
- Krypton
 - Spin 0 (9/2)
- Admixture from other isotopes

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Predictions for Heavy Nuclei at HERMES

BCA

BSA

(Strikman hep-ph/0301216)

- Current results ($-t < 0.7 \text{ GeV}^2$)

target	BSA	BCA
p	-0.18 ± 0.03	0.059 ± 0.028
d	-0.15 ± 0.03	0.061 ± 0.018
Ne	-0.22 ± 0.03	—
Kr	-0.17 ± 0.07	—

- Separation into coherent/incoherent fraction necessary
 - Cut at small t-values
- ⇒ Enrich coherent sample
- ⇒ Need MC to estimate contamination

Conclusions

- GPDs are a novel tool to describe the nucleon structure
- Access GPDs via exclusive processes (DVCS)
- Apply GPD formalism to nuclei
 - 3D distributions of quarks and gluons inside nucleus
 - Access to forces inside the nucleus
- (Polyakov, Physics Letters B555, 2003)
- Beam Charge Asymmetry observed on Hydrogen and Deuterium
- Beam Spin Asymmetry observed on heavy targets ranging from Deuterium up to Xenon
- Separate coherent and incoherent fractions
- Final period of HERMES dedicated to exclusive processes like DVCS
- Installation of Recoil Detector

The HERMES Recoil Detector

- Surround unpolarised gas target
- Detect recoiling nucleon
 - momentum range $> 0.25 \text{ GeV}/c$
- Measure complete final state
 - suppress semi-inclusive background
 - distinguish intermediate resonances (Δ)
- Currently being commissioned