Deeply Virtual Compton Scattering on Unpolarised Hydrogen and Deuterium at HERMES

Gordon Hill on behalf of the HERMES collaboration

IOP Nuclear Physics Conference, University of Birmingham

7th April 2009
Talk Outline

• Motivation for DVCS Analysis: GPDs

• The DVCS Process

• The HERMES Experiment

• Experimental Results

• HERMES DVCS Publication Status
Nucleon Spin

- HERMES was designed to investigate the spin puzzle - contributions to the nucleon spin

\[
\frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + L_q + L_g
\]

- \(\Delta \Sigma\): contribution from quark spin, found to be \(~33\%\) (HERMES Phys. Rev. D 75 012007)
- \(\Delta G\): contribution from gluon spin preliminary HERMES \(\Delta G\) measurements inconclusive

- \(L_g\): gluon angular momentum, currently not accessible
- \(L_q\): quark angular momentum, accessed through Generalised Parton Distributions
Generalised Parton Distributions

• Theoretical framework to describe nucleon structure

• Ji Relation (Ji PRL 78 (1997) 610): \( J_q(Q^2) = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} x[H_q(x, \xi, t, Q^2) + E_q(x, \xi, t, Q^2)] dx \)

where \( J_q = \Delta \Sigma + L_q \), allowing access to missing part of spin puzzle

• GPD H - helicity conserving

• GPD E - helicity flip

• Can be accessed in experimental asymmetries such as in the DVCS process
Deeply Virtual Compton Scattering

- Same final state \( \Rightarrow \) interference term in differential cross section
  \[
d\sigma \propto |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \mathcal{I}
\]

- \(|\tau_{BH}|^2 \gg |\tau_{DVCS}|^2\) at HERMES kinematics

- DVCS Asymmetries:

  **Beam Charge Asymmetry**
  \[
  A_C(\phi) = \frac{d\sigma(e^+, \phi) - d\sigma(e^-, \phi)}{d\sigma(e^+, \phi) + d\sigma(e^-, \phi)} \propto \Re(e(H))
  \]

  **Beam Spin Asymmetry**
  \[
  A_{LU}(\phi) = \frac{d\sigma(\overleftarrow{e}, \phi) - d\sigma(\overrightarrow{e}, \phi)}{d\sigma(\overleftarrow{e}, \phi) + d\sigma(\overrightarrow{e}, \phi)} \propto \Im(m(H))
  \]
The HERMES Experiment

- **PID, Tracking Detectors, Magnet**

- Data taken 1995 - 2005

- Recoiling target nucleon/nucleus not detected - missing mass cut used
Experimental Results - Hydrogen

\[ \propto -A_C^{\cos \phi} \]

\[ \propto Re[F_1H] \]

- Higher twist
- Leading gluon twist
- Associated DVCS %
Experimental Results - Hydrogen

\[ A_{LU,I} \cos \phi \]

\[ A_{LU,I} \sin \phi \]

\[ A_{LU,I} \sin 2\phi \]

\[ \text{Res. frac} \]

\[ \propto Re[F_1H] \]

\[ \propto \Im m[F_1H] \]

Higher twist

Associated DVCS %
Experimental Results - Deuterium

Coherent process: $e^\pm + d \rightarrow e^\pm + d + \gamma$  
Incoherent process: $e^\pm + p(n) \rightarrow e^\pm + p(n) + \gamma$

$\propto -A_C^{\cos \phi}$
$\propto Re[F_1\mathcal{H}]$

Higher twist
Leading gluon twist
Associated DVCS, Coherent process %
Experimental Results - Deuterium

Coherent process: $e^\pm + d \rightarrow e^\pm + d + \gamma$  
Incoherent process: $e^\pm + p(n) \rightarrow e^\pm + p(n) + \gamma$

$\propto Re[F_1\mathcal{H}]$

$\propto \mathfrak{Im}[F_1\mathcal{H}](p)$

$\propto \mathfrak{Im}[F_2\mathcal{E}](n)$

Higher twist

Associated DVCS, Coherent process %
Conclusions

• Results presented for hydrogen and deuterium beam charge and spin asymmetries show non-zero asymmetry amplitudes with expected sensitivity to GPDs

• Can be used to disfavour model variants, but none completely describe data

• Results expected to be published this year

• Glasgow Nuclear Physics group playing an important role in HERMES DVCS analysis, both in these results and in polarised target DVCS analysis

  • published: Transversely polarised hydrogen (JHEP 0806:066,2008)

  • soon to be published: Longitudinally polarised hydrogen and deuterium
Data Analysis: Fit Function

- Combined extraction of BSA from squared DVCS term and BSA and BCA from Interference term used

- Extended Maximum Likelihood Fitting technique used to extract asymmetry amplitudes from data

- Fitting function:

  \[ A_C = A_C^{\cos 0\phi} + A_C^{\cos \phi} \cos(\phi) + A_C^{\cos 2\phi} \cos(2\phi) + A_C^{\cos 3\phi} \cos(3\phi) \]

  \[ A_{LU,DVCS} = A_{LU,DVCS}^{\cos 0\phi} + A_{LU,DVCS}^{\sin \phi} \sin(\phi) \]

  \[ A_{LU,I} = A_{LU,I}^{\cos 0\phi} + A_{LU,I}^{\sin \phi} \sin(\phi) + A_{LU,I}^{\sin 2\phi} \sin(2\phi) \]

- Coefficients will be shown overall and as a function of \(-t, \ x_B \ & \ Q^2\)
Experimental Results - GPD Model

• **VGG model** *(Phys. Rev. D 60 1999)*

  • Regge and Factorised \( t \) dependence available

  • Double Distribution ansatz for GPDs

  • Quasi-elastic scattering on proton or neutron only

  • Includes twist-3 contributions

  • Skewness can be varied by free parameters for valence and sea quarks
Data Analysis: Systematic Studies

• Error bars: statistical errors

• Error bands: systematic errors

• Smearing, acceptance, misalignment and bin width correlated: simulate simultaneously in MC and assign 1 error

• Data points are not corrected for these affects

• Background correction for SIDIS background applied
  • also contributes to systematic error
Experimental Results - Hydrogen
Experimental Results - Deuterium