Exclusive Physics
@ HERMES

M. MURRAY, UNIVERSITY OF GLASGOW
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Exclusive Physics

Physics Governed by Generalised Parton Distributions
Generalised Parton Distributions

t - Mandelstam variable (squared momentum transfer to nucleon)

x - Fraction of nucleon's longitudinal momentum carried by active quark

$\xi$ - half the change in the longitudinal momentum of the active quark.
Four distributions of interest: $H$, $E$, $\tilde{H}$, $\tilde{E}$

$H$ and $E$ integrate over quark helicities

$\tilde{H}$ and $\tilde{E}$ are quark helicity difference distributions

$$J_q = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} \left[ H^q (x, \xi, t) + E^q (x, \xi, t) \right] x \, dx$$
GPD Physics

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Nucleon helicity inversion

Nucleon helicity conservation

\[ J_q = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} \left[ H^q(x, \xi, t) + E^q(x, \xi, t) \right] x \, dx \]

“Ji’s Relation”

GPD Physics

Form Factors (FFs)  Parton Distribution Functions (PDFs)  Generalised Parton Distributions (GPDs)
GPD Physics

\( H \) - unpolarised nucleon \hspace{1cm} \tilde{H} - polarised nucleon
GPDs describe only the soft part of the interaction

Accessed via cross-sections and asymmetries:
requires convolution with a hard scattering kernel

\[ H \rightarrow \mathcal{H} \quad \tilde{H} \rightarrow \tilde{\mathcal{H}} \quad E \rightarrow \mathcal{E} \quad \tilde{E} \rightarrow \tilde{\mathcal{E}} \]

Results in “Compton Form Factors” accessible through Exclusive Physics, which have real and imaginary parts
GPD Physics

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Accessed via cross-sections and asymmetries: requires convolution with a hard scattering kernel

\[ \Im m F(\xi, t) = F(\xi, \xi, t) \pm F(-\xi, \xi, t), \]
\[ \Re e F(\xi, t) = P_C \int_{-1}^{1} \frac{F(x, \xi, t)}{x - \xi} \pm \frac{F(x, \xi, t)}{x + \xi} \, dx \]
GPD Physics

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\[
\text{Im } \mathcal{F}(\xi, t) = F(\xi, \xi, t) \pm F(-\xi, \xi, t), \\
\text{Re } \mathcal{F}(\xi, t) = \mathcal{P}_C \int_{-1}^{1} \frac{F(x, \xi, t)}{x - \xi} \pm \frac{F(x, \xi, t)}{x + \xi} \, dx 
\]

Limited x access
DVCS @ HERMES

Forward spectrometer ⇒ measure asymmetries directly

\[ \langle Q^2 \rangle \approx 2.4 \text{ GeV}^2 \]
\[ \langle x_B \rangle \approx 0.1 \]
\[ \langle -t \rangle \approx 0.1 \text{ GeV}^2 \]

- \( 1 \text{ GeV}^2 < Q^2 \equiv -q^2 < 10 \text{ GeV}^2 \)
- \( 0.03 < x_B < 0.3 \)
- \( 0 \text{ GeV}^2 < -t \equiv -(p-p')^2 < 0.7 \text{ GeV}^2 \)
Can also polarize target (anti-)parallel or transverse to $\gamma^*$ direction
Leptoproduction of real photons has two subprocess: Deeply Virtual Compton Scattering and elastic scattering with Bremsstrahlung.
DVCS @ HERMES

Data
- MC Sum
- BH/DVCS
- Resonance Production
- SIDIS Production
- Exclusive $\pi^0$ Production

$1000. \times N_{\text{DIS}}$

$M^2_x \text{ GeV}^2$
DVCS @ HERMES

Wanted Signal

BH/DVCS from $\Delta$, e.g.
$e \Delta \rightarrow e \Delta \gamma \rightarrow e p \pi^0 \gamma$
$e p \rightarrow e X \gamma$
$e p \rightarrow e p \pi^0$
Higher terms in a Fourier decomposition correspond to higher twist and suppression.
Beam Asymmetries

Beam Charge Asymmetries access Re($\mathcal{H}$)
Beam Asymmetries

Beam Helicity Asymmetries access Im(\mathcal{H})

Larger values for the BHA than BCA - correlated to the difference in the CFF access?
HERMES DVCS

\[ A_C^{\cos(0\phi)} \]
\[ A_C^{\cos \phi} \]
\[ A_C^{\cos(2\phi)} \]
\[ A_C^{\cos(3\phi)} \]
\[ A_{LU,I}^{\sin \phi} \]
\[ A_{LU,I}^{\sin(2\phi)} \]
\[ A_{LU,DVCS}^{\sin(\phi - \phi')} \]
\[ A_{UT,I}^{\sin(\phi - \phi')} \]
\[ A_{UT,DVCS}^{\sin(\phi - \phi') \cos \phi} \]
\[ A_{UT,I}^{\cos(\phi - \phi') \sin \phi} \]
\[ A_{UL}^{\sin \phi} \]
\[ A_{UL}^{\sin(2\phi)} \]
\[ A_{LL}^{\cos(0\phi)} \]
\[ A_{LL}^{\cos \phi} \]
\[ A_{LL}^{\cos(2\phi)} \]

Hydrogen
Deuterium
Preliminary

ArXiv:0909.3587
ArXiv:0911.0095
ArXiv:0802.2499
ArXiv:1004.1077
ArXiv:1004.1077
ArXiv:0911.0095
ArXiv:0909.3587
ArXiv:0911.0095

Amplitude Value

-0.3 -0.2 -0.1 0 0.1 0.2 0.3
Target Asymmetries

Long. Pol. target asymmetries access $\text{Im}(\bar{\mathcal{H}})$

http://arxiv.org/abs/1004.0177

A. Airapetian et al, JHEP 06 (2010) 019

VGG Model:

Double Spin Asymmetries

Long. Pol. target / Long. Pol. Beam access $\text{Re}(\tilde{H})$

Caveat! Relatively large BH contribution to these asymmetries!

http://arxiv.org/abs/1004.0177

A. Airapetian et al, JHEP 06 (2010) 019
Exclusive Mesons

Data taken with all types of polarized targets; average the target polarization to leave unpolarized data
Exclusive Mesons

Predictions from GPD models fail to fit the data for polarized targets well.

The phase difference between helicity amplitudes $T_{11}$ and $T_{00}$ is much greater than models suggest.
Exclusive Mesons

Evidence of S-channel Helicity Conservation violation

Evidence for Unnatural Parity Exchange
GPD Discovery

New CFF Fit Result incorporating DVCS $A_{UL}$ moments

Postulate GPDs from first principle models

http://arxiv.org/abs/1005.4922  M. Guidal

http://arxiv.org/abs/0904.0458  Kumerički and Müller
Conclusions

• Exclusive Physics can be used to access information on Generalised Parton Distributions

• That information can tell us unique things about nucleon structure

• HERMES’ results can help illuminate a path to knowledge of nucleon structure.