Future GPD Measurements

Short, Medium and Long Term

Ralf Kaiser, University of Glasgow
• Current & Future GPD Experiments

• HERMES, CLAS, CLAS12
  COMPASS, PANDA

• Future Perspectives for GPD Measurements
Major GPD Experiments - Timeline

HERMES

COMPASS

PANDA

JLAB

JLAB 12 GeV

2008 2010 2015 2020 2025

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Major GPD Experiments - Timeline

- HERMES
- COMPASS
- PANDA
- JLAB
- JLAB 12 GeV
- EIC

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DVCS measurements with Recoil Detector in 2006/7 yielded about as much data as 1995-2005; data are being analysed.
Limits on $J_u/J_d$
HERMES Recoil Detector

582
8

![HERMES Recoil Detector Diagram](image)

- SciFi/Lightguide Connector Ring
- Photon Detector (3 layers tungsten/scintillator)
- C3 Collimator (Tungsten)
- Water Cooling for Si Det.
- Si Det. Connectors
- Si Det. Hybrid
- SciFi 2
- SciFi 1
- Thin-walled Scattering Chamber
- TIGRE Sensors
- Si Det. Frame (Aln)
- Target Cell

Talk by A. Mussgiller tomorrow
Kinematic Plane MC & Data

DVCS MC Events TDR 2002

DVCS Candidate Event Data 2007
DVCS, BH, ADVCS, background
Recoil Detector - Combined PID

![Graph showing PID vs Momentum for P and pi+ particles.](image)

- **P**: Peak for protons.
- **pi+**: Peak for pions.

PID (SSD + SFT) vs Momentum / [GeV/c]

- Axes: PID (SSD + SFT) on the x-axis, Momentum / [GeV/c] on the y-axis.

arXiv:0711.0755 (submitted to PRL)
$A = (\sigma^+ - \sigma^-)/\sqrt{(\sigma^+ + \sigma^-)}$

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$Q^2 (\text{GeV/c}^2)$

$\phi_{\gamma p}$

$\phi_{\gamma p}$

$\xi_{\text{independent}}$

$b_{val} = 1.0, b_{sea} = 1.0$

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2000 hrs at $L = 10^{35} \text{ cm}^{-2}\text{s}^{-1}$
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Projection for GPD H
$\vec{H} \cdot \vec{D}$ as a potential target for electro-production experiments at JLab

- $\gamma + \vec{H} \cdot \vec{D}$ spin-relaxation times: months –to– years at $\sim 0.5^0 K$ and 0.01 –to– 0.9 tesla
  $\iff$ 10 times higher temperature than conventional frozen-spin targets

- $e + \vec{H} \cdot \vec{D}$ depolarization mechanisms:
  (i) beam heating: $5 \, nA$ of $10 \, GeV$ electrons $\Rightarrow 5 \, mW$ heat in $2 \, cm$ of HD
    $\ll$ heating than $C_4H_9OH$, due to lower Z
    - ample cooling power due to higher holding temperature
  (ii) spin-diffusion of paramagnetic centers:
    - $e$ brems creates free radicals with randomly oriented nuclear spin;
      absolute number are small, but these can be sinks for polarization
    - spin-diffusion time measured at $2 \, K$: $\sim \infty$ for $\vec{D}$,
      $\sim 1 \, d$ for $\vec{H}$ at $2^0 K$; $\gg$ longer at lower $T$?

- potential advantages:
  $\iff$ low fields ideal for transverse polarization experiments $\iff$ beam not in detector
  $\iff$ no dilution in a pure target, very low backgrounds
  $\iff$ small bremsstrahlung background due to low Z

- $e + \vec{H} \cdot \vec{D}$ test scheduled for Spring, 2011, in CLAS at JLab
HDice Timeline

- pack and move equipment from BNL to JLab ✓
- HDice Lab – complete design of building modifications – Nov’08
- Building construction – Feb – June’09
- Construction of Cryogenic infrastructure – Apr-Sept’09
- Installation of Cryogenic equipment into HDice Lab – beginning June’09
- polarize test targets – Sept-Nov’09
- polarize sets of targets for E06-101 – Mar-June’10; Aug-Dec’10
- Design/construction of new In-Beam Cryostat for CLAS – May’08-July’10
- Installation in Hall B – July-Sept’10

- E06-101 run: $\gamma + H \cdot D$ – Sept’10-April’11
- e+HD test – April’11
- polarized targets for e+HD DVCS – June-Oct’11
- E08-021 run: $\bar{e} + H \cdot D$ – Nov-Dec’11
Transverse Asymmetry is large and has strong sensitivity to GPD $E$

CLAS 6 experiment scheduled for 25 days in 2011

$A_{UT} \sim \sin(\phi - \phi_S) \cos(\phi) \text{Im}\{F_2 H - F_1 E + \ldots\} + \ldots$

proton $x=0.25, Q^2=2.0$

V. Guzey

$E=0$
COMPASS Setup for DVCS Measurements

DVCS $\mu p \rightarrow \mu' p' \gamma$

- 2.5m cryogenic target to be designed and built
- 2011: long H2 target
- later: transversely polarized

$N_\mu = 2.10^8$/SPS cycle (duration 5.2s, each 16.8s)

Possibility for an increase of intensity?

$\gamma$ ECal1 + ECal2 $\theta_\gamma \leq 10^\circ$

+ additional calorimeter ECal0 at larger angle

4m long Recoil proton detector to insure exclusivity to be designed and built
Present 1m long Recoil Proton Detector in COMPASS for the hadron program (spectroscopy)
At COMPASS with $\mu^{+}$ and $\mu^{-}$ → access both \text{Im} H and \text{Re} H

with DVCS + BH with polarized and charged leptons and unpolarized target

$$d\sigma(\mu^{+\downarrow}, \phi) + d\sigma(\mu^{-\uparrow}, \phi) \propto \Im m(F_1 H + \xi(F_1 + F_2)\bar{H} - t/4m^2 F_2 E) \cdot \sin \phi$$

$$d\sigma(\mu^{+\downarrow}, \phi) - d\sigma(\mu^{-\uparrow}, \phi) \propto \Re e(F_1 H + \xi(F_1 + F_2)\bar{H} - t/4m^2 F_2 E) \cdot \cos \phi$$

Analysis through dependence in $\phi$ and $Q^2$
Absolute cross section measurements
Beam Charge and Spin Asymmetry at $E_\mu = 100$ GeV

COMPASS prediction

6 month data taking in 2010
250cm H2 target
25 % global efficiency

BC&SA

$Q^2$ vs $x_{Bj}$

$Q^2 = 2 \pm 0.5$

$Q^2 = 4 \pm 0.5$

$Q^2 = 6 \pm 0.5$

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$Q^2 = 4 \pm 0.5$

$Q^2 = 6 \pm 0.5$

Courtesy N.d’Hose
• 2008 test with muon beam (last week)

• DVCS feasibility study in the COMPASS environment, study existing recoil detector, calorimeter performance, extrapolate to larger, dedicated setup

• End of 2008 submit proposal for 2009-2015 to SPSC

• 2009 request for 30 days GPD pilot run

• From 2011 run with long recoil detector and liquid hydrogen target, later also with transverse target
2.7 m£ STFC Grant for the Dipole Magnet for Glasgow
• PANDA can measure the ‘cross channel’ or ‘time-like’ version of the same process, that depends on the same GPDs
• More precisely on Generalised Distribution Amplitudes, introduced by M. Diehl et al. to describe the inverse process [PRL. 81: 1782 (1998)].
The same factorisation proof as for DVCS does not hold for the crossed channel.

Alternative approach: Transition Distribution Amplitudes

TDAs extend the GPD concept to transitions  

Impact parameter space interpretation as for GPDs

Fourier transform gives a transverse picture of the pion cloud in the proton
• Current models of TDA predict small cross section (~100 fb)
• Need excellent detector system to remove background
• Measurement feasible with PANDA

Present and Future ep-Facilities

- **Luminosity [cm\(^{-2}\) s\(^{-1}\)]**
  - **HALL A**
  - **CLAS 12**
  - **CLAS**
  - **HERMES**
  - **COMPASS**
  - **H1**
  - **ZEUS**

- **E\(_{CM}\) [GeV]**

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Present and Future ep-Facilities

Luminosity $[\text{cm}^{-2}\text{s}^{-1}]$

- HALL A
- CLAS
- CLAS 12
- HERMES
- COMPASS
- EIC
- H1
- ZEUS

$E_{\text{CM}} [\text{GeV}]$

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Present and Future ep-Facilities

Luminosity $[cm^{-2} s^{-1}]$

- HALL A
- CLAS 12
- CLAS
- ep@ FAIR
- COMPASS
- HERMES
- ELIC
- eRHIC
- LHeC
- H1
- ZEUS

$E_{CM}$ [GeV]

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• Several concepts for future ep-facility: eRHIC at BNL, ELIC at JLab (together referred to as EIC), LHeC at CERN and ep@FAIR

• All designs use an existing machine and combine it with a second, new machine to a collider

• High luminosity, high energy, energy range

• GPDs are only part of the physics reach of such a facility
GPD Measurements - The Way Forward

DATA

LATTICE
DATA

LATTICE

MODELS
GPD Measurements - The Way Forward
GPD Measurements - The Way Forward

Data

Lattice

Models
GPD Measurements - The Way Forward

DATA

MODELS

LATTICE
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DATA

MODELS

LATTICE

HERMES
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COMPASS

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  - PANDA

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GPD Measurements - The Way Forward

DATA
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- EIC
- COMPASS
- HALL A

MODELS
- PANDA
- HERMES

LATTICE
- QCDSF
GPD Measurements - The Way Forward

DATA

MODELS

LATTICE

CLAS

EIC

COMPASS

HALL A

PANDA

HERMES

QCDSF

LHPC
GPD Measurements - The Way Forward

DATA
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- HALL A

MODELS
- PANDA
- HERMES
- QCDSF
- LHPC
- VGG

LATTICE
GPD Measurements - The Way Forward

DATA

CLAS
PANDA
HERMES

MODELS

EIC
COMPASS
HALL A

LATTICE

QCDSF
LHPC

VGG
DUAL
GPD Measurements - The Way Forward

DATA

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QCDSF

LHPC

LATTICE

DUAL

KMK-P
GPD Measurements - The Way Forward

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- LHPC
- KMK-P
GPD Measurements - The Way Forward

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GPD Measurements - The Way Forward

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GPD Measurements - The Way Forward

Combined Efforts by Experimentalists and Theorists required !!!
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• Generalised Parton Distributions are promising to revolutionize our picture of the nucleon and to solve the spin puzzle.

• Present experiments at HERMES and JLab are playing a pioneering role.

• Future experiments especially at JLab after the upgrade, but also at COMPASS and FAIR will further complete the picture.

• Ultimately a future ep-facility with high luminosity and an energy range up to higher energies will be required to finalise the picture.

• All of this will only be successful in the combination of experiments, lattice calculations and GPD model fits to the data.