First results from the HERMES Recoil Detector

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The Spin Structure of the Nucleon

Nucleon Spin:

\[
\frac{1}{2} = \frac{1}{2} \left( \Delta u + \Delta d + \Delta s \right) + L_q + \Delta G + L_g
\]

\[\Delta \Sigma \approx 30 - 35\% \text{ measured in DIS}\]

\[L_q, L_g \text{ and } \Delta G \text{ unknown}\]

Access to \( J_q \) via Deeply Virtual Compton Scattering (DVCS)

- Scattered beam lepton \( e' \)
- Real photon \( \gamma \)
- Recoiling proton \( p' \)

\[\text{HERMES Recoil Detector}\]

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The HERMES Spectrometer (before 2006)

- Fixed target experiment (uses 27.6 GeV/c HERA lepton beam)
- Storage cell target
- Various tracking and PID detectors
- DVCS: recoiling proton undetected → large background contamination (15%)
The HERMES Spectrometer (2006 - 2007)

- Recoil detector installed for the last two years of data taking
- DVCS: recoiling proton detected → background contamination <1%
The HERMES Recoil Detector

Superconducting Solenoid (1T)

Photon Detector
- 3 layers of Tungsten/Scintillator sandwich

Fiber Detector
- 2 barrels with 4 layers of scintillating fibers
- 2 parallel and 2 stereo layers per barrel

Silicon Detector
- 16 sensors
- Inside HERA vacuum
- 5 cm close to beam

Lepton beam
- 10.4 MHz bunch frequency
- 30 ps bunch length

Target cell
Momentum Reconstruction

- **Low-energy protons**
  - Momentum via sum of deposited energies

- **Medium-energy protons**
  - Momentum via dE/dx

- **High-energy particles (protons/pions)**
  - Momentum via bending in magnetic field

**Precise energy measurement in Silicon detectors**
Silicon Modules

HELIX chips
- 128 channels
- 10.4 MHz

FLEX foils
- 70 μm Kapton
- 20 μm Copper

Charge divider (1 : 5)

Sensors
- TIGRE design
- 300 μm
- 10 cm x 10 cm
- 128 x 128 strips
- 758 μm pitch

- 2 sensors per module
- 2 HELIX chips attached to each sensor side
- 8 modules in total
Silicon Modules

**Sensors**
- HELIX chips
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**Charge divider** (1:5)

**HERMES Recoil Detector**
- 128 x 128 strips
- 758 µm pitch
- 70 µm Kapton
- 20 µm Copper
- 128 channels
- 10.4 MHz

**TIGRE design**
- 300 µm
- 10 cm x 10 cm
Timeline

- Dec. 2005: Installation of the Recoil Detector at HERMES
- Feb. 2006: Start of data taking and commissioning
- Mar. 2006: Problems with target cell
- May 2006: Deinstallation and repair of Silicon modules
- June 2006: Installation of Silicon detector
- Sep. 2006: Finished commissioning
- June 2007: End of data taking

- Running stable over full data taking period
- ~ 95 % data taking efficiency
Pedestal Stability

- Pedestal run every 3 – 4 hours (1588 pedestal runs in total)
- ~ 85 % of channels are stable
- Remaining channels show medium or strong variations
Pedestal Drift

- Variations caused by beam current dependent pedestal position
- ~10 mA change in beam current between pedestal runs
- No systematics or symmetries seen
Pedestal Drift Correction

- After correction: pedestal drift < 1 ADC channel
- Remaining “jumps” are random and can't be corrected
Correlated Noise

- Pedestal after common mode (CM) correction in hardware
  - CM correction uses only first 16 channels of each chip
  - 3 – 4 ADC channels pedestal width
- Pedestal width increases with increasing channel number
- Correction via spline interpolation
  - Every 8th channel always read out (no threshold)
  - About 90% of data written to tape is just for this correction
Correlated Noise

- Remove actual hits from basepoints
- After correction: 3 – 4 ADC channels pedestal width over full chip

HERMES Recoil Detector
Crosstalk

- ~11 – 16% crosstalk to left neighbour
- ~15 – 21% crosstalk to right neighbour
- Crosstalk different for even and odd channels
Correction coefficients stable over full data taking period
Algorithm can recover signals in neighbouring channels even if below threshold
Calibration

- All modules calibrated at Erlangen Tandem
  - with protons of 3.5, 4.0, 6.0 and 9.0 MeV kinetic energy

- Calibration from HERMES data
  - Use negative pions: $0.2 \text{ GeV/c} < p < 0.5 \text{ GeV/c}$
  - Enough statistics to calibrate individual channels
  - Calibrate high-gain chips
  - Extrapolate to range of interest

- Each strip “sees” different
  - Momentum and
  - Path length distribution
Calibration using MIPs

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Calibration using MIPs

- Extrapolation to large energy deposits does not work
- ~ 5% channel to channel gain variation
- Will use this information in next iteration
Calibration using Protons

- Calibrate low gain chips in region of interest

- After correction for incident angle
- Substitute $E_{\text{Dep}}^{\ast \text{Inner}} = c_I \cdot E_{\text{Dep}}^{\text{Inner}}$ and $E_{\text{Dep}}^{\ast \text{Outer}} = c_O \cdot E_{\text{Dep}}^{\text{Outer}}$
- Fit Geant4 calculation to data points (2 free parameters)
- Works well but ...
- Not enough statistics to calibrate individual channels
Summary and Outlook

- All raw data correction algorithms implemented
- First iteration of calibration done
  - Channel by channel calibration needs understanding of MIP calibration
  - Feedback from momentum reconstruction improves incident angle correction
- New data production in progress
  - All subdetectors calibrated

- Physics Analysis
  - 38 Mio DIS events off Hydrogen; 10 Mio DIS events off Deuterium

- Efficiency studies
  - In advanced stage for fiber tracker
  - Started for Silicon detector

- Energy resolution
  - Studies in progress
Backups
Heavy Particles from Hydrogen Target

HERMES Recoil Detector
Crosstalk Correction – Clustersize

![Cluster Size Distribution Graph]

Cluster Size before Correction

Cluster Size after Correction
Calibration – Momentum and Pathlength Distributions

Perpendicular to beam

Momentum vs. Strip N Side

Parallel to beam

Momentum vs. Strip P Side

Pathlength vs. Strip N Side

Pathlength vs. Strip P Side
Leakage Currents
• 8 HELIX chips per module (8 x 300 mW)
Deeply Virtual Compton Scattering - DVCS

- GPDs: Probability function to take a parton with momentum fraction $x + \xi$ from the nucleon and put it back with momentum fraction $x - \xi$
- Same final state in DVCS and Bethe-Heitler
- Access to DVCS via interference term and azimuthal asymmetries:
  $$A_C, A_{LU}, A_{UT} \text{ and } A_{UL}$$