A Silicon Recoil Detector for the HERMES Experiment

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On behalf of the HERMES collaboration
Outline

1. The HERMES Experiment
2. Recoil Detector
3. Silicon Recoil Detector
   ➞ Sensors, Frame, Hybrid, Foils, Tests
4. Summary
The HERMES Experiment

→ Experiment at DESY Hamburg

→ 27.5 GeV longitudinally polarised $e^\pm$ from HERA accelerator

→ $< Q^2 > = 2.5 \text{ GeV}^2$
Internal polarized gas target (H, D, He, Ne, Kr)

Tracking: Silicon, Drift Chambers

PID: RICH, TRD, E/p Calorimeter
The HERMES Experiment

Exclusive Processes:
initial and final state fully known!

Deeply Virtual Compton Scattering
A Recoil Detector for HERMES

To improve the measurement of exclusive processes a Recoil Detector is presently being built.
A Recoil Detector for HERMES

- **Silicon** measuring low momenta protons
- **SciFi** for momentum and tracking
- **Photon** detector to improve exclusivity
- Superconducting **Magnet** providing field for SciFi
- A new **collimator** to reduce background hits
Recoil Silicon Detector

- Inside beam vacuum
- Diamond shape around target cell
- 2 layers of silicon
- 76% of $\phi$
- $23^\circ < \theta < 80^\circ$

Project of DESY, Erlangen, Gent, Glasgow
Recoil Silicon Detector

⇒ Large Dynamic Range required
⇒ Vacuum compatible components
Silicon Sensors
TIGRE sensors

- Largest commercially available silicon sensor
- Double sided
- $99 \times 99 \text{ mm}^2$, 300 $\mu\text{m}$ thick
- 758 $\mu\text{m}$ pitch
- Strip width: 702 $\mu\text{m}$
- SiO$_2$ layer ensures AC-coupling
**TIGRE sensors**

- Depletion voltage: 50 V
- Total capacitance $p$ ($n$): 52 pF (70 pF)
- Changes to original design:
  - Thicker SiO$_2$ layer
  - Bias Resistor
    $50 \, M\Omega \rightarrow 6.5 \, M\Omega$
TIGRE sensors

All TIGREs have been tested:

- Bias resistors p/n side for 3 strips
  - 3 strips: left, middle, right
- Interstrip resistance for 3 strips
- Coupling capacitor resistance for 3 strips
- Overall I/V–C/V characteristics: diode functionality, depletion voltage
- Long Term Test
The Holding Frame
Requirements for the holding frame:

- Sufficient stability
- Suitable for vacuum applications
- Thermal expansion coefficient close to that of silicon
# A Holding Frame

<table>
<thead>
<tr>
<th>Property</th>
<th>Silicon</th>
<th>Aluminium</th>
<th>Graphite</th>
<th>Shapal-M</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance</td>
<td>$10^{-4} - 10^4$</td>
<td>$5 \cdot 10^{-6}$</td>
<td>0.02</td>
<td>$10^{12}$</td>
<td>$\Omega \cdot cm$</td>
</tr>
<tr>
<td>Thermal Expansivity</td>
<td>2.6</td>
<td>23</td>
<td>7.4</td>
<td>4.4</td>
<td>$10^{-6} \frac{K}{cm}$</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>170</td>
<td>70</td>
<td>15</td>
<td>160</td>
<td>GPa</td>
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<tr>
<td>Thermal Conductivity</td>
<td>150</td>
<td>130</td>
<td>65</td>
<td>100</td>
<td>$\frac{W}{m \cdot K}$</td>
</tr>
<tr>
<td>Outgassing Rate</td>
<td>n.a.</td>
<td>$10^{-10}$</td>
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<td>$2.3 \cdot 10^{-11}$</td>
<td>$\frac{mbar \cdot l}{s \cdot cm^2}$</td>
</tr>
<tr>
<td>Costs per frame</td>
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## A Holding Frame

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### Go for Shapal-M

Sensors are glued with two component epoxy glue at $150^\circ$
Readout Hybrid
Two readout chip candidates were tested: APC and HELIX128-3.0
Extend Dynamic range with Charge division method:

Strip readout pad

10pF

High gain HELIX

Low gain HELIX
Readout Hybrid

Extend Dynamic range with Charge division method:

- Strip readout pad
- High gain HELIX
- Low gain HELIX
- 10pF

- Sufficient Dynamic Range
- HELIX already used in HERMES

Input charge (fC)

Output (ADC-counts)

0 100 200 300 400 500 600

0 200 400 600 800 1000

HELIX high gain
HELIX low gain

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Readout Hybrid

- Helix Chip
- Receivers
- Coupling Capacitors
- Flexfoil
- Line Drivers
- Pitch Adaptor

- 4 layers, with kapton cores
- Glued to aluminum heatsink
Chip Tests
Chip Tests

- Basic functionality (addressing, programming)
- Uniformity checked with internal testpulse
Chip Tests

372 chips tested

- 64 chips needed
- 153 Class A chips
- 100 Class A1
Kapton Readout foils

Readout Foils needed!
Kapton Readout foils

Beam

Target Cell

Scattered Proton

Traces

Flexfoil 1

Silicon 1

Flexfoil 2

Silicon 2

Flexfoil 3

Flexfoil 4
### Kapton Readout foils

**Different designs:** (\( \mu m \))

<table>
<thead>
<tr>
<th>Material</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kapton</td>
<td>25</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Copper</td>
<td>17</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Nickel</td>
<td>5</td>
<td>5</td>
<td>--</td>
</tr>
<tr>
<td>Gold</td>
<td>0.1</td>
<td>0.1</td>
<td>--</td>
</tr>
<tr>
<td>Kapton2</td>
<td>--</td>
<td>--</td>
<td>25</td>
</tr>
</tbody>
</table>

![Graphs showing data for different designs and materials](image-url)
An SRD Module
Assembly-Glueing

Stempel
Foil
Glue
Keramik

Glue: 2-Component Epoxy
Epotek H77 (Polytec)

Air bubbles below bondpads
Glue on foil

Preform

Preform: Woven material filled with Epoxy Glue.
Polytec TFT D18-1 SP4
Readout Scheme
Readout Scheme

- VME
- HLCU
- HADC
- ACC
- LV

~ 30 m

~ 3 m
Readout Scheme

HLCU: Programming, Clock, Triggering

[Diagram of an electronic circuit with labels HLCU, HADC, VME, and Load]
Readout Scheme

ACC: Repeater board, drivers/receivers

VME

HLCU

HADC

ACC

~ 30 m

~ 3 m

LV

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Readout Scheme

HADC: ADC, CMC, Zero Suppression

HLCU

HADC

VME

LV

128 channels
Trailers

Low Gain
High Gain

10 pF

22 pF

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Prototype Testing
Prototype testing

- Testbeams
  - DESY: MIP
  - Erlangen: Low Energy protons
- Laser Test Stand
- Detailed noise optimisation
- RF tests → Z. Ye’s talk (T401.5)
- Parameter tests → I. Hristova’s talk (T301.8)
Testbeam at DESY

- Electrons from pre-accelerator DESYII (1-6 GeV)
- Use Zeus Telescope
  - 6 Reference detectors
  - $\frac{S}{N} > 60$
  - pitch 25 (50) $\mu m$
Testbeam at DESY

### Testbeam at DESY

**Table 1:** Summary of Testbeam Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>345</td>
</tr>
<tr>
<td>Entries</td>
<td>8726</td>
</tr>
<tr>
<td>Mean</td>
<td>20.24</td>
</tr>
<tr>
<td>RMS</td>
<td>9.237</td>
</tr>
<tr>
<td>$\chi^2/\nu df$</td>
<td>355.9 / 73</td>
</tr>
<tr>
<td>P1</td>
<td>1341.</td>
</tr>
<tr>
<td>P2</td>
<td>15.64</td>
</tr>
<tr>
<td>P3</td>
<td>0.3644</td>
</tr>
</tbody>
</table>

**Graph:**

- **X-axis:** ADC Channels
- **Y-axis:** Entries

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Testbeam at DESY

‘Pre’ Prototype:

$\frac{S}{N} = 7.5$

$\epsilon = 99.73 \pm 0.04\%$

‘Final’ Prototype:

$\frac{S}{N} \sim 6.2$
Erlangen Testbeam

- Double Van De Graaff Accelerator
- Protons up to 11 MeV
- First tests being analysed
Laser Test

- Black Box
- Red Laser
- X-Y Table
- Spot $\sim 20\mu m$
Laser Test

- Uniformity
- Linearity
- Pipe Spread
Asymmetric Crosstalk $\sim 5.1\%$

Similar as reported by other groups
Summary

- Development of a Silicon Recoil Detector for HERMES
- Mechanical construction fixed and working
- First SRD module being tested and optimised
- Test installation in 2004