

The HERMES Recoil Detector - a combined Silicon Strip and Scintillating Fiber Detector for Tracking and Particle Identification

Nils Pickert^{*†}

Physikalisches Institut II, University of Erlangen-Nürnberg, Germany

E-mail: pickert@pi2.physik.uni-erlangen.de

The HERMES Collaboration will install a new recoil detector for the last two years of HERA-II running. This detector surrounds the internal gas target and will enable HERMES to study hard exclusive processes which provide access to generalised parton distributions (GPDs). Its main purpose will be positive identification of recoiling protons, improving the transverse momentum reconstruction of these particles and rejecting non-exclusive background events. Direct measurements of energy deposition and track direction will provide particle identification and momentum determination. First results of a cosmic test are presented.

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^{*}Speaker.

[†]on behalf of the HERMES Collaboration

1. Introduction

The HERMES Collaboration will install a new recoil detector in the winter shutdown of 2005/06, whose main purpose is to study hard exclusive processes during the last two years of HERA-II running. These hard exclusive processes will provide access to the generalised parton distributions (GPDs) [1] which represent a new description of the nucleon. From these distributions information on the total angular momentum of the quarks inside the nucleon can be gained via Ji's Sum Rule [2, 3].

The HERMES recoil detector will primarily serve to study the process of Deeply Virtual Compton Scattering (DVCS) on protons (figure 1a), which has already been observed with the existing HERMES Spectrometer [4, 5]. This process allows to access information on four GPDs, two of which appear in Ji's Sum Rule. The DVCS process interferes with the Bethe-Heitler process where the incoming or outgoing electron radiates a hard real photon in the Coulomb field of the nucleon (figure 1b). At the centre of mass energy of HERMES ($\sqrt{s} = 7\text{GeV}$) this interference leads to measurable azimuthal asymmetries around the virtual photon direction. The energy resolution for electrons and photons of the existing HERMES Spectrometer is not sufficient for clean identification of the exclusive DVCS process, and it has no acceptance to detect recoiling particles under large angles; therefore, a recoil detector is needed in addition to detect and to identify the recoiling protons, and to reject non exclusive background events.

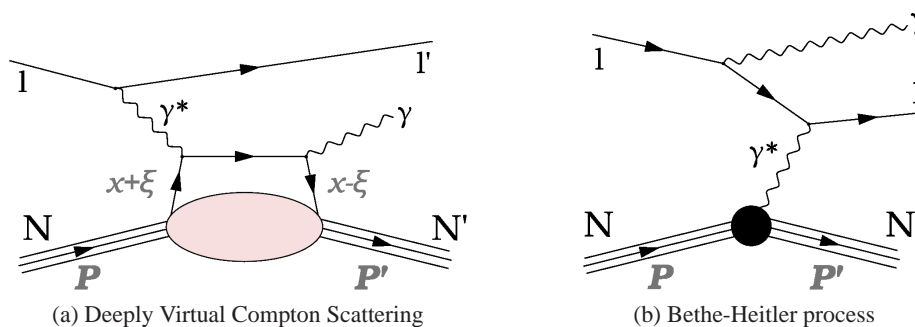


Figure 1: The two interfering $lN \rightarrow lN\gamma$ processes observed at HERMES.

2. The Recoil Detector

The recoil detector consists of three main components surrounding an internal unpolarised gas target: a two-layer silicon strip detector surrounding the target cell inside the vacuum, a scintillating fibre tracker and a photon detector consisting of three layers of tungsten radiators and scintillators [6]. The detectors are placed in a longitudinal magnetic field of 1 Tesla generated by a superconducting magnet. The fibre tracker and the silicon detectors are optimised to detect recoiling protons from hard exclusive processes. They cover a momentum range from 0.1 GeV/c to 1.5 GeV/c and provide the particle identification properties to discriminate protons from pions. The photon detector is used for particle identification of high momentum particles and for background rejection of neutral particles. All detectors will provide a measurement of the deposited energy.

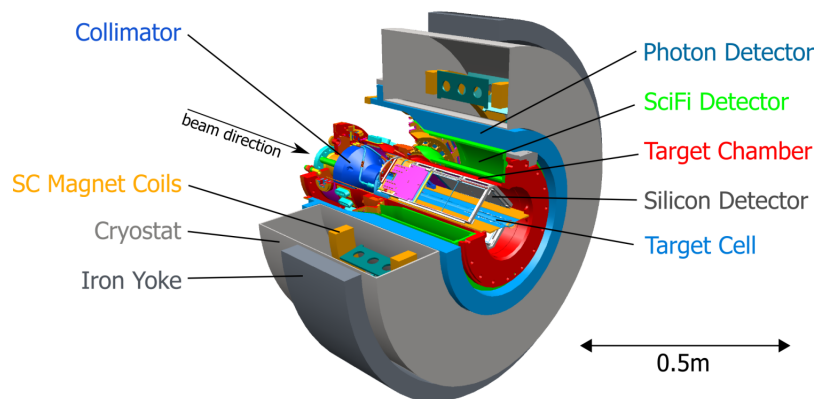


Figure 2: Overview of the recoil detector.

2.1 The Silicon Strip Detector

The innermost part of the recoil detector consists of 16 double sided silicon sensors based on the TTT design [7] of Micron Semiconductors, with 128 strips per side and a strip width of $758 \mu\text{m}$. The sensors measure $10 \text{ by } 10 \text{ cm}^2$ with a thickness of $300 \mu\text{m}$ and are arranged around the target cell in two layers of four modules, each containing two sensors. The necessary high dynamic range of up to 350 fC is established by a charge division readout where the signal is split into a high gain and a low gain path. Both signals are read out by Helix 3.0 readout chips. A signal to noise ratio of 6.5 for a minimum ionising particle could be reached at test beams with an efficiency of close to 99%. The detectors have been calibrated in test beams at DESY with minimum ionising electrons with a resolution of about 3%, and at the Erlangen Tandem accelerator with low energy protons of 4, 6 and 9 MeV kinetic energy with an energy resolution of better than 2%.

The silicon detector will provide energy measurements for low energy particles with momenta of $135 \text{ MeV}/c$ to $400 \text{ MeV}/c$. For particles of higher momenta space points for tracking will be provided.

2.2 The Scintillating Fibre Tracker

The momentum of faster particles will be determined from the bending of the particle tracks inside the magnetic field, measured by two barrels of scintillating fibres. Each barrel contains two parallel and two stereo layers of 1 mm round fibres (Kuraray SCSF-78), with a stereo angle of 10° between the layers. The detector is constructed as a self-supporting structure to minimise the material transversed by the particles. The 5120 channels of the detector are coupled via light guides to Hamamatsu 64-channel PMTs which are read out with front cards based on the GASSIPLEX chip. Additional fast timing information is provided by a TDC readout of the Dynode 12 signals of the PMTs.

The scintillating fibre tracker will provide space points for the tracking of protons up to a momentum of $1.4 \text{ GeV}/c$ and of pions up to a momentum of $800 \text{ MeV}/c$. It will also provide information for particle identification.

2.3 The Photon Detector

The photon detector consists of three layers of plastic scintillators with a cross section of 2 by 1 cm² and a length of 28 cm. A tungsten converter of 2 cm thickness is placed in front of the two inner layers. The converter layer in front of the outer layer consists of 1 cm tungsten. One layer is oriented parallel to the beam axis, the others are under stereo angles of $\pm 45^\circ$. The 164 channels of the detector are read out via three 64-channel PMTs.

The photon detector will provide photon detection for photons originating in decay processes of Δ^+ resonances and will do particle identification for particles of momenta higher than 600 MeV/c. For alignment purposes a cosmic ray trigger can be provided between HERA fills.

3. Cosmic Ray Test

From June to September 2005 the completely mounted detector was operated with the magnetic field turned on, and it was successfully tested with cosmic rays at a test site in the HERMES experimental hall. This test run is not only used to identify and solve the problems in running the detector as a complete system, but also to calibrate the scintillating fibre tracker and the photon detector. Tracking and resolution studies are underway.

First results give efficiencies of approximately 98% for the scintillating fibres and the photon detector, and about 80% to 90% for the silicon strip detector. The rather low efficiencies of the silicon detector are due to high common mode noise present in the test setup. A change in the electrical setup of the silicon modules applied after the cosmic ray test reduced this noise drastically, resulting in a noise behaviour as in the test beams. Efficiencies of the same order as in the test beams are expected with this change for the final installation. For the cosmic ray test data an additional offline common mode correction is also expected to result in higher efficiencies. First results on spatial resolution are 0.35 mm for the scintillating fibre tracker and 0.27 mm for the silicon strip detector.

References

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