Available online at www.sciencedirect.com
SCIENCE DIRECT®

Nuclear Instruments and Methods in Physics Research A 535 (2004) 538–541

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

The HERMES recoil detector: a combined silicon strip and scintillating fibre detector for tracking and particle identification

Björn Seitz

II. Physikalisches Institut, University of Giessen, 35392 Giessen, Germany

On behalf of the HERMES Collaboration
Available online 17 August 2004

Abstract

The study of hard exclusive processes at the HERMES experiment at DESY requires a recoil detector surrounding the internal gas target. It consists of a silicon strip detector inside the beam vaccum, a scintillating fibre tracker in a 1 T solenoidal field and a tungsten-scintillator sandwich detector for photon detection. This recoil detector will improve the selection of exclusive events by a direct measurement of the recoiling particle as well as by rejecting non-exclusive background events.

PACS: 29.40.Gx; 29.40.Mc; 20.40.Wk

Keywords: Tracking and position-sensitive detectors; Scintillation detectors; Solid state detectors

1. Introduction

The HERMES Collaboration [1] will install a new recoil detector for the envisaged final 2 years of the HERA-II running period. The study of hard exclusive processes requires a recoil detector surrounding the target. The detector focuses on positive identification of recoiling protons, improving the transverse momentum reconstruction of these particles and rejecting non-exclusive background events. The HERMES Recoil Detector shown in Fig. 1 will consist of three main components: a two-layer silicon detector surrounding the target cell inside the vacuum, a scintillating fibre tracker in a longitudinal magnetic field of 1 T and a photon detector consisting of three layers of tungsten radiators and scintillators [2]. The fibre tracker and the silicon detectors were optimized to detect recoil protons in a momentum range from 0.1 to 1.5 GeV/c. Their particle identification properties allow the discrimination proton from pions over the whole

E-mail address: bjoern.seitz@desy.de (B. Seitz).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2004.07.190

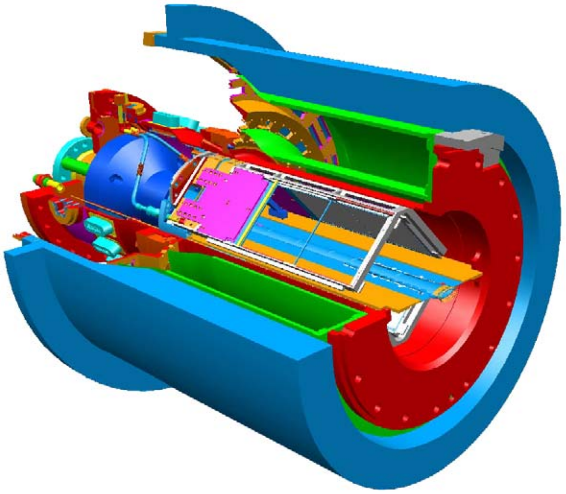

Fig. 1. Schematic view of the HERMES recoil detector presently under construction. The electron beam enters from the left. In the centre the target cell is shown surrounded by the SSD in a diamond-shaped configuration. The outer layers show the two barrels of the SciFi detector and the photon detector.

momentum range. Momentum determination for low momenta particles stopping inside the silicon detector is performed using the $\Delta E - E$ technique. The momentum of fast particles will be determined by their bending in the magnetic field. The photon detector is used for particle identification of high-momentum particles and for background rejection of neutral particles.

1.1. The silicon strip detector (SSD)

The SSD consists of 16 double-sided TIGRE detectors[1] of 300 µm thickness covering an active area of $99 \times 99\,\mathrm{mm}^2$ each. They feature 128 strips on each side with a strip pitch of 758 µm. Strips on either side are perpendicular to each other allowing space point reconstruction. The SSD is sensitive to energy depositions from minimum ionizing particles (MIP) up to the large energy deposition expected from protons stopping in either silicon layer. To cover the large dynamic range of the expected signals the TIGRE sensors are connected to the read-out electronics using a fanout which splits the signals by capacitive charge division. Every sensor strip is connected to a high- and a low-gain channel allowing signals from 4 up to 270 fC to be analysed. The read-out itself is based on HELIX128-3.0 chips.

[1]MICRON Semiconductors Ltd.

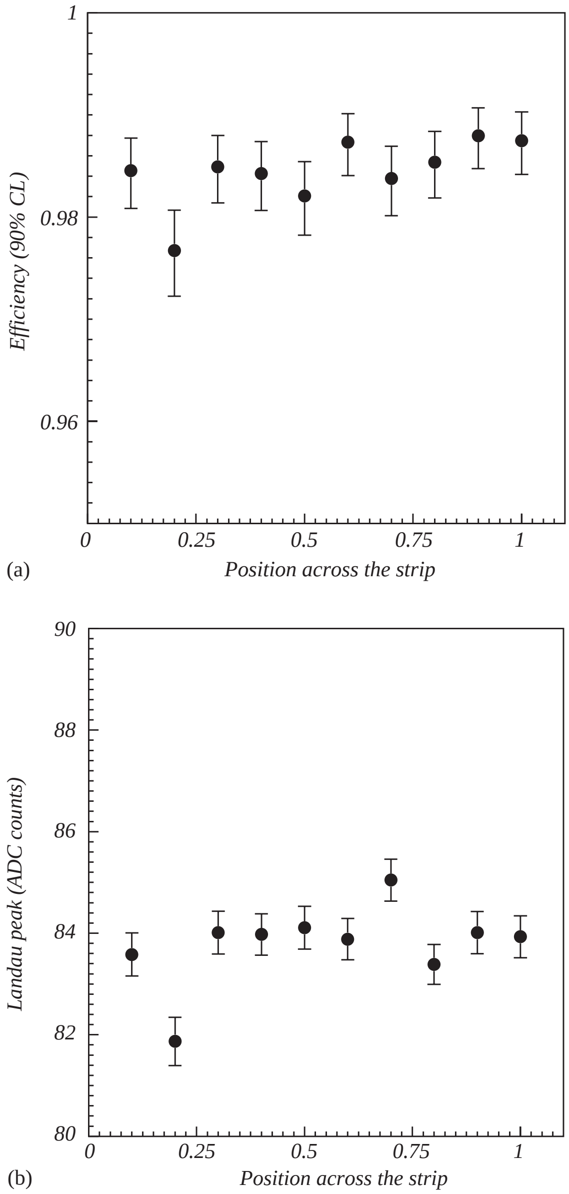

Fig. 2. (a) and (b). Efficiency of the SSD prototype measured with a 6 GeV electron beam at DESY as a function of the position along the strip (left) and energy response as a function of the position along the strip. The coordinates are relative to the strip width of 758 µm.

1.2. The scintillating fibre detector

Particles of higher momenta will be measured in two barrels consisting of 4 layers of 1 mm Kuraray SCSF–78 scintillating fibres each. A stereo angle of 10° between each two adjacent layers of each barrel allows space point reconstruction. The diameters of the barrels are 220 mm and 370 mm, respectively. The read-out of the fibres is done via 3.5 m long light guides of Kuraray clear fibres coupled to Hamamatsu H–7548 64 chn. PMTs. The read-out is based on front-end cards using GASSIPLEX chips. In addition, the Dynode 12 signals of the PMTs are used to extract fast timing information. The cylinders are build from 72 SciFi strips as self-supporting structures to minimize the material transversed by the particles.

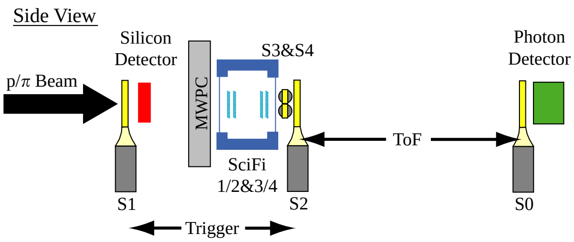

Fig. 3. Schematic view of the detector set-up used at the GSI test beam. The trigger is provided by a coincidence of scintillators S1 and S2. The MWPC allows to determine the point of impact on the SciFi modules under test. The 1.9 m distance between S0 and S2 is used for time-of-flight particle discrimination.

2. Detector response to electrons, pions and protons

Modules of all detectors were put to test beams at DESY and GSI. The test beam at DESY features a 6 GeV electron beam which was used to test the position dependence of the SSD performance with MIPs. These measurements were performed using a Si–telescope as reference detector. Fig. 2 shows the response of the test module to electrons of 6 GeV/c as a function of the relative position along the strip. The efficiency of the module is measured to be $\varepsilon = 98.73\%$. The energy response is homogeneous.

A mixed proton/pion beam was used at GSI. The set-up used is shown in Fig. 3 Components of all three subdetectors were tested simultaneously. Beam momenta of 300, 600 and 900 MeV/c were used focussing on tests of the response, efficiency and particle identification properties of the SciFi detector [3].

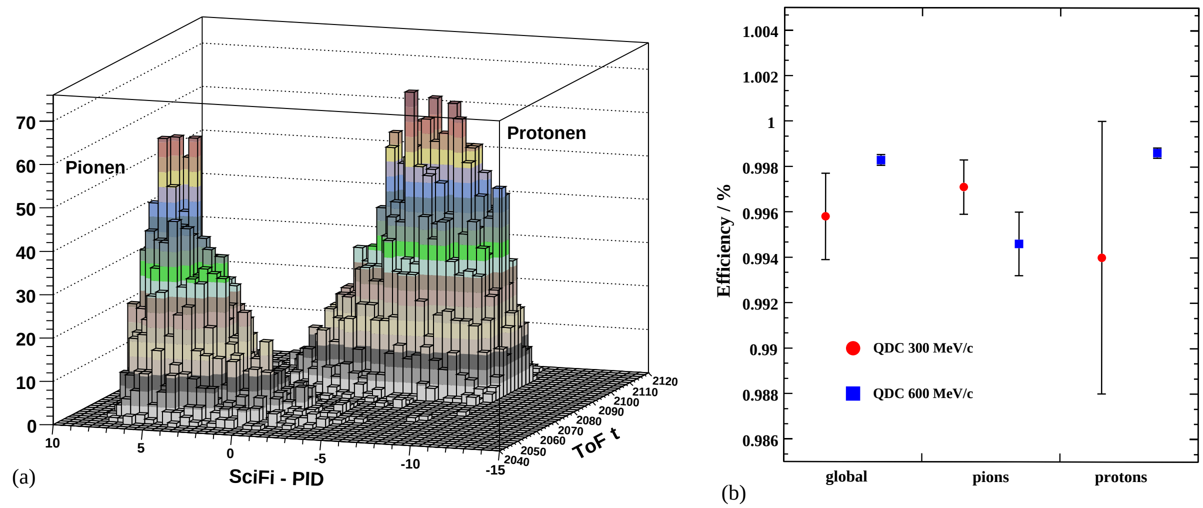

Fig. 4. (a) and (b). Particle identification with the SciFi test set-up vs. particle identification using the time-of-flight technique at the GSI test beam (left). The SciFi detector is capable to detect pions and protons equally with an efficiency exceeding 99% for all momenta and particle species measured (right).

Test beam results for protons and pions taken with prototype modules of the SciFi are shown in Fig. 4 The left figure shows the PID response of a combination of 4 staggered SciFi modules compared to the particle discrimination reached by the time-of-flight technique. The right figure shows the detection efficiency of one module to measure protons and pions at two relevant momenta. This test was performed using CAEN V792 QDC modules. A similar performance was achieved with a prototype of the photon detector.

3. Summary

The HERMES Collaboration will install a recoil detector surrounding the internal gas target for the final phase of the HERA-II run. The detector is currently being assembled and prepared for installation. Prototypes of the different detector components were tested in various test beams ranging from low energy protons to mixed pion/proton beams up to high energy electrons. All prototypes fulfill or exceed the design criteria.

References

[1] K. Rith, Prog. Part. Nucl. Phys. 49 (2002) 245.
[2] The HERMES Collaboration, The HERMES Recoil Detector Technical Design Report, HERMES Interal Note 02-003, 2002.
[3] W. Sommer, Diploma Thesis, University of Giessen, Germany, 2003.