First data from the HERMES Recoil Detector

Nils Pickert, On behalf of the HERMES Collaboration

Physikalisches Institut 2, Universität Erlangen-Nürnberg, Germany

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Abstract

The HERMES Collaboration has installed a new Recoil Detector surrounding the internal gas target to upgrade the existing spectrometer. It detects and identifies low energy protons at large angles originating from hard exclusive processes. These measurements will provide access to generalised parton distributions. The Recoil Detector consists of a silicon detector inside the beam pipe, a scintillating fibre tracker, and a photon detector. All three sub-detectors are located inside a superconducting solenoidal.

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1. Introduction

HERMES is one of the three experiments at the HERA collider at DESY, Hamburg. It uses the 27.5 GeV longitudinally polarised electron/positron beam and an internal gas target to explore and disentangle the different contributions to the spin of the nucleon [1]. The HERMES spectrometer is a forward angle instrument with an acceptance of $\pm 170$ mrad horizontally and $\pm (40 - 140)$ mrad vertically. In January 2006 the existing detectors were extended by the installation of a recoil detector surrounding the internal gas target (Fig. 1) [2]. The main purpose of the upgrade is to measure low energy particles under large angles originating from hard exclusive processes, like Deeply Virtual Compton Scattering (DVCS), which has already been observed semi-inclusively with the HERMES-Spectrometer alone [3]. These hard exclusive processes give access to the generalised parton distributions (GPDs). From these parton distributions, information on the angular momenta of the quarks can be gained via Ji’s sum rule [4]. In the reaction $ep \rightarrow e'\gamma p$, the DVCS process interferes with Bremsstrahlung processes, which leads to a beam spin and beam charge azimuthal asymmetry around the direction of the virtual photon.

2. The detector

2.1. The silicon detector

The silicon detector measures the momentum of recoiling protons in a range of 135–400 MeV/c via their energy deposition and provides space points for the tracking of minimum ionising particles, too. It consists of 16 double sided silicon sensors based on the TTT design of Micron Semiconductors, with 128 strips per side and a strip width of 758 $\mu$m. The necessary dynamic range is established by splitting the signal into a high gain and a low gain path: each strip is read out by one HELIX chip connected directly to the sensor and by a second chip connected via a 10 pF capacitor [5].

As the silicon detector is mounted inside the HERA vacuum it is strongly influenced by the electromagnetic fields of the beam, resulting in a high amount of common mode noise. This common mode noise is a shift measurable in all strips connected to one readout chip. The noise is generated mostly on the chip itself, as there is no correlation between the high gain and the low gain path of the same sensor. An electromagnetic shielding already reduces this noise by some amount, an additional on-line reduction is done in the ADCs using the average of the first 16 not-hit strips to determine a noise estimate. However, as the correlation over the whole sensor is not linear, an
additional reduction is necessary. Some strips are read out unsparsified and are used as base points for a spline estimate of the common mode shift. A reduction of the common mode noise by about a factor of 5 is achieved, allowing the detection of minimum ionising particles with a signal to noise ratio of 5:1 in the high gain path. Slow protons stopped in the silicon produce an energy deposition of 6.2 MeV (equivalent to 60 MIPs) which is measured in the low gain path with a signal to noise ratio of 250:1.

2.2. The scintillating fibre tracker

The scintillating fibre (SciFi) tracker measures the particles of momenta above 250 MeV/c using two barrels consisting of two fibre layers each. The signals of the fibres are read out with Hamamatsu-64 channel photo multipliers. The PMT signals are processed in GASSIPLEX read out chips which are sample-and-hold chips with an integration time of 6 HERA bunches. A TDC samples the dynode 12 signals of the PMTs to extract fast timing information on the events. Using this technique, an average multiplicity of four per detector-layer and triggered event is reached. The efficiency of a detector layer is around 98%, as expected from beam tests done at GSI [6].

2.3. The photon detector

The photon detector consists of three layers of 1.1 cm thick scintillator bars with tungsten converter material, the inner converter with a thickness of 6 mm, the outer two with 3 mm. The innermost scintillators are parallel to the beam, the outer...
layers have stereo angles of $\pm 45^\circ$. The detection of photons, especially those originating from $D^+$-decays, allows the reduction of non-exclusive background events. The multiplicity per triggered event and layer for normal running is around 1, for running with high target density around 1.2.

3. First data

The recoil detector was installed at HERMES in January 2006 and is taking data since. Fig. 2 shows the energy loss in the inner layer of the silicon detector versus the energy loss in the outer silicon layer. The punch through point at an energy loss of 6.2 MeV in the outer layer is clearly visible. Fig. 3 shows the possibility of kinematically separating elastic events from deep inelastic scattering events with the silicon detector only.

Fig. 4 shows a selection of events containing mainly elastic $e^-p$-scattering. It shows the azimuthal angle of the scattered proton measured with the SciFi tracker versus the same angle reconstructed from the scattered lepton detected in the spectrometer. An angular resolution of 8 mrad is obtained. The gap results from the spectrometer acceptance.

The sub-detectors are working as specified and will continue taking data until the HERA end-of-running in July 2007.

References