PREPARATION OF TESTS OF THE FIRST PROTOTYPE MODULE FOR THE HERMES SILICON RECOIL DETECTOR

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Abstract

An outline of the theory and operational details of the HERMES silicon recoil detector is given. The initial tests to be carried out on the hybrid chips for the TIGRE sensors in the silicon recoil detector, and the software to control the movement of the TIGRE sensors in the testbeam are both described in detail, as this was the focus of my work here. Testing will begin upon the delivery of the first HERMES hybrid, which are currently in production.

Contents

1 Introduction

1.1 HERMES

The HERMES experiment is a fixed target experiment started in 1995 with the goal of explaining the spin sub-structure of nucleons. This is described by Generalised Parton Distributions (GPD's), whose determination will require inputs from many exclusive scattering processes and other data. These may give an insight into the orbital angular momentum of quarks, which is essential to a full description of spin on a sub-nucleon level. The challenge arises from the necessity of exclusivity: For an exclusive reaction (like ^{eg} Deeply Virtual Compton Scattering, DVCS), the energies and momenta of all the components involved are required.

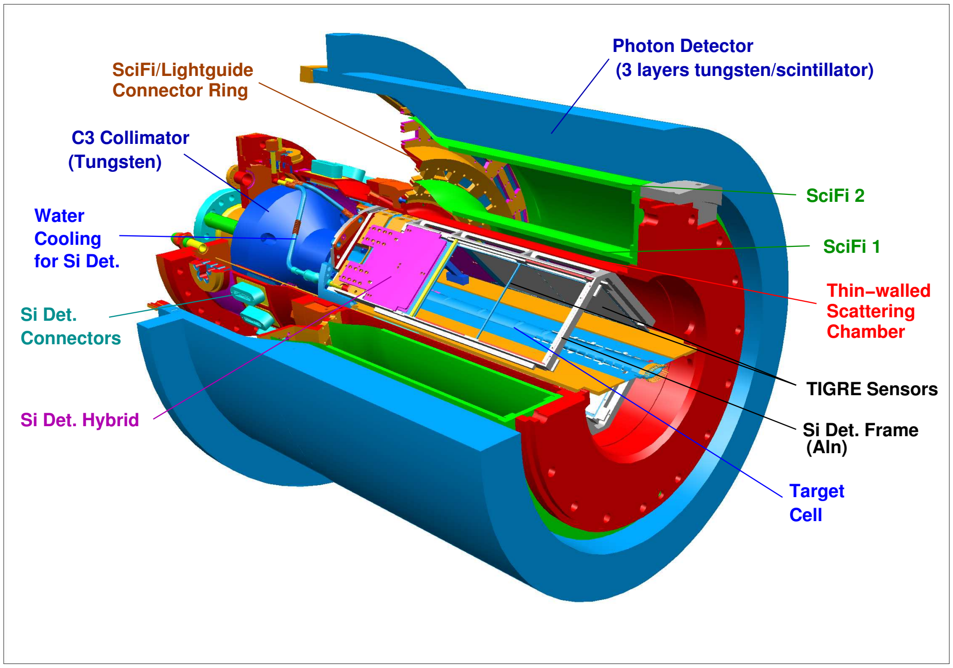

Figure 1: The HERMES Recoil Detector

Since the momenta of the scattered protons is very low in comparison with that of the scattered electrons, it cannot be accurately determined from conservation laws alone, as the uncertainty in the measurement of the scattered electron is often greater than the momentum of the recoiling proton. This is one motivation for the construction of a dedicated recoil detector. The other one is to detect other 'recoil products', like pions from $\Delta \rightarrow N\pi$, such as to be able to sort out the physics process of 'associated DVCS', $\gamma^{\star}p \rightarrow \gamma\Delta \rightarrow \gamma N\pi$.

1.2 Recoil detector

The recoil detector consists of three parts (see Fig 1): a silicon detector around the target cell which are both inside the beam pipe, a fibre tracker outside the beampipe, and finally a scintillating photon detector outside this. The thickness of the walls of the target cell and the beam pipe are kept as low as possible, in order to minimise their effect on the particles passing through them. This allows particles with very low momenta to be detected. The silicon detector determines the momentum of the recoiling nucleons (or nucleon plus pion) by measuring the energy deposited by them as they pass through it. It is because the protons are low momentum that the detectors must be as close as possible to the target cell, and in the beam-pipe vacuum. The Silicon detector can differentiate between protons

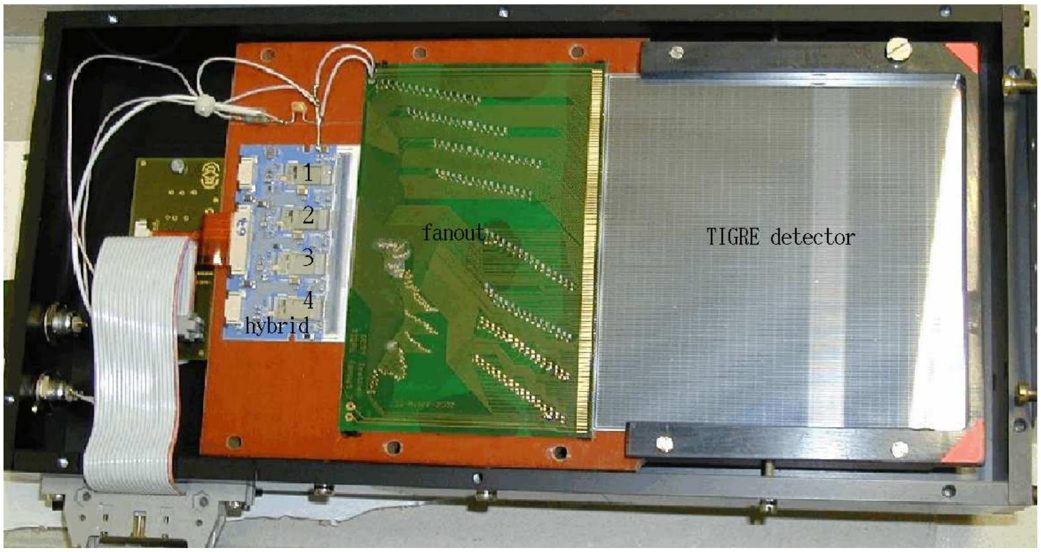

Figure 2: TIGRE and Hybrid on mounting

and pions up to momentum of about 200 MeV/c. The scintillating fibre detector outside the silicon detector is used to discriminate between protons and pions with momentum between 250 and 450 MeV/c. The photon detector is the outermost part of the recoil detector, and serves several functions: photons from π^0 decays can be detected, thus it may be possible to reconstruct the path of the meson if two decay photons are observed. Also, the pion/proton separation can be extended to momenta of 800MeV/c. A more in-depth description of the recoil detector can be found in Ref 1.

1.3 The Silicon detector and Helix chipset

The silicon detector is made of an array of sixteen pre-made silicon sensors (TIGRE's). These are fixed in a square pipe surrounding the beam axis (see Fig 3). The TIGRE sensors are of double-sided type with detection directions at right-angles to each other, having 128 channels per side and a channel separation of 758 microns. Hence a unique 2D-position is obtained for a single particle. The charge is registered in a particular channel by the creation of electron hole pairs in the channel, which are stored until readout. The detection efficiency of the detector is around 99 per cent. Each TIGRE sensor has a two-fold readout, per side 128 channels each for low and high gain, respectively. The channels are read out using a hybrid chip array, which includes four 128 channel HELIX128 -3.0 microchips (Fig **??**). The HELIX consists of a preamplifier, a pulse shaper, where the signal is given a semi-Gaussian shape and a buffer which stores the signals in a pipeline

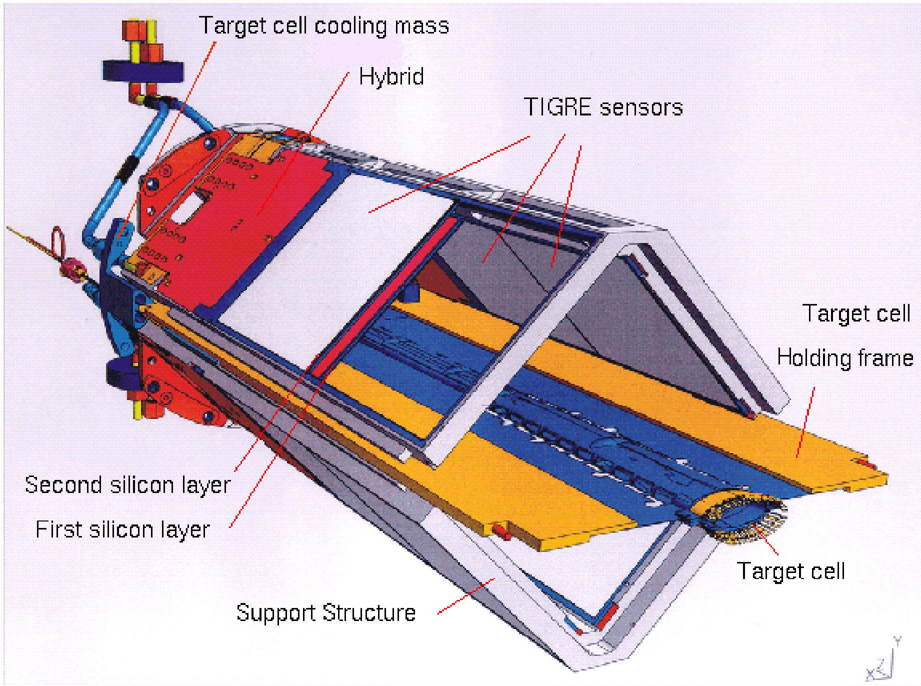

Figure 3: Target cell with silicon detectors

cell. These hybrid devices will be operating in the beampipe vacuum close beside the TIGRE sensors (see Fig 2), and thus need to be cooled due to the absence of convective heat transfer. The silicon detector can determine the momentum of an incident particle, as the particle deposits energy as it passes through. The energy deposition with distance through the silicon follows a Landau distribution for both electrons (Ref 2) and protons (Ref 3). These particles can be distinguished by the amount of energy they deposit for a given beam energy described by the Bethe-Bloch parameterization of the Landau distribution.

It is possible to measure the momentum of the particle with precision, as we are dealing with particles which have momenta in the part of the plot which is to the left of the minimum (^{ie} those with less than the minmum ionising particle momenta). The gradient of the energy deposited against particle momentum is large in this area, thus it is possible to calculate momenta accurately.

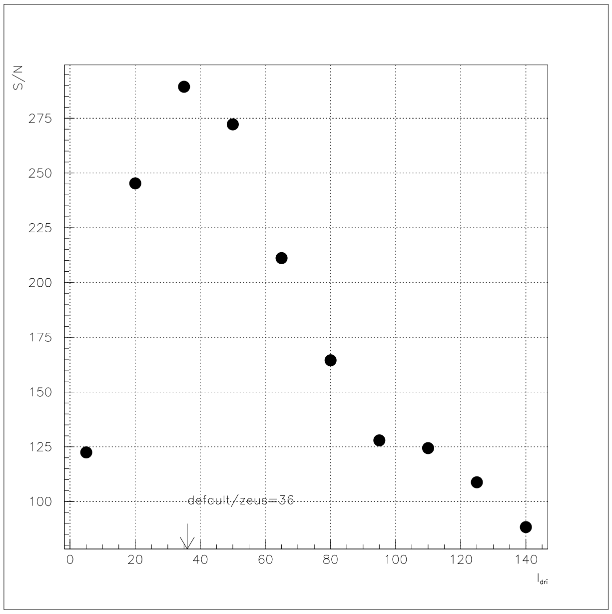

Figure 4: Variation of S/N with I_{driver} for hybrid

2 Tests

2.1 Lab Hybrid tests

The final hybrids for the recoil detector have not been manufactured yet, but the general properties can be studied as the Zeus experiment uses the same readout mechanism, and donated a spare hybrid to HERMES for testing. The Helix has a number of parameters which can be altered, and the presence of a particle can be simulated with the injection of a charge directly onto an input channel. The parameters were each adjusted individually, in order to find the settings for the hybrid which maximise the signal to noise ratio (S/N), and to find the regions in which the chip works correctly (see Fig 4 and Ref 4). The Zeus team have already done such fine tuning, but the hybrids which will be manufactured for HERMES will have different mountings and some passive component differences which may influence the optimal settings. It is therefore necessary and desirable to examine these again. Before any fine tuning of the hybrid can take place, a comprehensive list of basic tests need to be carried out in order to ensure that the chip is in working order. These tests, which will be carried out as the hybrids are delivered to Zeuthen, are as follows:

- Check power consumption and temperature of hybrid. This is crucial, as if the temperature of the chip is not stable then ensuring that it receives adequate cooling in the beam vacuum may be impossible.

- A check of the signal quality, to ensure that digital data will be read and received properly. This also encompasses a check on the risetime and falltime of the signal, and that any reflections in the circuitry are minimised.

- The analogue outputs are tested, with the risetime, falltime and damping measured, and also the impact of crosstalk from the digital signals quantified.

- The four HELIX chips on the hybrid are then put through some basic tests to ensure that the hybrid assembly process has not damaged them.

- The noise characteristics of the hybrid are then measured for various configurations of capacitors on board. After this, the ground potential of the hybrid is matched to the bias voltage of the TIGRE detectors, and the fine tuning can begin.

Over the range of each parameter to be varied in the fine tuning, a reading is taken with and without charge injection. The reading taken with no charge injection is called the pedestal. The pedestal can be subtracted from the the reading taken with charge injection to leave only the injected signal. It is important to quantify correctly the noise associated with a reading. The pedestal measurements over all channels are Gaussian distributed. The noise is given by the standard deviation of the pedestal distribution,σ. This allows the setting of a minimum signal value, in terms of the noise. Any value below this threshold is rejected as noise, and any value above it is taken as a signal. 3σ is commonly used as a threshold, as over 99.5 per cent of the pedestal values fall within the 3σ limit, and is thus rejected.

As can be seen from Fig 4, adjusting these parameters can have a marked effect on the performance of the chip. In this case, the parameter I_{driver} controls the output driver current. It is of particular interest to model the form of the signal from the shaper, which has a semi-Gaussian form (see Fig 5). as adjusting the parameters of the HELIX change the location of the peak of the output. It is this peak that is to be read out from the chip, thus timing the signal readout to coincide with the peak from the shaper is of critical importance. The signal to read the output of the shaper is sent from the HLCU (sequencer). This signal is known as a trigger. The output from the Hybrid is then sent to the nalogue to digital converter (ADC). The user must introduce a delay in the reading of the shaper which can be found by fitting the output from the shaper with the function below, parameterised in time:

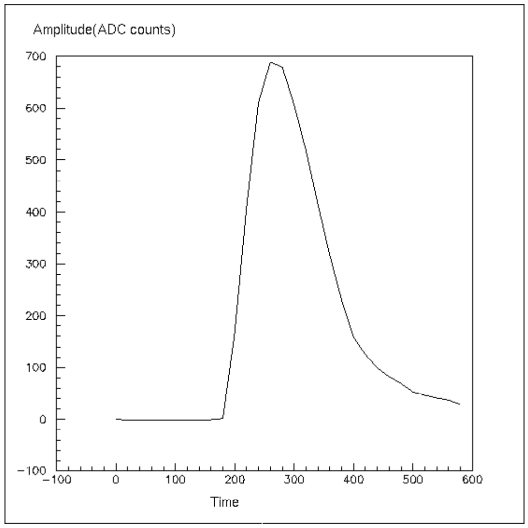

Figure 5: Shaper output to be parameterised by Gaussian

$$G(t) = Ae^{-(\frac{t+t_0}{\tau_2})} sin(\frac{t+t_0}{\tau_1})$$

where A is the amplitude, τ_1 determines the period of the sin function, τ_2 determines the rate of decay of the function, and t_0 is a phase constant. I have been involved in the gathering of data from the test hybrid from Zeus, in preparation for the testing to be carried out on the HERMES hybrids which are currently in production.

2.2 Labview program for motor table in DESYII testbeam

The TIGRE sensors are to be tested in the DESYII ring in Hamburg, in order to be able to calibrate the detectors properly before they are commissioned in HERMES. The sensors will be tested with electrons in the 1 to 6 GeV range. The sensor is mounted on an electronically controlled table, allowing movements in 3 axes (x and y normal to beam and ϕ the rotation angle around the x-axis) via a graphical control in Labview. The table needs to be controlled from the test beam control room which is 30 metres from the table. This distance was greater than the maximum cable length for the GPIB interface which the table used, so it was necessary to change the interface from a GPIB to an RS-232 (9-pin serial cable). In order to change the interface, it was necessary to modify the Labview program. Labview is a graphical programming package (see Figs 6 and 7), and the main program (called a 'visual interface' or 'vi') is composed of several smaller vi's (sub-vi's). Each of these sub-vi's is similar to an object or function in conventional programming languages. All the sub-vi's were modified to be compatible with the

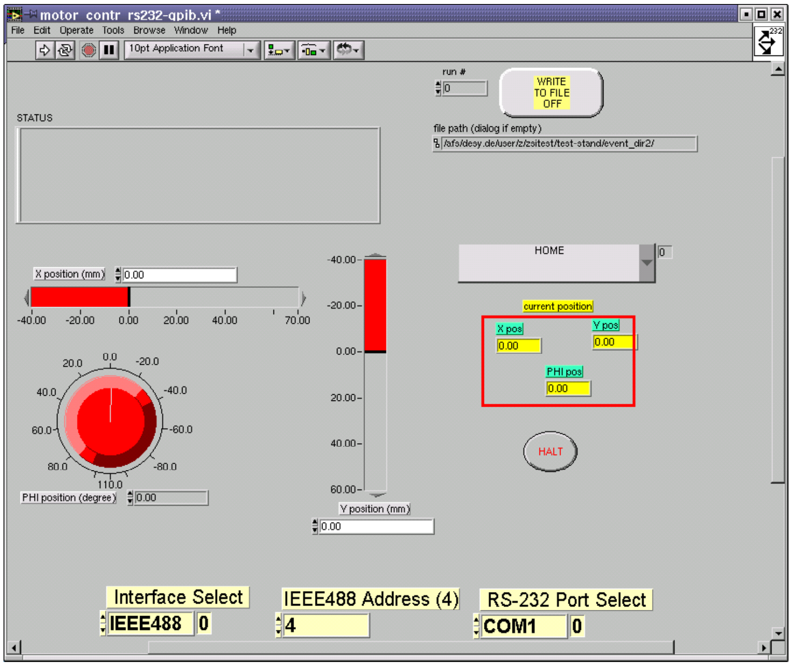

Figure 6: Labview graphical interface to control table

new interface, and the modified program was tested successfully at the test beam site in Hamburg. An overview of the Labview program which controls the table follows

Labview software for PI C-844 motor controller via RS-232

Introduction

The motors controlling the table are guided from the PI C-844 DC motor controller. The existing labview program for the table, which used the GPIB interface, has been modified to use the RS-232 interface. This also involved the modification of several sub-vi's.

This section provides an overview of the program for a user, while section 2 examines the program in more detail.

The Main VI: motor-contr-rs232-gpib.vi

This is the main interface from which the user controls the table, and receives error information.This contains all the features of the previous version, but has an error display and a RS-232 port selector. An operational description of the vi now follows.

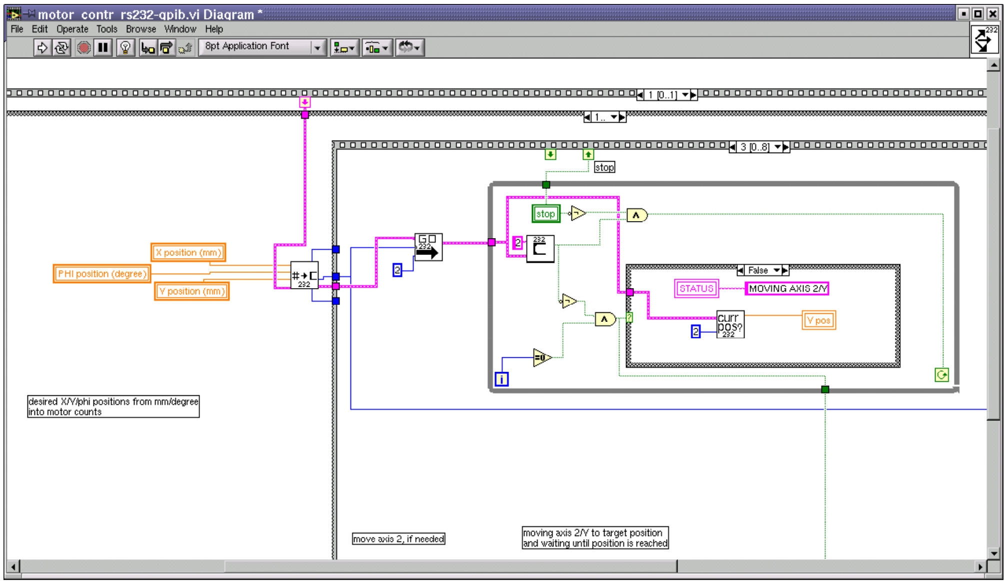

Figure 7: Graphical program structure in Labview. The thick black square is a while loop, and the sub-vi's can be seen as boxes with inputs and outputs.

Initialisation.

Upon starting, the VI first conducts an initialisation procedure which checks the ports and interface. An error will stop the program and display the initialisation error. The axes are sent to their positive limits, and then to the origin as part of the initialisation. A message informing the user of this is displayed before the axes are moved.

Send to home

After a succesful initialisation, the user may select to send the table to 'home', or to to another specified position (target). If the user elects to send the table to it's home, confirmation is requested before the command is executed. Upon confirmation, the message 'the three axes are being sent to their origin' is displayed on the front panel. For each axis, the target position of 0 is sent and the position of the axis is compared to this until they are equal. A message is then displayed to the user indicating that the axis is now at the origin. If the axis cannot be moved, an error message is displayed. When all three axes are at the origin, a message to this effect is displayed.

Sending the axes to a target position

If the vi is used to send the axes to a user defined position, the position entered is first converted to machine counts. There is a sequence structure with nine frames that is now completed. For each axis, the target position is set. A check is then performed to see whether or not the axis is already at the desired location (and it displays this position), or that it is being moved to the desired position.

When the axes are in the correct position, the message '(x,y,ϕ) position reached!' is displayed. If the option is selected on the front panel, the position is then written to a file. If the halt command is used while the axes are moving, then the axes are stopped and the position of the axes when the halt command was executed is displayed.

The sub-vi's

Below is a short summary of each of the sub-vi's used in the main vi described above. Note that every sub vi has an error input/output. It is easy to recognise in the Labview program as the thick pink line entering and leaving the vi. Note that the basic building blocks of the sub-vi's listed below are the vi's which are supplied by the table manufacturer, PI. The two used are C844-query.vi which sends a command which requires a response (those ending in a '?') and reads the response, and C844-send.vi which simply sends a command which needs no response. Both of these can be found on Red in the library: /home/si/desytestbeam/PI/C844A10.llb

counts-to-mmdegree232.vi

This converts the motor steps into mm/degrees for the axis required. It has an input for counts, and one to specify the axis (0,1,2). It has an output for mm and one for degrees. Note that the correct output required is specified by the input, mm for axes 1 and 2 (x and y), and degrees for axis 3 (ϕ).

currentposrs232.vi

This sends the command CURR:TPOS? to the controller, which returns the current position of an axis.

go-to-posrs232.vi

AN axis is selected with the AXIS n, (n=0,1,2 for x,y and ϕ). A target position for the axis is then set with the TARG n (n is the target position, in counts) command.

halt232.vi

This allows the immediate termination of the current command. It Stops the table immediatly be setting the target position for the three axes to the current position with the TARG:POS n command, where n is the current position in counts. It is executed by a switch on the front panel of the main vi.

home232.vi

This is used to send the table to it's home position (the origin). It sends the command TARG:POS 0 for each axis, which sends the table to the origin

motor-condrs232.vi

This checks to see if the selected axis is in motion by reading the motion event register with the command STAT:MOD:COND? This returns a Boolean value (True if moving, False if not)

number-to-cc232.vi

converts the x, y and ϕ positions to motor steps. It has inputs and outputs for the three axes. Note that it is different from the device which computes the reverse in this respect, as this vi can do all the axes at once, whereas the other one can only do one axis, specified by the user.

writeposition232.vi

this writes the x, y and ϕ positions to a file. It has inputs for the positions of the axes in mm and degrees, an input for the run number for which there is an indicator on the front panel, and an input for the file path.

2.3 Conclusion

The silicon recoil detector is capable of measuring the momentum of incident nucleons accurately. The hybrids need to be examined to ensure that they work properly, which involves the testing procedure outlined above. Once this is complete a more detailed fine tuning process can take place, in order to extract optimal performance from the Hybrid. This is necessary as the hybrid currently used for testing from Zeus has some fundamental differences to the hybrids to be used for HERMES. When the testing of the hybrids has been completed, the tests to be carried out at DESYII can take place. The software to control the table which will hold the TIGRE detectors during testing in the DESYII test beam was tested successfuly, and subject to the installation of the RS-232 cable to the control room, is ready to run.

References/Acknowledgements

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2:*Eric Switzer*, *Measurements of Electron Energy Deposition in the HERMES Silicon Recoil Detector (1GeV-6 GeV)* , *Summer Student report*, *2003*
3:*M Kopytin et al*, *Decision on the readout chip for the new HERMES Silicon Recoil Detector*, *HERMES-INTERNAL 02-020*, *June 2002*,
4:*W Fallot-Burghardt et al*, *Helix128-x*[1] *User Manual*, *ASIC Labor Heidelberg*, *1999*

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