The EUDET High Resolution Beam Telescope - Towards the Final Digital Readout

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***Abstract*— A high resolution (σ <3 μm) beam telescope based on monolithic active pixel sensors is being developed within the EUDET collaboration. EUDET is a coordinated detector R&D programme for a future international linear collider providing test beam infrastructure to detector R&D groups. The telescope consists of six sensor planes with a pixel pitch of 30 μm and can be operated inside a solenoidal magnetic field of up to 1.2 T. A general purpose cooling, positioning, readout infrastructure and data analysis tool is available. In summer 2008 the pixel telescope will be used by five different groups as reference system for tests at the high energy hadron test beam facility at CERN. In order to improve the resolution a high resolution pixel plane with a pitch of 1 μm will be added. In this presentation the performance of the telescope in the different tests will be summariesed and the design of the final telescope with full digital readout will be presented.**

***Index Terms*— Silicon Pixel Detectors, ILC, Telescope, Test beam**

I. Introduction

A 500 GeV electron-positron linear collider is the next great international project in High Energy Physics. In order to achieve that goal, an intense international planning effort with a number of R&D projects has started. EUDET is one project within that context with the aim to improve the infrastructure for doing detector R&D for the future international linear collider. EUDET is partially funded by the European union as a so-called “Integrated Infrastructure Initiative” within its 6^{th} Framework Programme for Research and Technological Development.
In this presentation the test beam results of the pixel beam demonstrator telescope will be discussed. The demonstrator telescope is only the first phase of this project, a full scale telescope will follow in 2009. This demonstrator telescope will not satisfy the final requirements (see section II) with respect to readout speed. But a first test facility will be available quickly to satisfy immediate and urgent test needs of various research groups working on pixel detectors in Europe. The final telescope will be constructed using sensors with fully digital readout and integrated correlated double sampling (CDS) and data sparsification.

II. Telescope Requirements

The beam telescope is to be used for a wide range of R&D applications and quite different devices under test (DUT), from small (a few millimetres) to large (up to one meter) size. Depending on the project and on the size of the device the requirements as to precision and coverage are quite different. Still, the system should be easy to use so that a high efficiency in the use of the facility can be achieved.

Due to the limited energy of the electron beam from DESYII $(1-6$ GeV$)$ the precision that can be reached in any device is limited. However, with a careful optimisation of the telescope setup with respect to dead materials and positioning of the telescope planes the precision of the predicted impact position of beam particles on the DUT plane should reach less than $3\ \mu\mathrm{m}$ at 5 GeV [1]. This is achieved by reducing the amount of material in individual planes while maintaining point precision on the telescope planes of around $2-3\ \mu\mathrm{m}$. It is also foreseen to place a high resolution plane ($\sigma \approx 1\ \mu$m) in front of the DUT to improve the precision of the telescope. The mechanical setup should allow for a wide range of different configurations from a very compact one useful for pixel sensors to a two-arm layout with sufficient space in between the arms to accommodate TPC or calorimeter prototypes. The lateral dimensions of the active area should be large enough to cover high precision pixel devices without mechanical movement of the device under test. Obviously, for larger devices mechanical actuators will have to be used. A minimum size of 20 mm in one lateral dimension is adequate. The second dimension could possibly be smaller. The speed of the device should allow to take full advantage of the beam rates and hence should be able to operate at readout rates of up to 1000 frame/sec.

Finally, the overall setup of the telescope should be flexible enough to make it transportable in order to use it at other beam lines outside of DESY, e. g. at higher energy hadron beam lines.

III. Sensors

The sensors for the telescope have to provide a single point resolution of $2-3\mu\mathrm{m}$ with a minimum of material. Also, a reasonable lateral coverage is required and the readout has to be fast enough to reach a telescope frame rate of 1 kHz. The CNRS-IPHC institute in Strasbourg, France [5] has developed, fabricated and tested a number of monolithic active pixel sensors (MAPS) with large enough arrays for the telescope. The MimoTel prototype, was chosen for the demonstrator telescope. This chip is designed in the AMS 0.35 OPTO process [6] with an epitaxial layer of 12 μm. The sensor is divided in 4 sub-arrays of 64$\times$256 pixels each. With a pixel pitch of 30$\times$30 μm^2 this results in an active area of 7.7$\times$7.7 mm^2, not fulfilling the

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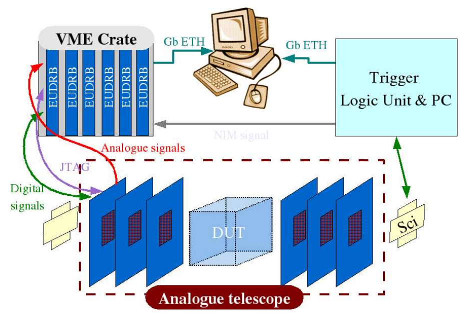

Fig. 1. Schematic layout of the DAQ system.

final telescope requirements, but suitable for the demonstrator. While the chip shows a good signal-to-noise ratio and high point precision of 3 μm, its architecture is simple without integrated data reduction or parallelisation.

The final telescope will be constructed using the so-called Mimosa22+ chip with fully digital readout and integrated zero suppression. It will be a combination of the Mimosa22 and the Zuse01 chips, both developed in the framework of the EUDET telescope development. The geometrical parameters of Mimosa22+ will be such a way to match the DAQ readout speed and the needs for a test beam optimally.

IV. DAQ System

A schematic layout of the planned DAQ system is shown in Fig. 1. The sensor is mounted on a PCB which includes digital and analogue signals buffering : the Proximity Board. This test board is controlled by the DAQ board which provides digital signals to drive the chip and to acquire analogue outputs. JTAG protocol is generated by software and is interfaced to a PC parallel port.

Sensors are connected to the signal conditioning and digitising module installed on the front end board. An FPGA on the front end board is used to process the digitised data stream from the sensor to achieve common mode suppression and data sparsification. The sparsified data are then transferred, upon reception of a readout trigger signal, over the VME-64x bus, to a PC for event building and archiving.

V. Telescope Mechanical Design

It is foreseen that the beam telescope will be operated in widely varying R&D applications with very different DUTs. The telescope provides six telescope reference planes for redundancy and flexibility. For large DUTs mechanical actuation is foreseen in order to move the device through the active area of the telescope. The telescope is subdivided into two arms to allow more flexibility without limiting the size of the DUT which will be located between the two arms. In Fig. 2 the telescope is shown as it was installed at the SPS testbeam at CERN in summer 2007. Three sensor jigs (L-piece) are positioned on a track system. The minimal distance between the first and the third layer is 2 cm, the maximum level arm of each sensor are is 15 cm. Each L-piece holds one proximity

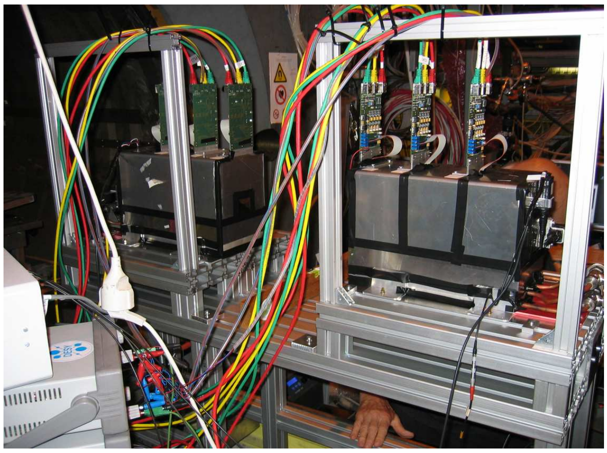

Fig. 2. Mechanical concept of the telescope.

board housing the pixel sensor. The further electronics is placed close to the telescope.

VI. Outlook

In this presentation the results of a high resolution beam telescope based on pixel sensors will be summarised. This is a project within the EUDET initiative, partially financed by the EU. In summer 2008 the demonstrator version of the telescope will be used by five different users (CALICE digital HCAL, DEPFET, MimoRoma, LCFI, SiLC). At the NSS 2008 in Dresden it is planned to present results on the performance of the telescope during test beams at DESY and CERN. Above that the design of the final telescope will be presented.

VII. Acknowledgement

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References

[1] A.F. Zarnecki, Telescope Resolution Studies, EUDET Anual Meeting, Munich, October 2006
[2] K. D. Stefanov, “CCD Vertex Detector for the Future Linear Collider”, Nucl. Instrum. Meth. A **501** (2003) 245.
[3] P. Fischer, W. Neeser, M. Trimpl, J. Ulrici, N. Wermes, “Readout concepts for DEPFET pixel arrays”, Nucl. Instrum. Meth. A **512** (2003) 318.
[4] R. Turchetta et al., “A monolithic active pixel sensor for charged particle tracking and imaging using standard VLSI CMOS technology”, Nucl. Instrum. Meth. A **458** (2001) 677.
[5] Y. Gornushkin et al., “Tracking performance and radiation tolerance of monolithic active pixel sensors”,Nucl. Instrum. Meth. A **512** (2003) 299.
[6] Austriamicrosystems, Application Note AMS 0.35 OPTO, http://www.austriamicrosystems.com/05foundry/indexc35.htm