

The EUDET high resolution pixel telescope

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ABSTRACT

Within the EUDET consortium a high resolution pixel beam telescope is being developed. The telescope consists of up to six planes of monolithic active pixel sensors and can be operated in a magnetic field of 1.2 T. A flexible data acquisition environment is available for the telescope and the system is equipped with all the required infrastructure. Since the first installation of a demonstrator telescope in 2007, it has been extensively tested and used by various detector R&D groups. The results of test beam measurements are described here, demonstrating the telescope performance. The sensors of the final telescope will provide digital outputs and zero suppression.

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1. Introduction

A linear electron–positron collider operated at the centre-of-mass energy of at least 500 GeV is the next great international project in high energy physics [1]. The EUDET project [2], which is supported by the EU in the 6th Framework Programme (FP6), aims to provide infrastructure for the R&D of detector technologies towards the international linear collider. Within the EUDET project the JRA1 activity works on the improvement of test beam infrastructure. For this purpose, a high resolution pixel telescope is being developed. The design goals include a high position resolution ($\sigma < 3.0 \mu\text{m}$) and readout rate of 1 kHz. Additionally, the telescope can be operated in a 1.2 T solenoid magnet (PCMAG).

The construction of the telescope is performed in two steps. In June 2007, the so-called demonstrator telescope was installed for the first time using an analog readout. After the first successful operation at the electron beam at DESY, the demonstrator was transported to CERN and its performance was studied using 180 GeV hadrons at the SPS [3]. After the first successful integration of a Device Under Test (DUT) in September 2007 [4], the demonstrator telescope has been used by various groups and was improved continuously. More data processing will be moved to the sensors in the fully digital final telescope, which will become available in spring 2009.

2. The sensor

The MIMO TEL sensor, used for the demonstrator telescope, was developed by the CNRS-IHPC Institute in Strasbourg, France. It is a Monolithic Active Pixel Sensor (MAPS) produced in the AMS 0.35

OPTO process. Sensors with a thickness of the epitaxial layer of 14 or 20 μm are available. In total, the sensor is 680 μm thick. Four sub-arrays of 64×256 pixels are read in parallel. With a pixel pitch of $30 \times 30 \mu\text{m}^2$ this results in a sensor size of $7.7 \times 7.7 \text{ cm}^2$. A high resolution sensor with a pitch of 10 μm can be located close to the DUT to further increase the resolution. The effects of different telescope geometries and different beam energies have been studied using simulations in great detail [5,6]. The sensor for the final telescope will be described in Section 7.

3. The DAQ system

The DAQ system can be summarised as follows: all data from the sensors are transferred via frontend boards to an intermediate readout and data reduction board called EUDRB (EUDET Data Reduction Board) [7]. The EUDRB board allows the first steps of the data processing online to be performed. Two I/O busses are supported: for the telescope the VME64x bus is used to allow high speed data transfer and synchronous operation with other devices while a USB2.0 interface is foreseen for standalone testing. A mother/daughter board scheme has been followed to maximise the flexibility. All computing and memory elements are located on the motherboard while the sensor specific components have been implemented on removable and interchangeable daughter cards. The two following modes of operation have been implemented in the EUDRB firmware so far:

- *Transparent mode*: All pixel signals are transferred without further data processing. This mode is important for debugging and for the characterisation of the telescope sensors itself.
- *Zero suppressed mode (ZS)*: The correlated double sampling (CDS) is performed online and only the signals and addresses of pixels above a certain user-defined threshold are

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transferred. This mode is intended for data taking at high rates keeping the output files reasonably small.

The output of the EUDRB boards is collected by an MVME6100 single board computer, which is located in the same VME64x crate. Finally, the data are sent to the main DAQ PC using gigabit ethernet. This computer can also collect the information from the DUT.

Another important component of the DAQ system is the trigger logic unit (TLU) [8]. It is considered as the replacement for a NIM crate and can generate any coincidence or anticoincidence of four trigger scintillators. Six LVDS and two TTL interfaces are provided. Furthermore, the TLU generates event numbers and time stamps. It is connected by USB2.0 to a control PC running the Linux operating system that is in turn connected to the main DAQ PC through gigabit ethernet.

Fig. 1 shows the DAQ system of the EUDET pixel telescope as described above.

A custom DAQ system named EUDAQ has been implemented in C++ [9]. Several producer tasks communicate with a global run control using sockets. These producer tasks connect to the hardware of the beam telescope, to the TLU and eventually to the DUT. Data from all producers is sent to the central data collector and can be monitored by several processes. An online monitor, based on the ROOT framework, shows online data quality monitoring histograms and a process to collect log messages is available. EUDAQ runs on MacOS, Linux and Windows using gwin.

4. User integration

Different scenarios for the integration of the DUT in the DAQ system of the EUDET pixel telescope are possible:

- *Integration at hardware level:* In this case the user has to provide a hardware interface able to read out the telescope sensors and the DUT. This approach is supported by the EUDRB boards, but is only feasible for some dedicated DUTs.
- *Integration at DAQ software level:* The user provides their own DAQ hardware to read out the DUT, but the data are treated by a common DAQ software. In the case that the EUDAQ is used as the common DAQ system, a producer to read out the DUT needs to be implemented.
- *Integration at trigger level:* This default scenario was chosen by most users so far, because it is easy to implement and relatively safe. Different hardware and software are used for

the telescope and the DUT. The synchronisation is done using the trigger, busy and reset logic provided by the TLU. To protect against slippage of event numbers between the telescope and the DUT, the event numbers provided by the TLU can be read by the DUT.

- *Integration at data level:* Both, the DUT and the telescope use their own dedicated DAQ hardware and software. The data streams are combined offline by interprocess communication. In this scenario the synchronisation and the configuration during the start-up might be difficult.

5. The offline analysis software

For the offline reconstruction of track positions in the DUT the software package EUTelescope [10] has been developed, which is implemented as a set of Marlin processors [11]. This design allows to integrate the DUT data at different steps of the analysis chain. Furthermore, the package can be executed on the Grid to allow a fast processing of large datasets.

Fig. 2 summarises the structure of the offline analysis package. Each step in the analysis procedure is implemented in a separate Marlin processor. It is possible to run each processor separately or to execute the whole analysis chain by a single command. In the first step the data are converted from the native format used by the EUDAQ software to the LCIO format. Afterwards a pedestal correction is applied and clusters are searched for. It is possible to improve the reconstructed cluster positions using the η algorithm. Clusters are accordingly transformed into hits in the telescope frame of reference. Details about the configuration of the telescope, e.g. the distances between the telescope sensors or their layout, are stored using the geometry description toolkit, GEAR. The alignment procedure is based on the Millepede II package and uses full tracks in a simultaneous fit to derive the alignment parameters. Finally, tracks are fitted using the hits after the alignment constants have been applied. The result of the track fit can be saved in a ROOT file if needed by the user of the telescope.

6. Test beam results

In this section results from test beam measurements to characterise the demonstrator telescope are discussed. The first part of the data was taken at DESY in August 2007 using a compact setup of the telescope where five MimoTELS were mounted at a distance of 2.5 cm from each other. Further studies

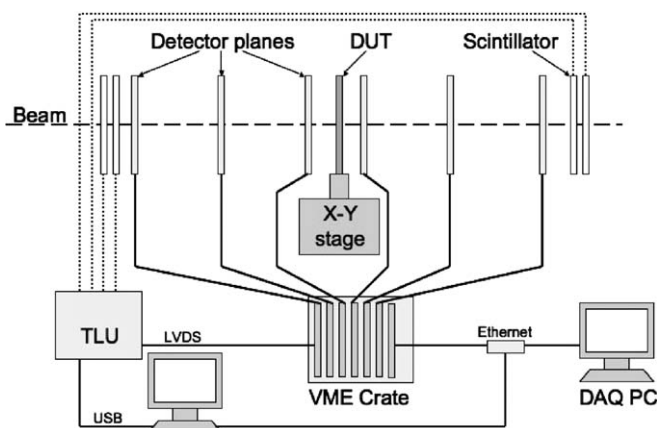


Fig. 1. The DAQ system of the EUDET pixel telescope.

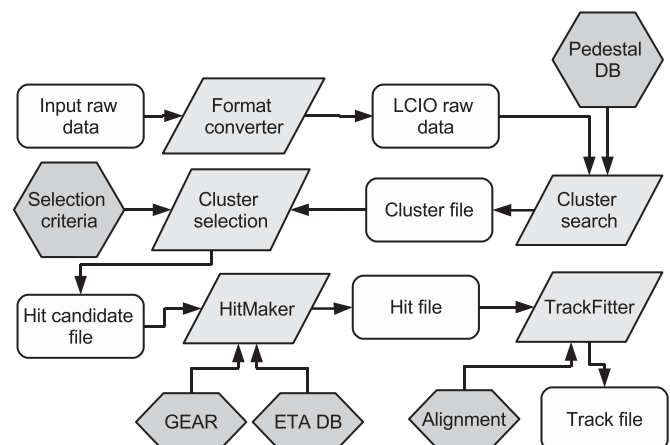


Fig. 2. Schematic overview of the offline analysis package EUTelescope.

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