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EUDET Pixel Telescope Copies

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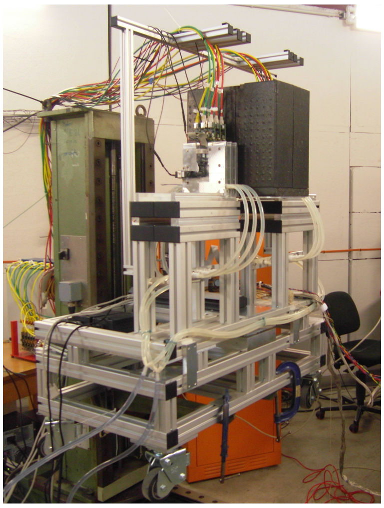
Abstract

A high resolution beam telescope ($\leq 3\mu$m) based on monolithic active pixel sensors was developed within the EUDET collaboration. In this report the development of the project over the EUDET project time will be summarised.



1 Introduction

Topic of the EUDET Joint Research Infrastructure 1 (JRA1) was the improvement of test beam infrastructure. One main item was a large bore 1 Tesla magnet with a diameter of 85 cm and a stand-alone Helium cooling. The magnet itself was provided by KEK and within EUDET the necessary infrastructure was provided. The evolution of the magnet project will be summarised in section **??**.
The second item within JRA1 was a high resolution pixel telescope and readout rate of 1 kHz. The idea of the EUDET pixel telescope is an easy to use system with well defined interfaces enabling test beam studies on a rather short time scale. The telescope has to provide the precision for high momentum beams of electrons, pions, and protons at hadron machines as well as at low momenta test beams like the electron beams at DESY(1-6GeV) where the precision is dominated by multiple scattering. The final telescope with fully digital sensors can be used with both, high and moderate, granularity reference planes in order to better fulfill user needs and requirements. The performance in terms of spatial resolution of this telescope demonstrator has been measured with a 120 GeV pion beam at CERN and the results obtained for the single plane and telescope resolution are well in agreement with the design specifications. A pointing resolution of better than 2 μm was obtained for the DUT position in the centre of the telescope. Numerous detector R&D groups used the telescope for their test beam studies at the DESY electron beam and the CERN-SPS hadron beam since the first commissioning in 2007. In SectionX -X the development of the project over the years will be summarised. The report is a write-up of the talk "Very busy infrastructures - EUDET JRA1 from 2006 till 2010" in the EUDET JRA1 Plenary session during the 2010 Annual Meeting.

2 The Superconducting Magnet PCMAG

The evolution of the Task A "Magnet" can be summarised as follows:

2006

- Lending details about magnet loan finalised
- Arrival of magnet at DESY in November
- First turn on of magnet December 10th

2007

- Field map measurement July
- Final field map available only in December because the analysis of data more challenging than expected

2008

- Transfer line for filling the liquid helium was improved and the existing procedure automated
- Installation of large TPC prototype

2009

- Completion of rotatable table

2010

- Regularily used by TPC group and users

3 Overview of the Telescope

Already during the Kick-Off Meeting of the EUDET consortium it was decided that the telescope should have the following attributes to allow the general application of such a device:

1. DUTs: from small pixel sensors to larger detectors
2. Movement of DUT to scan larger surface
3. Large range of conditions: cooling, positioning, (B-Field)
4. Easy to use: well defined/described interface
5. Very high precision: ¡3 ?m precision even at smaller energies
6. Trigger rate 1kHz
7. Movable!

A two staged approach was planned to have a user telescope ready as soon as possible. A demonstrator telescope with analog sensors was foreseen for the summer 2007 while the final Telescope was planned for the late summer of 2009. The final version was designed with digital sensors, final resolution of better than 3 μm and high readout rate (1kHz). In Figure 3 all main items for such a pixel telescope are shown and in the following the evolution of the system over the years described.

Sensors The heart of the telescope are the Mimosa26 sensors within the separate sensor boxes. Each of the six planes consists of 576×1152 pixels with a pitch of 18.5 μm. The active area is 10.6×21.2 mm^2. In each pixel the amplification and correlated double sampling is included. On the sensor chip also the zero suppression is done. The sensors are described in section 4.

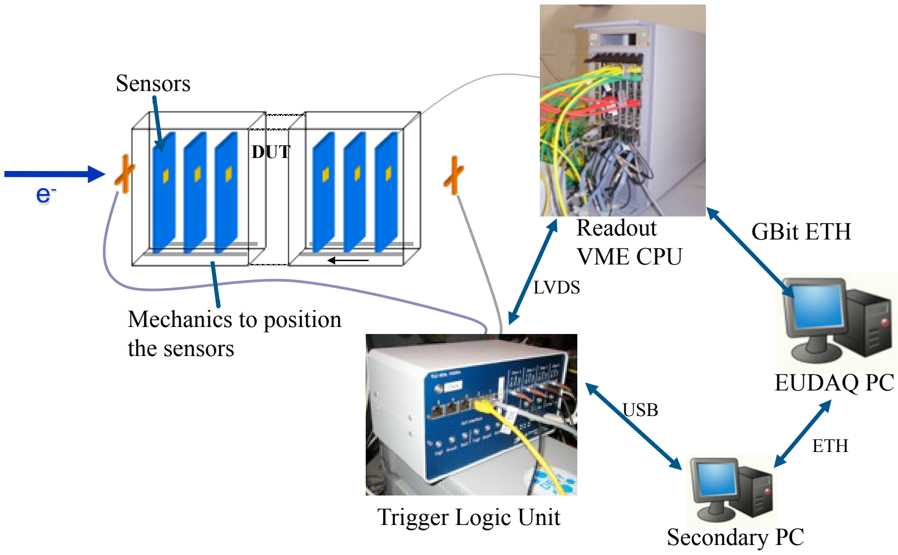


Figure 1: Overview on the cable necessary ingredients for a full telescope

DAQ Hardware The binary signals from the sensors are send to a DAQ board. In the current version of the telescope these are the EUDRBs. This will not be the same system for copies of the telescope. The alternative system will be described in section 5

TLU The trigger logic unit distributes the trigger to the EUDET telescope and the connected DUTs. The TLU and its copies will be described in section 5.3.

Mechanics A simple flexible mechanics was developed to keep the reference plane on one plane while providing an easy to access space for the DUT. Details can be found in section 6.

4 The Reference Sensors

As sensors for the six telescope planes the Mimosa26 are used. This is the final sensor for the EUDET telescope with an active area of 21.2 x 10.6 mm2 (1152 columns of 576 pixels). The pitch of the pixels is 18.4 μm resulting in 663 thousand pixels and a intrinsic resolution of about 4 μm. The integration time is 115 usec. Each column is terminated with a discriminator. The zero suppression is already included in the chip architecture. The sensor is read out in a rolling shutter mode, the rows being selected sequentially by activating a multiplexer every 16 clock cycles.
Depending on the requirements and the beam for the telescope copy, the sensors can be provided in an unthinned version (715 μm) or thinned down to 50 μm. The latter is recommended for a low energy beam. The Mimosa26 was implemented in September

2009 into the final telescope and since then running without problems. The sensor development was done in different stages.

4.1 Evolution of the Sensor

2006

- SDC propotype 1 (MimoTel) planned and achieved for month 9
- High resolution plane Mimosa18 also available

2007

- SDC prototype 2 (SUZE01) available in month 15
- Intermediate chip (Mimosa22) submitted

2008

- SUZE01 fully tested
- Mimosa22 available month 27
- Telescope Chip Mimosa26 fully designed

2009

- Mimosa26 returned from foundry end of February, first results are available in March
- Available for telescope spring; implementation in telescope postponed tomSeptember on users request

In Figure 2 pictures of the three main sensors are depicted. The MimoTel is the analog chip developed for the Demonstrator telescope. It was serving as main reference plane sensor from summer 2007 till late summer 2009. Mimosa18 is the high resolution plane which can be added to the telescope for further improvement of the pointing resolution. The final telescope sensor with fully digital readout and a high resolution of 3.3 um is the Mimosa26.

5 Data Acquisition

The Task "DAQ" comprises DAQ hardware, DAQ software as well as tracking and reconstruction software for evaluation.

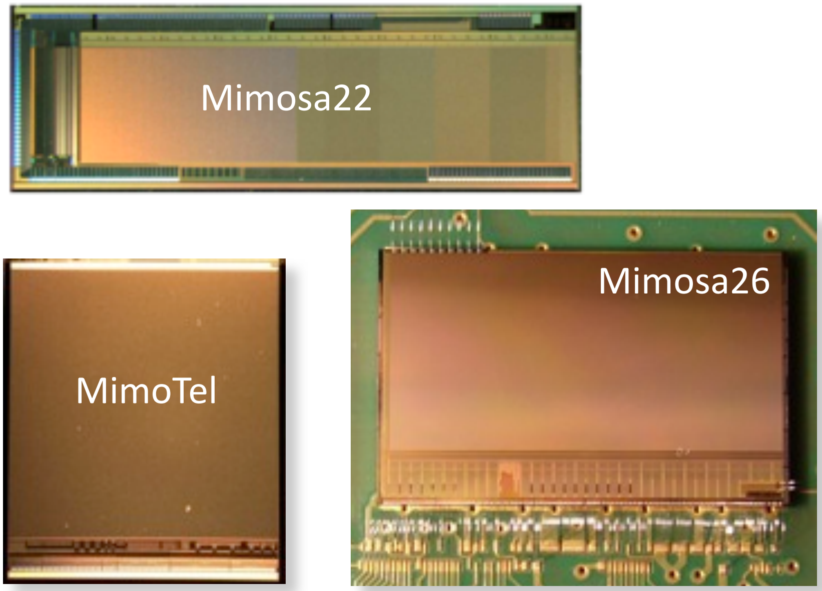


Figure 2: The three different Mimosa generations developed for and during the EUDET project (not to scale). MimoTel is the analog chip for the Demonstrator telescope, Mimosa18 the high resolution an Mimosa26 the final digital sensor.

5.1 Evolution of Task

2006

- Decision on DAQ hardware and software concept
- First trigger logic unit (TLU) available

2007

- First EUDRB available (spring)
- DAQ software EUDAQ first version tested
- Full system tested at beams at DESY and CERN
- Analysis and reconstruction software tested

2008

- Updates in firmware of EUDRB and TLU
- Final version of EUDAQ available
- Reconstruction software finalised

2009

- Upgrade of EUDRB producer for the Final sensor (TC)
- Implementation of EUDRB firmware for (TC)

2010

- Mainly user support (DUT implementation in EUDAQ)
- Preparation of a DAQ system for AIDA

5.2 EUDRB

The EUDRB was developed by INFN to read out the analog telescope sensor MimoTel and modified to also readout the fully digital sensor Mimosa26. A further series of EUDRBs for a number of telescope copies would be possible, but difficult on a time scale of one year. Out-sourcing the board to a company like CAEN is also feasible, but this would probably require a minimum of one year. Only with the support from CAEN the maintenance of the telescope over many years would be possible.

5.3 Trigger Logic Unit

A custom Trigger Logic Unit (TLU) has been constructed. It has four inputs, which may be used as scintillator inputs or vetos, and generates a trigger signal as an arbitrary function of these signals. It also has an internal trigger generator that can be used for taking pedestals without beam, or for testing purposes. The trigger is then distributed to up to 6 DUTs, which must acknowledge the trigger, and may optionally clock out the value of the internal trigger counter. The TLU has also undergone an upgrade for the nal system, taking into account feed- back from the rst version. New features include extra LEMO connectors for DUTs to interface to, with both NIM and TTL levels, and several internal scalers, allowing easier measurements of trigger rates and efficiency. The TLU provided for the copy described here will be a copy of the original build within the Helmholtz Alliance.

6 Telescope

This task comprises mechanics, cooling and telescope infrastructure. The telescope is divided into two arms (see Fig. ??), each of three planes. The planes are installed on light tight jigs positioned on a track system, allowing the positioning of the planes to be adjusted to suit the user. Each jig is connected to a cooling system, in order to keep the temperature of the sensors stable. The position of the two arms can be adjusted depending on the size of the DUT, allowing the inner planes to be placed as close as possible to the DUT, but also allowing space for larger devices (up to 35 cm). In the space between the arms there is an optional X-Y table, to enable the positioning of the

DUT to be adjusted. For the nal telescope, modications have been made to improve the cooling, and to facilitate alignment of the telescope planes with the DUT. The arms can also used separately for example for test within a magnetic field.

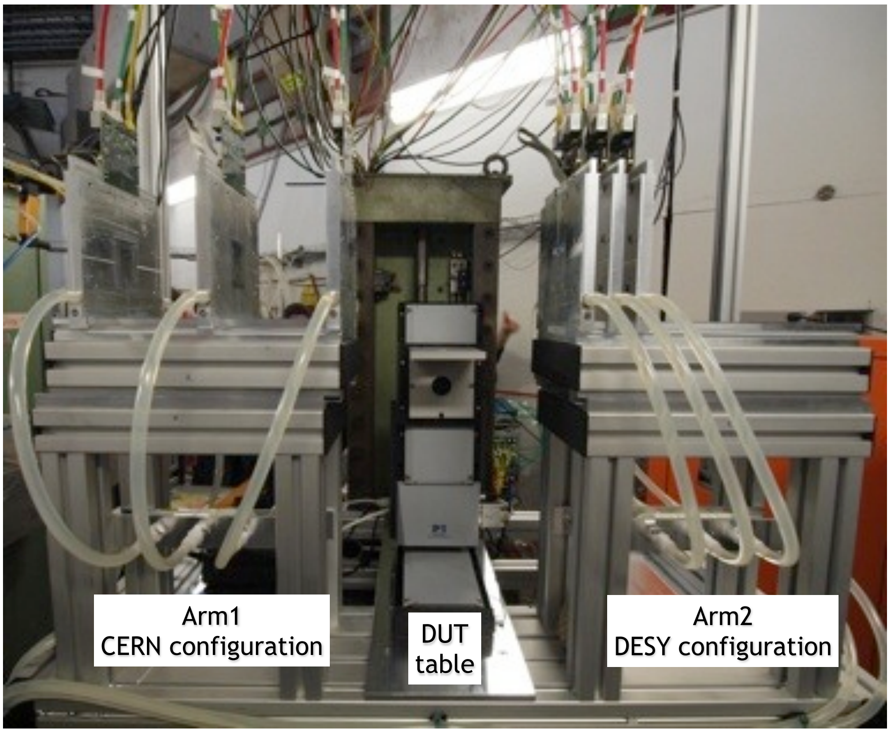


Figure 3: Picture of EUDET telescope at DESY. Arm 1 has the CERN configuration with the planes with 15 cm

6.1 Evolution of Task

2006

- Simulations on setup to define concept
- Design fixed: Flexible mechanics needed with two telescope arms and adjustable space for DUT

2007

- Finalisation and production of mechanics
- Procurement of additional infrastructure e.g. cooling, power and XY table
- June: Demonstrator telescope available!

2008

- Improvement of mechanical alignment and cooling
- Testbeam at CERN with many different users proved overall concept

2009

- Decision to delay final telescope until after summer as users prefer known demonstrator over final telescope
- Final telescope available!

2010

- Almost continuous user business!

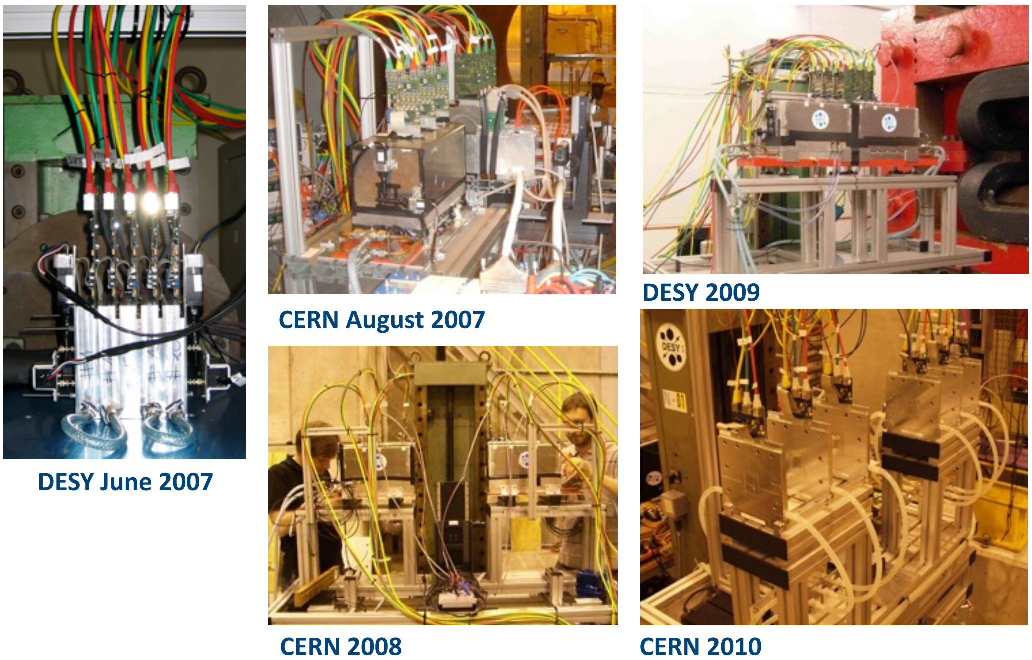


Figure 4: Pictures of the EUDET telescope at different stages during the project.

Acknowledgement

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