EUDET: Detector R&D Towards the International Linear Collider[1]

J. Mnich[2]

December 07, 2007

Abstract

EUDET is an initiative supported by the European Union to improve infrastructures for detector R&D, in particular for the International Linear Collider (ILC). The programme is focused on providing support for larger scale prototype experiments as well as on facilitating collaborative efforts. The project encompasses developments for vertex detectors, gaseous and silicon tracking, and highly granular electromagnetic and hadron calorimeters. In total 31 European institutes participate in the project, plus 27 other institutes in Europe and abroad which are associated members and linked to the progress and later exploitation of the infrastructures. In all its activities EUDET is closely linked to the international R&D collaborations for the ILC detector. The R&D infrastructure programme is described and some results of the R&D efforts are presented.

[1] Presentation at the IEEE 2007 Nuclear Science Symposium and Medical Imaging Conference, Honolulu, October 2007

[2] DESY, Hamburg, Germany

1 Introduction

Over the past years the detector R&D for the ILC has identified several candidate technologies for vertex and tracking detectors and calorimetry which meet the challenging demands for the physics at the ILC. Now the R&D efforts enter into a phase where these technologies have to be extended to larger prototype detectors to verify their feasibility and to optimise the overall detector performance. The EUDET project [1] provides with support from the European Union a framework for the development and construction of larger prototypes for ILC detector technologies. The project started in January 2006 for a duration of four years and it encompasses the design and construction of infrastructures for vertex and tracking detectors as well as electromagnetic, hadronic and forward calorimeters. Most of these infrastructures will be initially commissioned at DESY but they are designed to be movable such that they can later be exploited at other laboratories in Europe and abroad.

Even though EU funding can only be allocated to European groups the project is open to world-wide collaboration. Several non-European institutes are associated and contribute to the design and construction of the infrastructures anticipating their subsequent exploitation.

2 Project Overview

EUDET is an Integrated Infrastructure Initiative in the sixth framework programme (FP6) of the European Union [2]. The project started beginning of 2006 for a duration of four years. The total budget is 21.5 million Euro out of which 7 million Euro are contributed by the European Commission. It assembles 23 contractual partners from 31 European universities and laboratories working on detector R&D for a linear collider experiment. In addition 27 associated institutes worldwide participate in the design and construction of the infrastructures as well as their later exploitation.

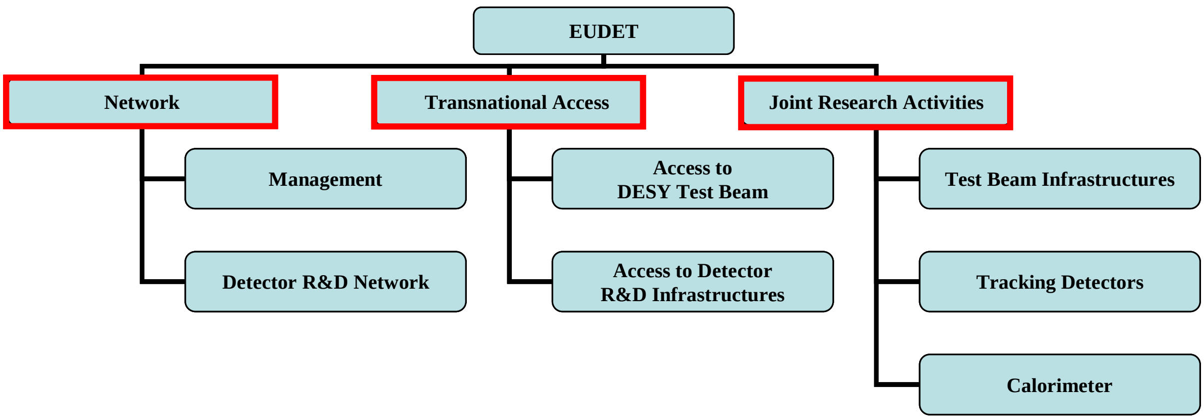

Fig. 1. Layout of the EUDET project.

The layout of the project is sketched in Fig. 1. It is based on three pillars. Important is the networking between the partner institutes which also addresses research topics of broad interest. The joint research activities (JRA) actually focus on the design and construction of the infrastructures. The third base consists of transnational access activities supporting European groups in the scientific use of the infrastructures. The three activities are split into several work packages or tasks. Examples of these tasks, their status and plans, are discussed below.

3 Detector R&D Network

One important pillar is the establishment of a detector R&D network which intensifies the collaboration in Europe. All infrastructures are designed in an international collaboration and appropriate communication and management structures have been set up. Another aspect is the development of a common simulation and analysis framework. This includes the analysis of upcoming testbeam campaigns of individual detectors as well as combined experiments, but also contributions to the simulation work required for the design of the ILC detectors.

The network is complemented by work on the improved simulation of hadronic showers incorporating testbeam results from highly granular calorimeters and by access to state–of–the–art deep-submicron technology for chip development as required for almost all modern particle detectors. An easy-to-use, customized design kit has been developed which together with training courses organized within the project allow engineers from smaller laboratories to participate in the development of modern deep-submicron electronics.

4 Testbeam Infrastructure

The JRA on testbeam infrastructure consists of a large bore magnet and a high-precision beam telescope. The magnet supplied by the associated partner KEK (Japan) provides a field of about 1 Tesla in a bore of 85 cm diameter. It possesses a light-weighted coil and a stand-alone He supply thus making it ideally suited for experimentation in a testbeam. The cooling and control infrastructure which is supported through EUDET funds has been set up at DESY in close collaboration with KEK and the device is available for experiments in the testbeam area since summer 2007.

The scientific exploitation of the magnet, for instance for tests of a high precision TPC, requires the knowledge of the magnetic field to very good accuracy. The goal is to determine the field inside the magnet to a precision of 10^{-4}. Measurements of the magnetic have been taken in summer 2007 and the data analysis is ongoing. Fig. 2 shows the magnet during the field mapping measurement campaign.

A multilayer pixel telescope in MAPS technology is under construction with the potential of a space resolution of about 1 µm. As part of the project pixel detectors in DEPFET and CCD technology are set up and used to independently validate the performance of the device. The telescope itself consists of six layers of MAPS detectors as well as a versatile DAQ system with well defined interfaces easily adaptable by other detectors which want to use the telescope for reference measurements (see section VII).

A first version of this telescope is available since summer 2007 and commissioned in the DESY testbeam. Its performance and first results are described in more detail in reference [3]. The device has been tested successfully in testbeams at DESY and CERN together with test detectors in CCD and DEPFET technology (Fig. 3). The preliminary analyses show that the expected performance goals are met. Now the fully digital device with improved readout speed is under construction and expected to be available end 2008.

Fig.2. The EUDET magnet at the DESY testbeam line with field measuring

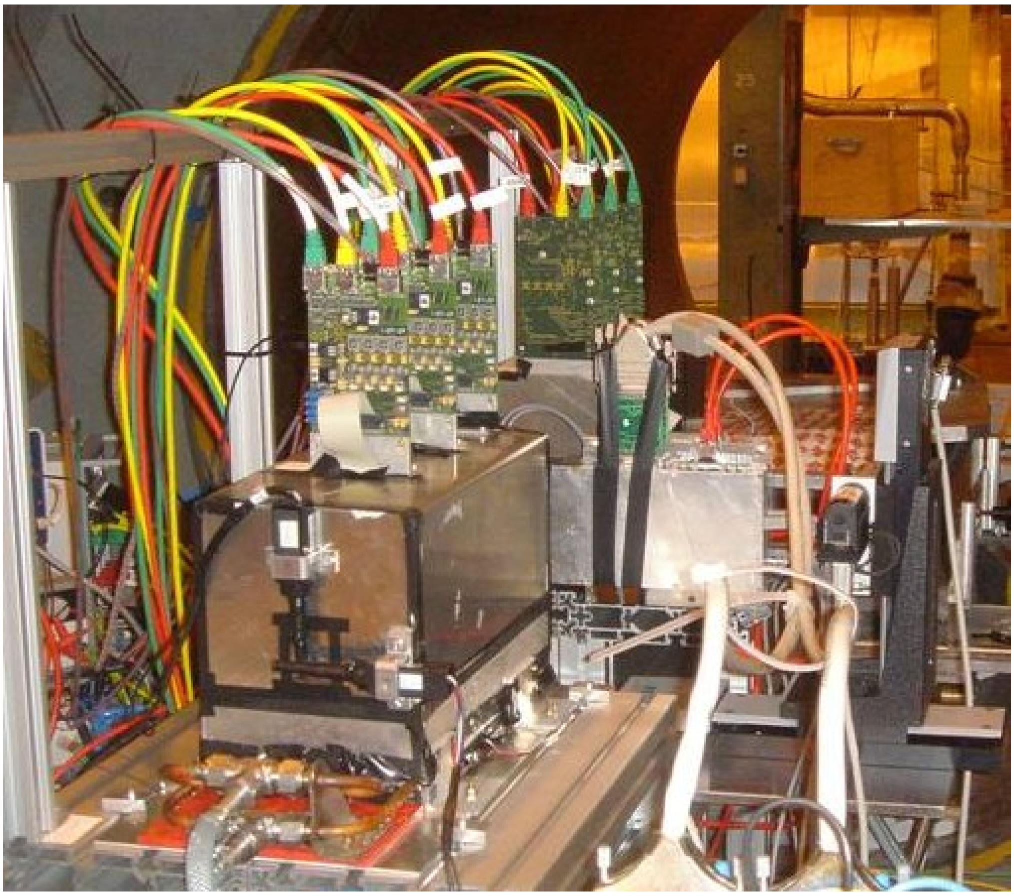

Fig.3. The EUDET beam telescope during measurements at the CERN testbeam.

5 Tracking Detectors

The two main options for the main tracker of the ILC detector, Time Projection Chamber (TPC) and silicon strip detectors, are part of the EUDET programme. A large TPC fieldcage is under construction to be equipped with GEM or MicroMegas based readout structures which have demonstrated in small prototypes their potential to achieve single point space resolutions of 100 µm or below. To this aim the fieldcage will be equipped with a modular endplate to receive large surface gas amplification structures. The development of modern readout electronics adapted for micro pattern gas detectors is also part of the TPC project.

The TPC infrastructure has been fully designed and will become available in 2008. Then testbeam experiments with large surface GEM and MicroMegas amplification structures in a high field magnet will be possible (see Fig. 4).

The TPC developments are complemented by the development of a silicon pixel based readout supporting the design and procurement of the TimePix chip which combines the ultimate resolution of a pixel device with a drift time measurement resulting in three-dimensional tracking capabilities. Here the goal is to develop and construct a TPC diagnostic module including DAQ system providing the best possible imaging of tracks to improve the understanding of gaseous tracking related issues.

First TimePix prototypes are operational since the end of 2006 showing very good performance [4]. Efforts are now concentrating on the design and construction of the TPC endplate module. It will comprise a multi-chip-module covering a larger sensitive surface and will become available in 2009.

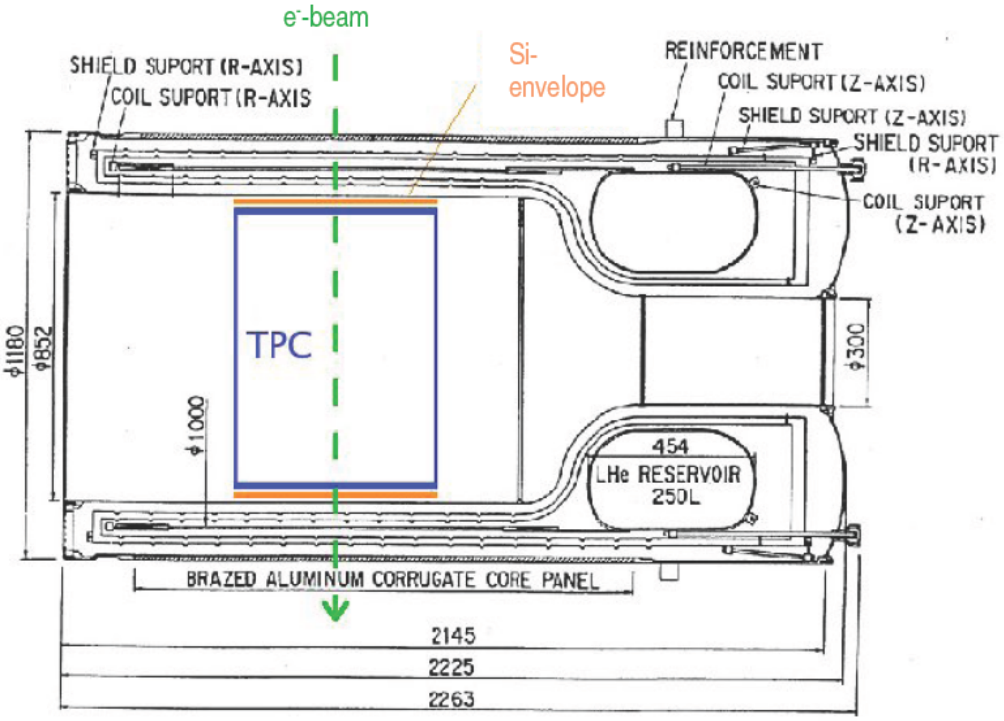

Fig. 4. Sketch illustrating future experiments with the TPC inserted in the EUDET magnet at the DESY electron testbeam.

The development of a large silicon strip tracking detector is also supported. In the framework of EUDET large and light mechanical structures for the silicon strip detectors are developed as well as prototypes for cooling and alignment systems. In addition, the design of multiplexed deep-submicron front-end electronics is supported. Also in this area significant progress has been achieved since the start of the project.

6 Calorimeter Infrastructure

The anticipated physics at the ILC requires calorimeters with unprecedented energy resolution, in particular for jets. Particle flow algorithms based on highly granular electromagnetic and hadronic calorimeters are considered to be a promising candidate to achieve the goals. In EUDET scalable prototypes for these main calorimeters are developed and constructed, together with developments of silicon sensors and calibration systems.

Fig. 5 shows the design of the tungsten absorber structure for an electromagnetic calorimeter which will partially be constructed from EUDET funds. It will be the basis for important studies towards the ILC detector calorimeter. Among the critical design issues is the power dissipation of the readout electronics which is completely embedded in the detector. The low duty cycle of the ILC (0.5%) can be exploited to power pulse the electronics avoiding cooling systems which would deteriorate the calorimeter performance. EUDET will allow for large scale studies to study this and other R&D issues.

A similar detector architecture with embedded electronics is foreseen for the hadron calorimeter. It includes the development of very front end readout electronics ASICs for electromagnetic and hadron calorimeters on a common platform and a unified DAQ system. First prototypes of ASICs and DAQ components have been produced and successfully tested.

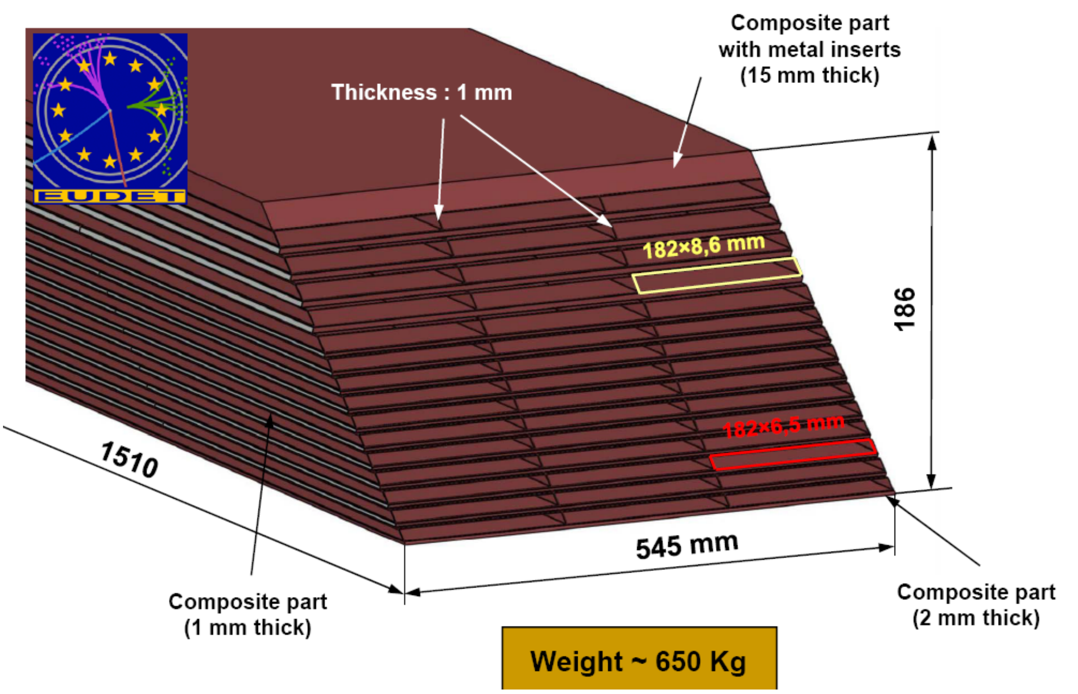

Fig. 5. Design of a scalable tungsten based absorber structure for the development of an ILC electromagnetic calorimeter.

The project also includes positioning and calibration systems for the very forward calorimeters. This is complemented by the development of a common front-end electronics and data acquisition system for all calorimeters. Several electronic chips have been developed in EUDET for the calorimeter and are now under test. The full calorimeter infrastructure is expected to be available in 2009.

7 Transnational Access

The EUDET infrastructures are open to be used by other interested international groups which perform R&D on particle detectors for the ILC, other high energy physics projects or other scientific research work. In the framework of the transnational access instrument which is part of this EU programme travel support to European groups using the installations can be provided. The goal is to encourage transnational European collaboration and to stimulate the exploitation of research infrastructures by groups based at other European countries.

Infrastructures open to EUDET transnational access are the DESY [5] electron testbeam and the infrastructures developed and constructed as part of the EUDET project: the beam telescope, the TPC prototype, the silicon TPC diagnostic endplate, silicon tracking as well as the calorimeter infrastructure. Interested users can apply for access and travel support through the EUDET web page [1]. Projects are then evaluated based on a short scientific proposal. It should be noted that support in the transnational access scheme is open to all scientific projects and not restricted to specific ILC related applications.

8 Conclusions and Summary

This paper summarizes the EUDET project and discusses the significant progress achieved since its start beginning of 2006. Examples of achievements are the TimePix chip, the commissioning of the large bore magnet and the first operational version of the beam telescope. In 2008 most of the remaining EUDET infrastructures are to be completed such that they can be exploited.

The project is embedded in international ILC detector R&D collaborations such as CALICE [6], LCTPC [7] and SILC [8]. It is providing additional funds for European partner institutes for ILC detector R&D and can support through the transnational access scheme other groups in their research for the ILC or other projects. Most importantly for the ongoing phase of the R&D programme which is focusing on larger detector prototypes EUDET has played an important role in establishing and fostering collaboration in Europe and has also made major contributions to the international R&D efforts. At around mid-term the project is well on track with major milestones already accomplished.

Acknowledgement

I am grateful to my colleagues in EUDET for the excellent work they are performing and the superb collaboration. I thank K. Desch, F. Sefkow and J. Timmermans for the careful reading of the manuscript. This work is supported by the Commission of the European Communities under the 6th Framework Programme “Structuring the European Research Area”, contract number RII3-CT-2006-026126.

References

[1] URL: www.eudet.org
[2] URL: cordis.europa.eu/fp6/

[3] A. Bulgheroni, “First test beam results from the EUDET pixel telescope”, presentation at the IEEE 2007 Nuclear Science Symposium and Medical Imaging Conference, Honolulu, these proceedings.

[4] J. Timmermans, “Three-dimensional reconstruction of single-electron clusters in a gaseous detector read out by the TimePix pixel circuit”, presentation at the 11th Vienna Conference on Instrumentation,, February 2007, Vienna, URL: http://vci.oeaw.ac.at/2007/

[5] Details on the DESY testbeam facilities can be found at the URL: testbeam.desy.de

[6] URL: http://polywww.in2p3.fr/activites/physique/flc/calice.html

[7] URL: http://alephwww.mppmu.mpg.de/~settles/tpc/lp/lp.html

[8] URL: http://silc.in2p3.fr/