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TPC Task Status Report

K. Dehmelt* on behalf of the LCTPC Collaboration

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Abstract

A Large Prototype of a Time Projection Chamber with a diameter of 770 mm and a length of 610 mm is being tested with novel amplification structures based on Micro Pattern Gas Detectors. The LP allows to measure tracks with up to 125 space points with pad readout and is presently installed in a DESY II test beam area, immersed in a magnetic field of about 1 T. The LP is a worldwide effort and is also partially provided as EUDET projects. A description of the setup and the status of the present project as well as further plans will be given.

*DESY, Hamburg, Germany

1 Introduction

TPCs based on Micro Pattern Gas Detectors (MPGD) are described in the ILC Reference Design Report [1] and will be the central tracking device for the ILD detector whose Letter of Intent [2] has been recently submitted and has been validated by the International Linear Collider Steering Committee (ILCSC). It will have dimensions of 2.8 - 4 m in diameter and 3 - 4.6 m in length. They are expected to provide 200 space points with pad readout, along a particle track with the Rϕ spatial resolution of 100 μm per row or better. The momentum resolution of $\delta(1/pt) \leq 0.5 \times 10^{-4}(GeV/c)^{-1}$ is envisaged in the magnetic field of 3-4 T.

2 The Large TPC Prototype

Several relevant topics towards the ILC detector will be pursued with a Large Prototype (LP) of a TPC [3] which have been studied at small and medium sized TPC prototypes and will be . The LP has a diameter of 770 mm and a length of 610 mm. The prototype fits into a superconducting magnet (permanent current magnet, PCMAG), installed in a test beam area at DESY in Hamburg. PCMAG can be excited to a magnetic field up to 1.25 T. The test beam will consist of electrons with a momentum of up to 6 GeV/c and will allow to measure tracks with the LP of up to 125 space points with pad readout. The aim of these tests is not only to enhance the results obtained with smaller size TPC prototypes to a system on a large scale, but also to understand the issues which become visible when constructing such a large TPC.
The main objective of the setup is to bring together several items which are making an environment for exploring the feasibility of a TPC at large scale.
These items are projects within the EUDET framework as well as from non-EUDET projects, which are:

- Field Cage
- Readout Electronics
- DAQ and Monitoring
- Gas-/HV-system
- Common Software
- Silicon Envelope
- End Plate
- MPGD Detector Modules
- Beam-/Cosmic Trigger
- Infrastructure: Test beam, Magnet, and supporting devices.

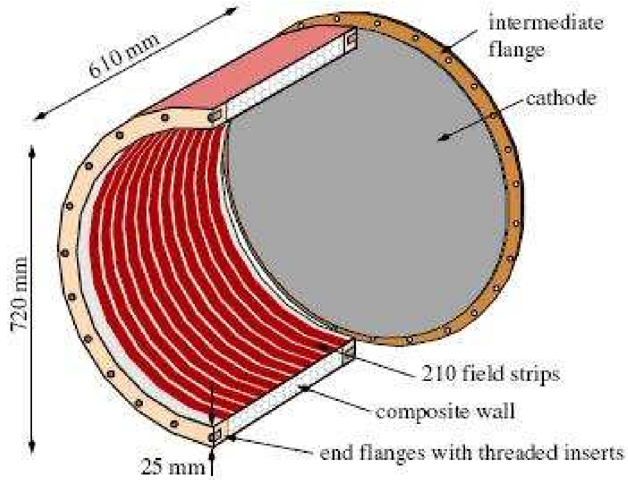

Figure 1: The LP field cage.

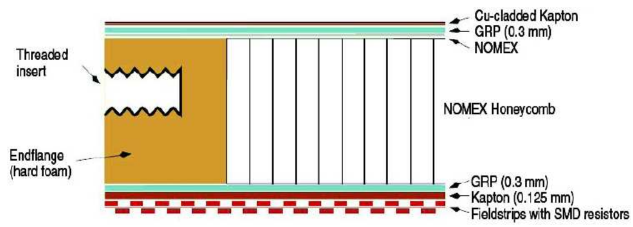

Figure 2: Sandwiched structure for the field-cage.

2.1 The Field-Cage

Part of the LP is a field-cage (FC, Fig. 1), which is made out of composite materials (Fig. 2). The materials were chosen such that they guarantee a maximum of stability, though providing a minimum of material for the traversing particles. The homogeneous electrical drift for the ion and electron clouds in the TPC volume will be provided through a series of field strips, which have to be arranged such that the relative distortions of the field are below 10^{-4} within the drift volume. This can be achieved with mirror strips that lie on an intermediate potential. The field cage has been surveyed after production. In order to achieve an electric field homogeneity of $\Delta E/E \simeq 10^{-4}$ certain requirements have to be fulfilled. From the mechanical aspect the barrel's axis should not be off its nominal direction, i.e. parallel to the field cage's wall by more than $100\mu m$. Another requirement is the parallelism of the anode with respect to the cathode. Here the distances should not exceed $\delta l \simeq 100\mu m$ at the edges from the anode/cathode.
In turned out that the axis requirement was not fulfilled and the deviation is $500\mu m$. Calculations show that this will degrade the field homogeneity by a factor of almost 10.

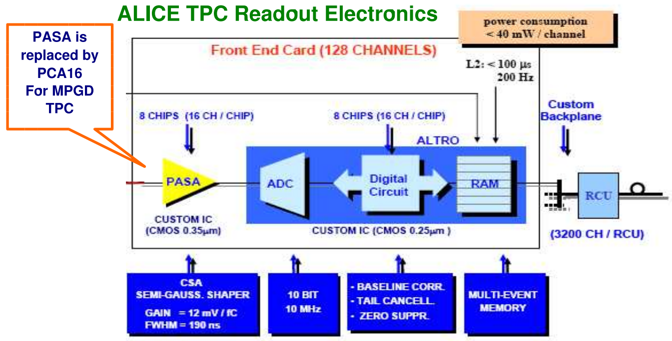

Figure 3: Schematics of the ALTRO electronics. The PASA chip has been replaced by the PCA16 chip. The AFTER electronics which will be used for the MicroMegas modules have a similar setup.

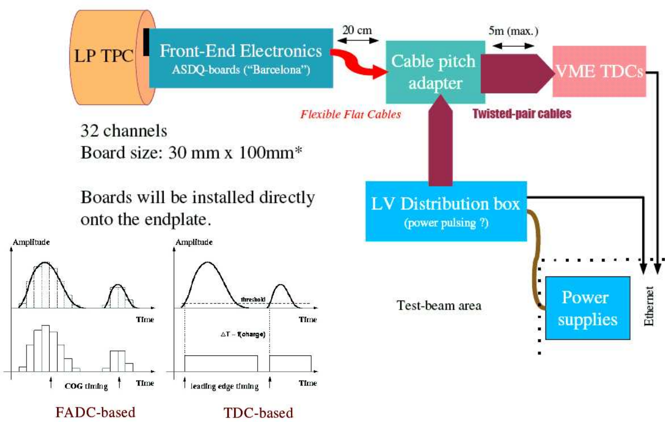

Figure 4: Schematics of a TDC based electronics.

2.2 Readout Electronics

The LP is being operated with a large number of channels that will read out the signals on either pads or CMOS pixels. The pad readout system is based on readout electronics that was developed for the ALICE experiment at the LHC: ALICE TPC Read Out [4] (ALTRO, Fig. 3). Starting with 125 ALTRO chips, which corresponds to 2000 channels, the chip will digitize the TPC signals with a sampling frequency of 40 MHz. The readout system will be extended by 1600 chips with 25 MHz sampling rate. In order to adopt this chip to the specifics of a MPGD based TPC, a new charge sensitive preamplifier has been developed (PCA16). Furthermore, a TPC readout electronics is under development in order to be tested. Here the time of arrival and charge of the signals on the pads are measured with the help of a TDC [5] (Fig. 4). The charge is measured indirectly, with the help of a charge-to-time converter. For the MicroMegas option the AFTER-based TPC electronics has been used, from T2K which has been successfully commissioned.

2.3 DAQ and Monitoring

Every readout (ALTRO and AFTER) provides its own DAQ and is in the responsibility of the various groups. However, a DAQ trigger system has been provided which is based on a Trigger Logic Unit (TLU) [6]. The TLU is a development of the University of Bristol and was extended by the University of Brussels with a distributor box [7]. The TLU is basically providing comparators which allow to synchronize up to four detectors with trigger signals and event numbers. The distributor box extends these features by getting an event number from the TLU an tag the event with a time stamp.It is communicating with the DAQ PCs and also provides a common clock.

The monitoring has been partially established with a Distributed Object Oriented Control System (DOOCS) [8]. The hardware is connected to a control system with Beckhoff devices and parameters that are monitored are so far are connected with the gas properties like gas temperatures, gas pressure, etc.

2.4 Gas-/HV-system

A basic gas system for the LP has been installed with mass flow controllers, safety valve, stainless steel flexible tubing and a monitoring of the gas parameters.

A two fold HV-system has been installed that provides the necessary voltages for the drift fields (up to 20 kV) through FUG-HV-supplies and a CAEN based system for the HV for the different MPGD panels. It is foreseen that these systems to be integrated into the monitoring devices under DOOCS.

2.5 Common Software

The need of a common software for the LP tests stems from the goal of a common data taking, common data stream, common data format, and a unified reconstruction and analysis. In order to achieve these goals a general software framework for the Linear Collider community has been used which uses a modular approach: Modular Analysis and Reconstruction for the Linear Collider (MARLIN) [9].

This concept has been used in order to develop MarlinTPC [10], a modular Marlin based simulation, digitization, reconstruction, and analysis code for the TPC. This package is under development and is tailored for the need of a test beam setup as depicted by the LP.

2.6 Silicon Envelope

In order to have precise external reference points w.r.t. the tracks within a TPC, a set of highly accurate Si-strip modules have been deployed on the surface of the TPC (Fig. 5). They will offer a position accuracy of $\sim 15\mu m$ in Rϕ as well as along the TPC-axis.

First beam tests have been performed and the analysis for alignment procedures are ongoing.

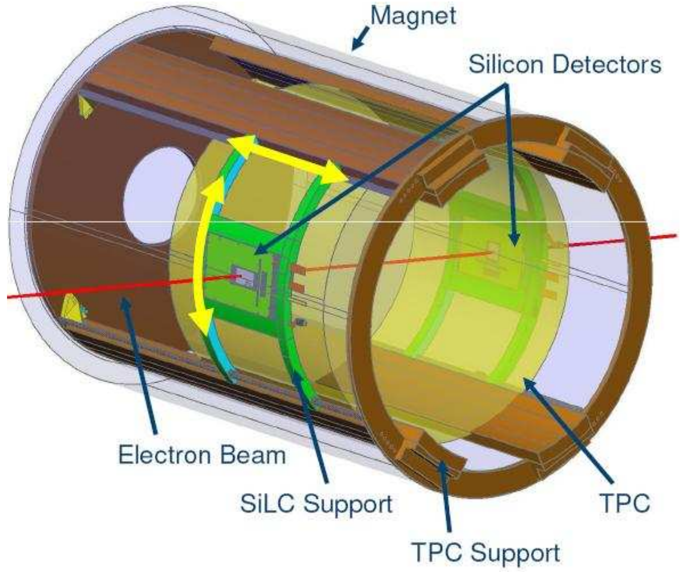

Figure 5: Silicon detectors which are mounted on a support structure around the LP.

2.7 Anode End plate

End plates were designed such that amplification modules can be mounted in a pattern that is a circular subsection of a possible TPC for the ILC (Fig. 6). The end plates allow to position the modules to an accuracy of better than 50 μm. Several areas have been cut out in order to implement further devices for usage with the TPC, e.g. laser insertion holes.

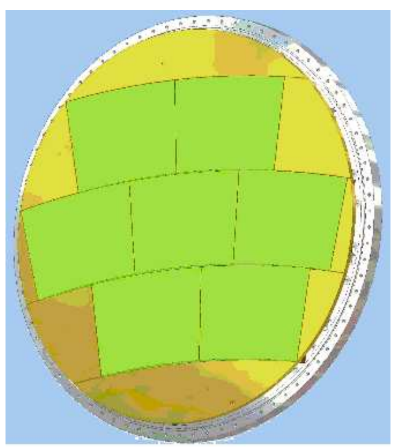

Figure 6: Anode end plate with amplification modules and termination plates.

2.8 Amplification Modules

The TPC has been equipped with MPGD readout instead of the Multiwire Proportional Chamber (MWPC). The MPGD under consideration are Gas Electron Multiplier (GEM)

[11] and Micromesh Gas detector (MicroMegas) [12] (Fig. 7) with standard signal pads as well as with CMOS pixel (TimePix) readout [13] (Fig. 8). For the MicroMegas option

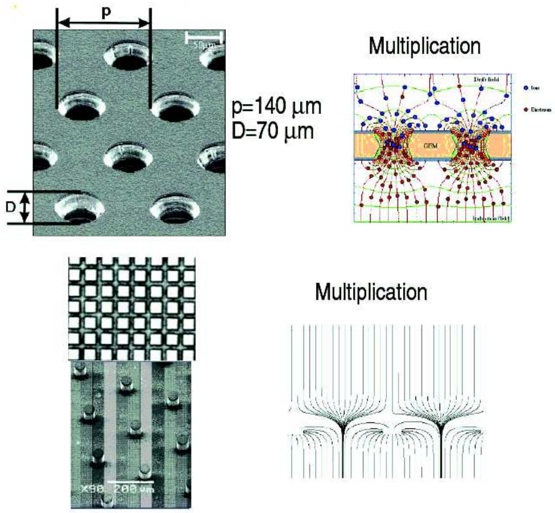

Figure 7: MPGD techniques. Upper: GEM, lower: MicroMegas.

the resistive bulk technology [14] has been used. Modules in the next future will also be equipped with gating devices in order to reduce the ion back flow into the sensitive volume.

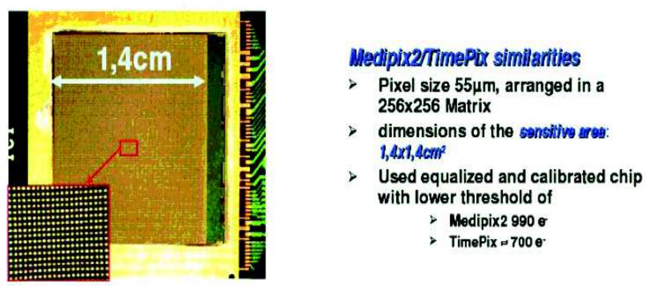

Figure 8: MediPix readout technique.

3 Scintillator Hodoscope

For commissioning and calibration as well as for reference issues a scintillator hodoscope is being used test beam setup (Fig.10). It is detecting cosmic muons in standalone as well as in test beam modus. The hodoscope consists of several layers of scintillator slabs. Five slabs, each with a size of $873 \times 175\,mm^2$ will make the layer on top of the TPC. The longer side of the slabs will be parallel to the TPC's axis. The bottom layer will be made up of two layers. One layer will have three slabs parallel, and the other layer will have four slabs perpendicular to the TPC's axis.

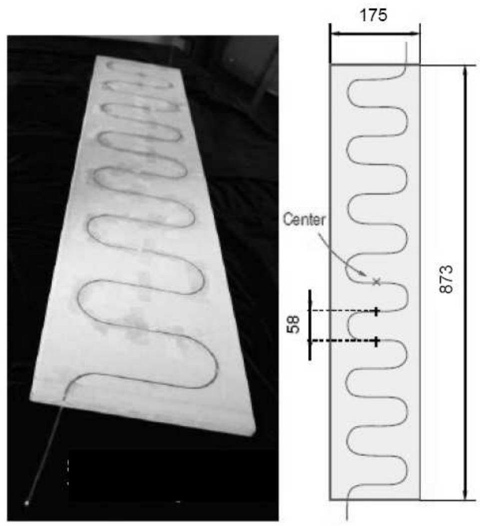

Figure 9: Scintillator slabs produced by UNIPLAST in Vladimir (Russia).

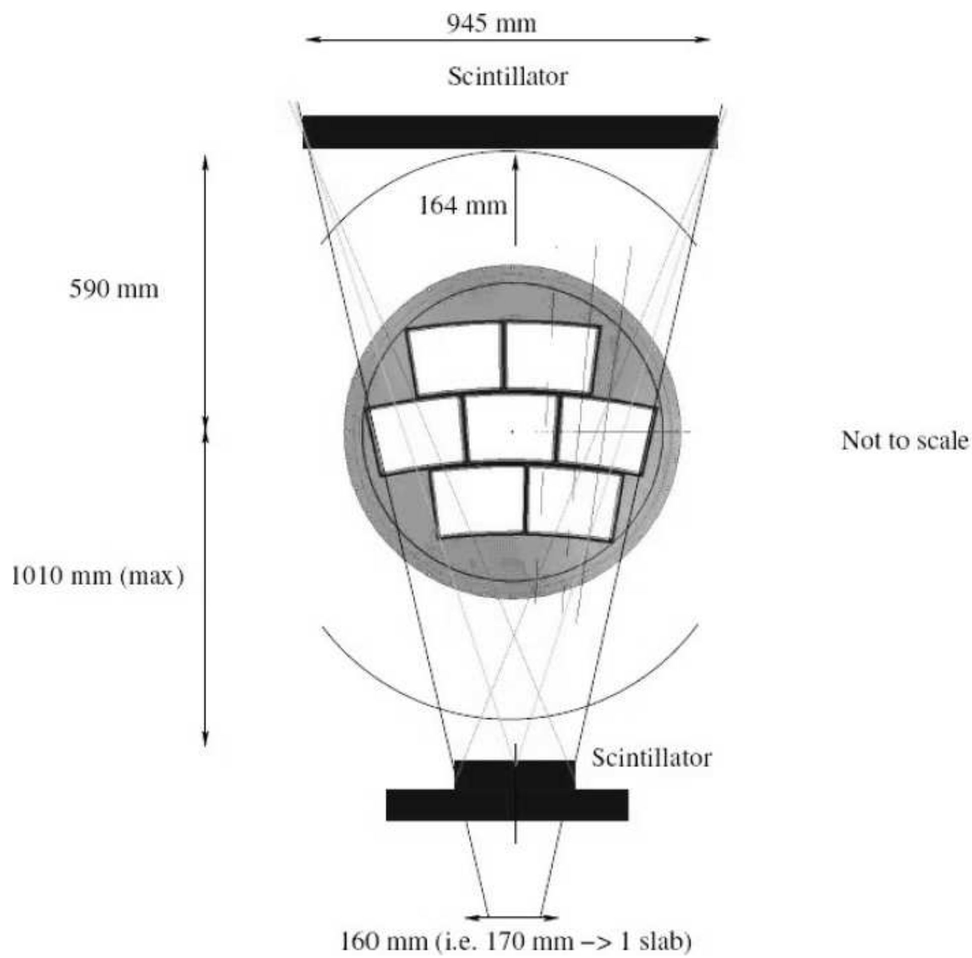

Figure 10: Scintillator hodoscope setup with the LP TPC. The central disk depicts the end plate of the TPC.

The slabs have a white chemical reflector in order to increase the light yield. In addition the slabs are covered with tape so that light other from the signal cannot enter the scintillator. The slabs are placed in a aluminum box with openings at the face sides. There the scintillator light is transformed into electric charge with Multi Photon Pixel Counters (MPPC) [15] with an active area of $1 \times 1\,mm^2$ and a pitch of $100\,\mu m$. The MPPC is a novel type of photon counting device made up of multiple APD (avalanche photo diode) pixels operated in Geiger mode and available in room temperature operation. The MPPC is essentially an opto-semiconductor device with excellent photon counting capability and which also possesses advantages such as low voltage operation and insensitivity to magnetic fields, which is the case here due to operation at PCMAG. Complementary a standard beam trigger hodoscope has been installed. Two pairs of scintillator fingers with an active area of about $20 \times 20mm^2$ are separated by about 1m. The area of coincidence can be chosen according to the needs of the experimenters since they are installed on a frame with sliding mechanism.

4 Infrastructure

4.1 Test beam Area

The DESY II accelerator is providing electrons/positrons with an intensity of $\sim 10^{10}$ particles, with energies up to $7\,GeV$ [16]. The particles in the test beam areas emerge from converted Bremsstrahlung beams due to $7\,\mu m$ carbon targets in the DESY II beam pipe and subsequent collisions with targets on the way to the test beam areas. The produced electrons/positrons experience a dipole magnet, which controls the energy and spreads the beam out into a horizontal fan. Eventually a set of collimators form the beam for usage in the test areas.
The electrons in the test beam area are minimum ionizing particles (MIP), their energy distribution is nearly flat and the Bremsstrahlung spectrum has an $1/E$ dependence. Typical particle rates in the test beam area can be seen in Table 1.

Energy / GeV	Rate (3mm Cu) /Hz	Rate (1mm Cu) /Hz
1	330	220
2	500	330
3	1000	660
5	500	330
6	250	160

Table 1: Estimated particle rates from DESY II.

4.2 Superconducting Magnet PCMAG

The LP will be placed in a superconducting magnet PCMAG, which is provided by KEK. PCMAG is a rather lightweight magnet: a low mass coil and no return yoke make its weight to be $460\,kg$. It has a usable diameter of about $85\,cm$ [1] and the usable length is about $130\,cm$. Its 3342 windings with an operating current of $480\,A$ provide a magnetic field density of up $1.25\,T$ in the center region of the magnet. The field is homogeneous within 3% in the region of $\pm 30\,cm$ of the center, whereas larger deviations are expected in the remaining region (Fig.11). This, however, allows for establishing correction tests during operation.

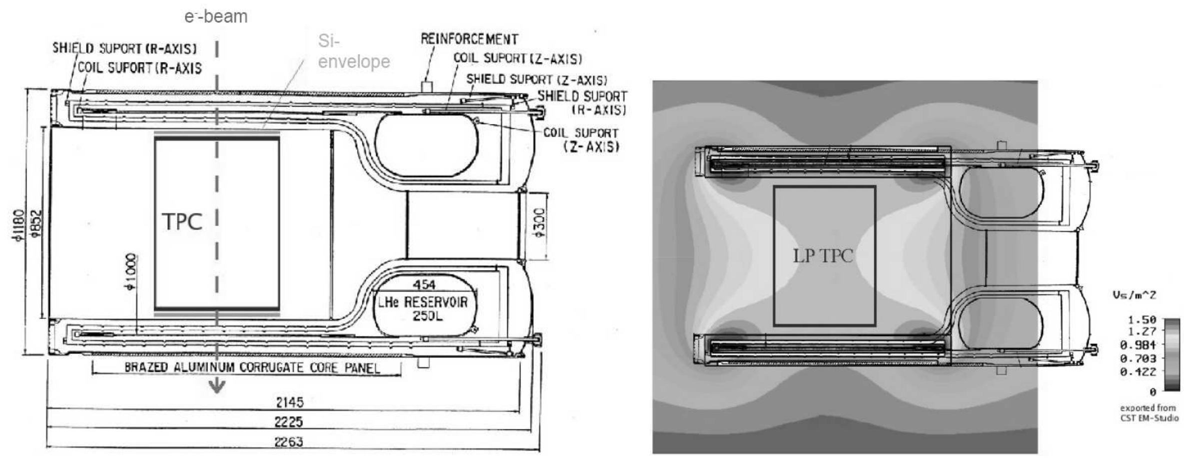

Figure 11: Schematic drawing of PCMAG and its field density distribution.

The magnet is operable and was tested twice within the DESYII T24/1 test beam area. A field measurement was performed in July 2007 and the proper determination of the field map has been performed [17].

4.3 Supporting Devices

A set of supporting devices has been installed in order to obtain flexibility in the test beam setup. The TPC itself has to be inserted into the bore of PCMAG. There it needs to be moved in order to make “use” of the magnetic field in-/homogeneity. Since the inner wall structure of PCMAG is rather thin (1 mm), the TPC has to be supported independently. This has been achieved by a rail system which is implemented in a cylinder. The cylinder is attached at the frame of PCMAG.

Since the beam is fixed in space one needs to move the TPC in order to make use of its full drift volume. Therefore the magnet has been installed on a movable stage that allows lifting, sliding, and rotating the whole system, PCMAG and TPC.

[1] The DESY survey team measured the mean diameter to be $852\,mm$.

4.4 Developments

For the electronic readout of the various MPGD modules one needs to miniaturize the existing electronics. The current scheme has a chain which consists separately of an analog frontend, an ADC, and digital processing units. R&D has been started to implement all these devices in a single chip based on ALTRO electronics. The current design exists with a PCA16 connected to ADCs and afterwards to a digital processing unit based on a two-channel-prototype.
Future plans are to adopt the design to a real geometry, understanding the heat production and cooling issues, as well as a power pulsing scheme. For the latter an FPGA prototype has been already developed by a Japanese group.

5 Summary

A field cage, cathode end plate, and cathodes have been delivered as EUDET projects so that a large prototype of a TPC could be constructed. Furthermore an anode end plate and MPGD modules were installed, a total of 3200 channels of ALTRO electronics respectively 1800 channels AFTER electronics are in use. The LP is a testing bed for several readout techniques based on MPGD in connection with a test of mechanical feasibility of a large TPC. A total of 13 weeks of test beam operation has been performed so far and more tests are planned for the year 2010.
A sophisticated ensemble has been established in order to perform R&D whose goal is to obtain confidence that a TPC with MPGD readout will be a suitable central tracking device for an ILC detector.

Acknowledgment

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