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Status of the Large TPC Prototype

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Abstract

A Large Prototype (LP) of a Time Projection Chamber (TPC) has been constructed by the LCTPC (Linear Collider TPC) collaboration. It has a diameter of about 750 mm and a length of about 600 mm, which allows to measure tracks with up to 125 space points with pad readout. The LP has started to become operable in the 4^{th} quarter of 2008 and will be tested under e^- irradiation in a DESY II testbeam area, immersed in a magnetic field of about 1 T. The field-cage (FC) of the TPC as well as the test beam facility including a superconducting magnet are provided as EUDET projects.

A description of the setup and the status of the project will be given.

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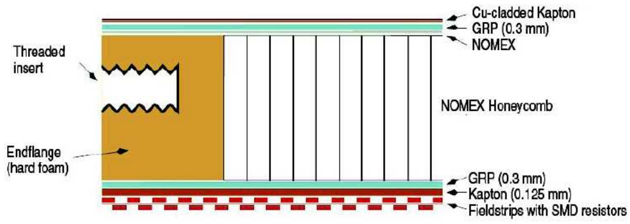

Figure 1: Sandwiched structure for the field-cage.

1 Introduction

A detector at the International Linear Collider (ILC) will have a high-precision tracking system inside a calorimeter system, and both systems will have very high granularity. These will be contained in the detector solenoid which will produce the high magnetic field (4T) needed to reduce backgrounds at the vertex and to enable very good momentum resolution. TPCs based on Micro Pattern Gas Detectors (MPGD) are described in the ILC Reference Design Report [1] and have dimensions of 2.8 - 4 m in diameter and 3 - 4.6 m in length. They are 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 have been studied at small and medium sized TPC prototypes and will be pursued with a Large Prototype (LP) of a TPC [2]. The LP will have a diameter of about 750 mm and a length of about 600 mm. This prototype will fit into a superconducting magnet (permanent current magnet, PCMAG) that has been installed in a test beam area at DESY in Hamburg. PCMAG will deliver 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.

2.1 The Field-Cage

Part of the LP is a field-cage (FC), which is made out of composite materials (Fig. 1). 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.

2.2 Anode Endplate

Endplates 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. 2). The endplates 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.

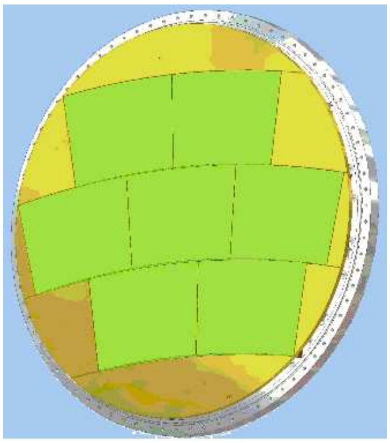

Figure 2: Anode endplate with amplification modules and termination plates.

2.3 Amplification Modules

To realize the excellent space point resolution, a TPC with MPGD readout instead of the Multiwire Proportional Chamber (MWPC) readout is needed. The MPGD under consideration are Gas Electron Multiplier (GEM) [3] and Micromesh Gas detector (Micromegas) [4] (Fig. 3) with standard signal pads as well as with CMOS pixel (TimePix) readout [5] (Fig. 4). For the Micromegas option it is intended to use the resistive bulk technology [6]. Modules will also be equipped with gating devices in order to reduce the ion back flow into the sensitive volume.

2.4 Test Procedures

Correction techniques for E- and B-field distortions have to be evaluated and the LP in connection with PCMAG offer a good opportunity to test these techniques since PCMAG does not have a return yoke, thus providing a field inhomogeneity. A system using photoelectrons produced at the cathode can be used for verifying and correcting these distortions (Fig. 5). Gas mixtures will be tested according to their performance, e.g. low diffusion, sufficient number of primary electrons and small electron attachment, sufficient large drift velocities of electrons and ions in acceptable fields and to test gating conditions in the case of GEM gating.

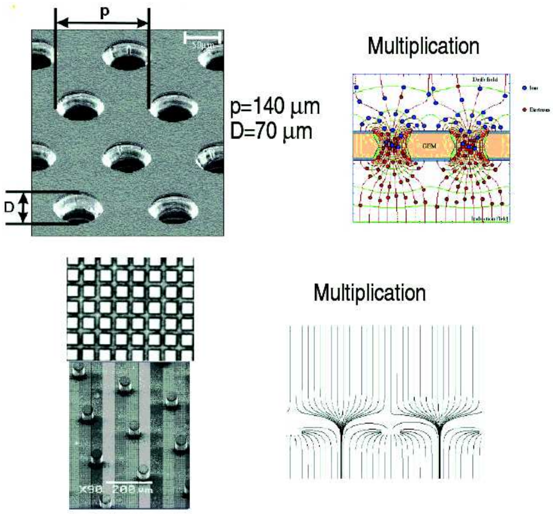

Figure 3: MPGD techniques. Upper: GEM, lower: Micromegas.

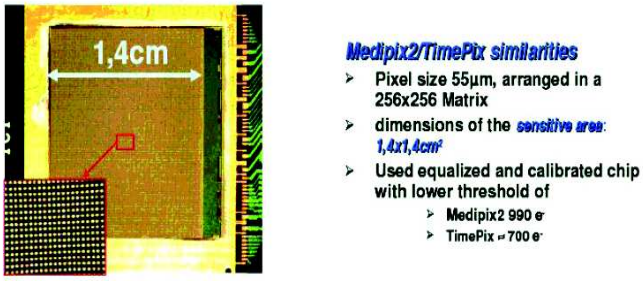

Figure 4: MediPix readout technique.

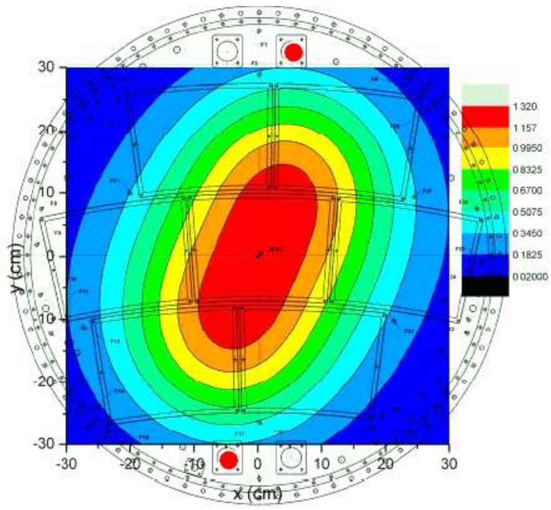

Figure 5: Charge distribution on the anode of an photoelectron calibration system.

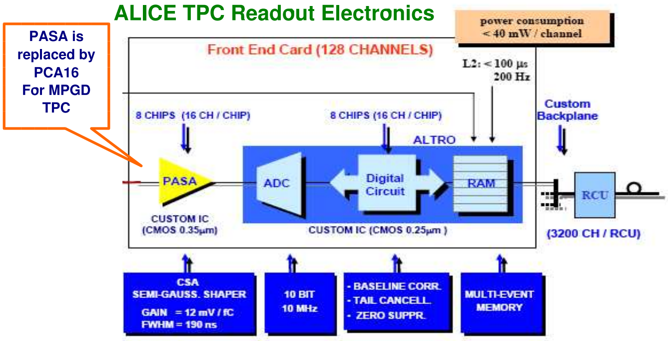

Figure 6: Schematics of the ALTRO electronics. The PASA chip will be replaced by the PCA16 chip. The AFTER electronics which will be used for the Micromegas modules have a similar setup.

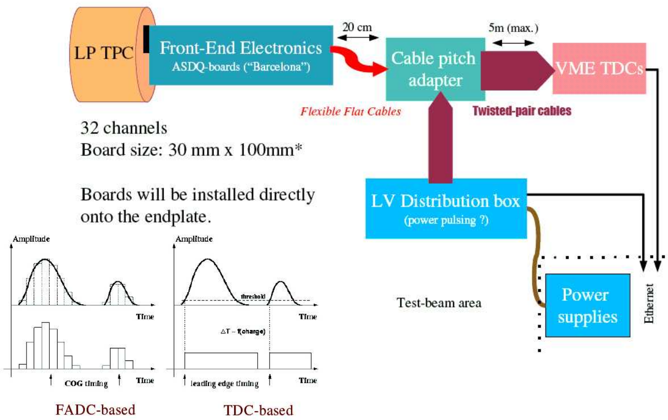

Figure 7: Schematics of a TDC based electronics.

2.5 Readout Electronics

The LP will operate 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 [7] (ALTRO, Fig. 6). 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 will be tested, where the time of arrival and charge of the signals on the pads are measured with the help of a TDC [8] (Fig. 7). The charge is measured indirectly, with the help of a charge-to-time converter. For the Micromegas option the AFTER-based TPC electronics will be used, from T2K which has been successfully commissioned.

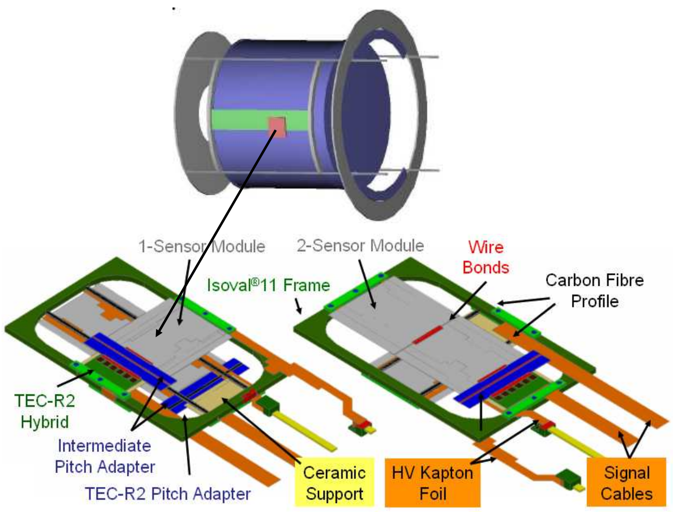

Figure 8: Silicon detectors which are mounted on a support structure around the LP.

2.6 Supporting Devices

In order to have precise external reference points w.r.t. the tracks within a TPC, a set of highly accurate Si-strip modules will be deployed on the surface of the TPC (Fig. 8). They will offer a position accuracy of $\sim 15\mu m$ in Rϕ as well as along the TPC-axis. A cosmic muon hodoscope will be installed around the TPC in order to cross-check the obtained results with other than the beam particles. Furthermore, a laser system will be implemented which allows to produce well defined tracks in the TPC.

3 Testbeam Area

The DESY II accelerator is providing electrons/positrons with an intensity of $\sim 10^{10}$ particles, with energies up to $7\,GeV$ [9]. The particles in the testbeam 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 testbeam 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 testbeam area can be seen in Table 1.

4 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

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.

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.9). This, however, allows for establishing correction tests during operation.

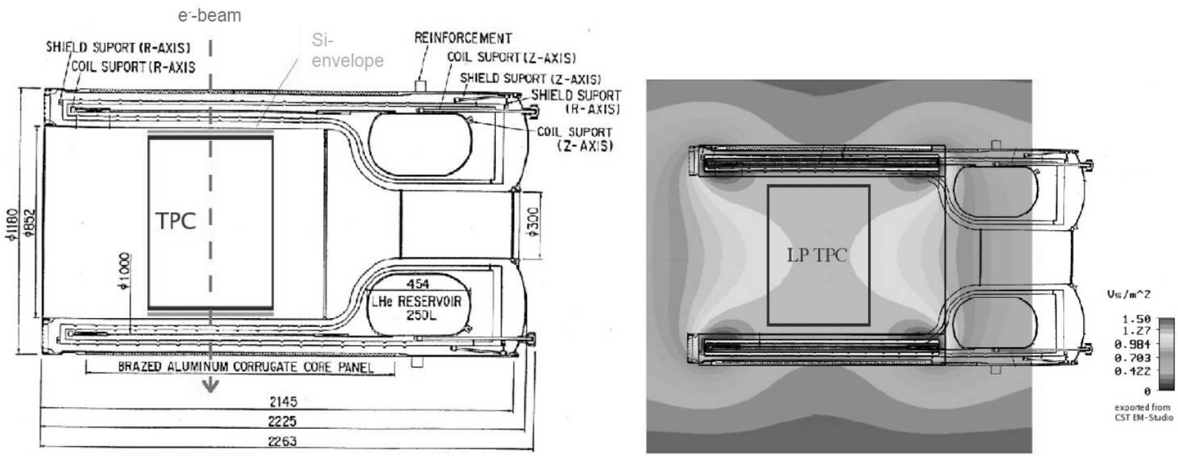

Figure 9: Schematic drawing of PCMAG and its field density distribution.

The magnet is operable and was tested twice within the DESYII T24/1 testbeam area. A field measurement was performed in July 2007 and the proper determination of the field map has been performed [10].

5 Scintillator Hodoscope

For commissioning and calibration as well as for reference issues a scintillator hodoscope is foreseen to be included in the testbeam setup (Fig.11). It will be detecting cosmic muons in standalone as well as in testbeam modus. The hodoscope will consist 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.

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

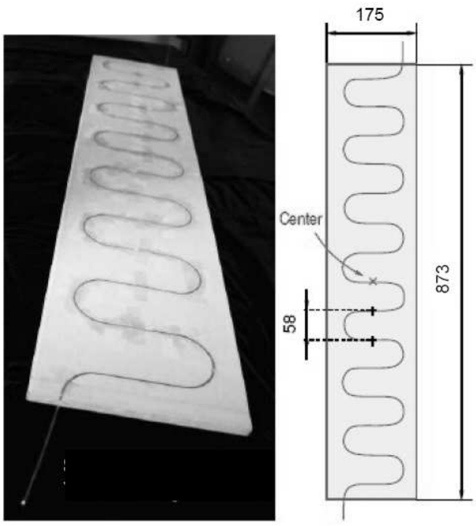

Figure 10: Scintillator slabs produced by UNIPLAST in Vladimir (Russia).

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.
The slabs will have a white chemical reflector in order to increase the light yield. In addition the slabs will be covered with tape so that light other from the signal cannot enter the scintillator. The slabs will be placed in a aluminum box with openings at the face sides. There the scintillator light will be transformed into electric charge with Multi Photon Pixel Counters (MPPC) [11] 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.

6 Summary

A large prototype of a TPC is being constructed, tested and commissioned. 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 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. The preparations for the LP tests are in their final stage and the LP has been exposed to electrons emerging from the DESY accelerator by the end of the year 2008.

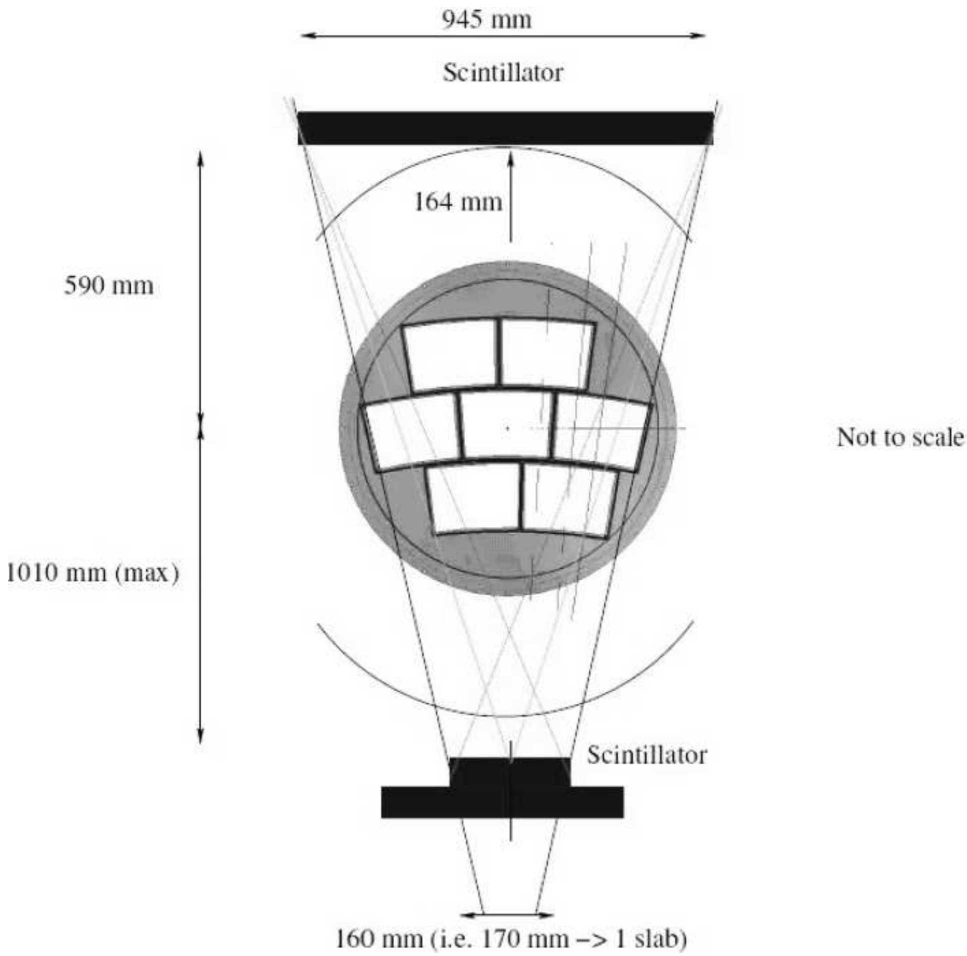

Figure 11: Scintillator hodoscope setup with the LP TPC. The central disk depicts the end plate of the TPC.

Acknowledgement

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