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First Data Taking of the SiTPC module at the Large TPC Prototype

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Abstract

An end cap module for the LC-TPC Large Prototype (LP) was designed and constructed consisting of a stack of three Gas Electron Multipliers and eight Timepix chips. This module was placed in the LP and the setup was tested with the 5 GeV electron test beam at DESY, Hamburg.

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1 Introduction

Within the task SiTPC of EUDET JRA2, TPC endplate modules based on Timepix CMOS pixel chips [1] are being developed. Within EUDET, they are provided as a diagnostic infrastructure to detect ionization clusters with the highest possible spatial resolution. Here we report on the commissioning and first data taking wit ha SiTPC module using a triple-GEM stack and 8 Timepix chips as gas amplification and readout devices (milestone and deliverable JRA2-D11). For the first time eight Timepix chips were operated simultaneously covering a total area of 15.68 cm^2 with 524,288 readout channels. The data was taken in June 2009.

2 The Module

The readout module has been designed and constructed at the University of Bonn. The mechanical layout of the module is shown in figure 1. Its geometric form and size is given by the standard panels of the LC-TPC Large Prototype. The total height of the module is required to be 45 mm to allow a level alignment with the other elements of the end plate. Therefore, an aluminum backframe of a height of 40.5 mm was used which was provided by the Cornell University.
The readout plane has been glued on top of the backframe. The plane is made of a 1.6 mm thick PCB (top view see figure 2). An aluminum reinforcement has been glued to the back of the PCB to ensure the flatness of the PCB and to improve the thermal stability of the readout chips by enlarging the cooling surface. At the center of the readout plane there is a 74×31 mm^2 cut-out, that is used to mount the Timepix chips. On the left side of figure 2 seven pads for HV connections are visible. Around these pads a significant part of the copper has been removed to minimize possible leakage currents

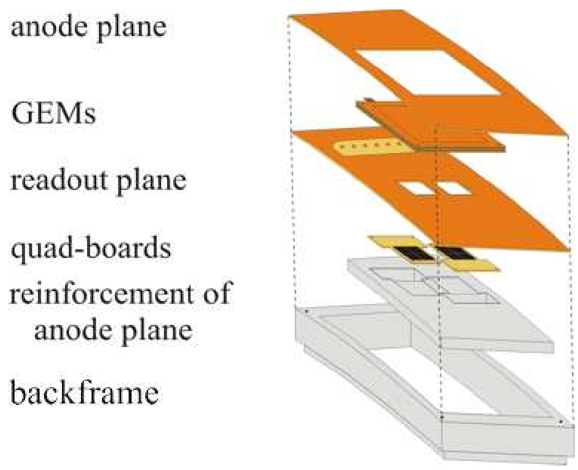

Figure 1: Schematic drawing of the individual layers of the readout module.

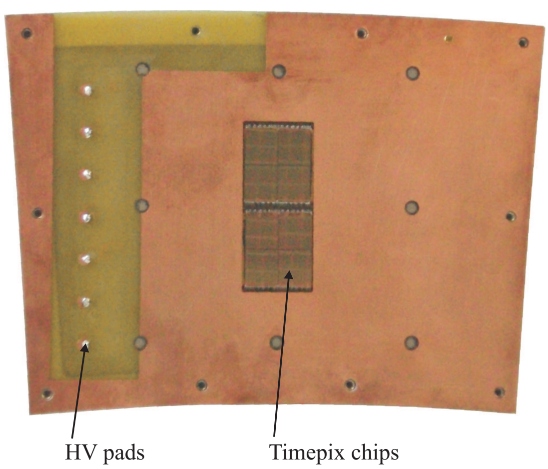

Figure 2: Top view of readout plane with eight Timepix chips mounted.

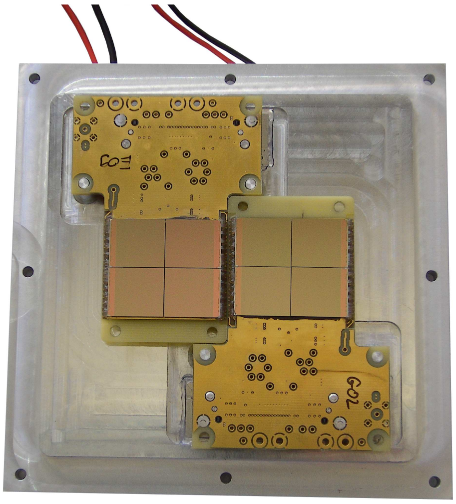

Figure 3: Two quad-boards mounted on the reinforcement plane.

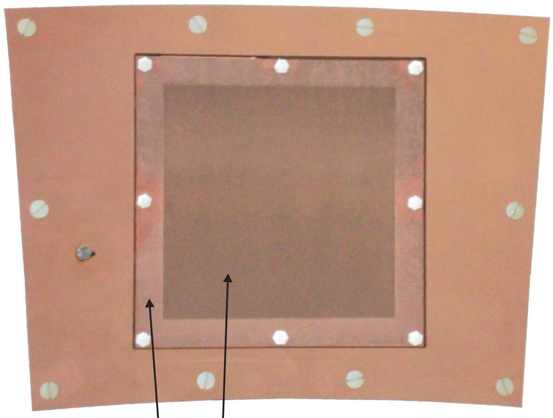

Figure 4: Top view of the anode plane and the topmost GEM placed at the center.

and to avoid shortcuts of the GEM contacts to ground potential.
The eight Timepix chips are mounted on two quad-boards (chip carrier for four Timepix chips) provided by NIKHEF. Fig. 3 shows the two boards mounted on part of the reinforcement. They have been glued on a ceramics plate with a well defined tickness so the chips' surfaces are at the same level as the copper coating of the readout plane.
The anode plane is mounted at a distance of 1.3 mm on top of the readout plane. It is used to terminate the electrical field of the drift volume at the inactive part of the readout module and it is electrically connected to one of the HV pads of the readout plane. The anode plane is made of the same material as the readout plane. As shown in figure 4 a GEM stack consisting of three standard CERN Gas Electron Multipliers (GEMs) is mounted in a 126×126 mm^2 cut-out of the anode plane. The GEMs feature an active area of 100×100 mm^2 with a hexagonal hole pattern. The hole sizes are 60 µm in the kapton, 70 µm in the copper and the hole pitch is 140 µm. The two copper electrodes are separated by a 50 µm thick kapton layer. The GEMs are mounted on one side on a 0.5 mm thick GRP frame and they are fixed by polyurethane screws and spacers. The spacing between the GEMs is only 1 mm to reduce the diffusion between the GEMs as much as possible. To minimize the gap between the top electrode of the GEM and the anode plane the copper electrode was extended beyond the active area to the edge of the stack.
Before the test beam operation the high voltage stability and gas tightness of the module were tested in a small test detector at the lab in Bonn.

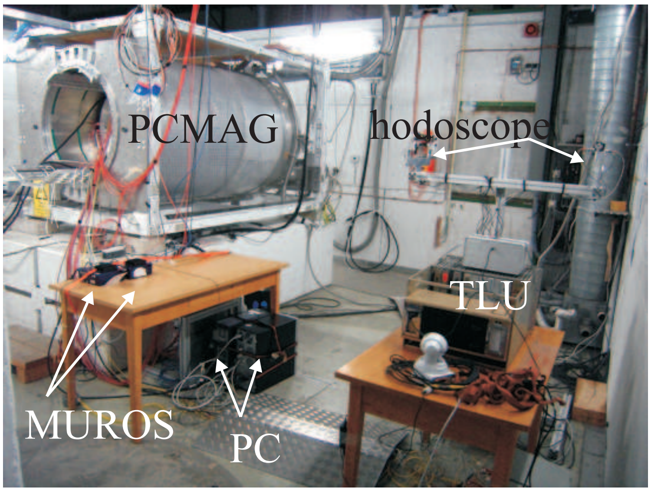

Figure 5: Testbeam area T24/1.

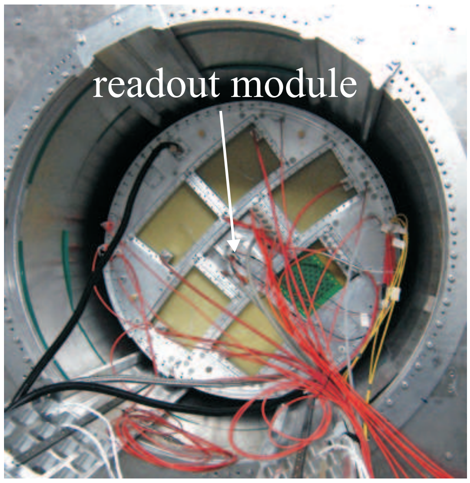

Figure 6: The LP end cap equipped with the readout module.

3 Test Beam Measurements

The test beam setup in the area T24/1 at DESY is shown in figure 5. On the right-hand side a hodoscope made up of scintillators is visible. The signals of these detectors were routed into the Trigger Logic Unit (TLU [3]), which is used to synchronize the readout electronics and computers.
On the left-hand side of figure 5, the large superconducting magnet PCMAG is visible. The Time Projection Chamber was inserted in the magnet. The readout module was mounted in the middle opening of the end cap (s. figure 6). Each quad-board was connected to and read out by a MUROS2 [2]. Due to the limited cable length the MUROSes as well as the computers had to be operated in the stray field of the magnet (see figure 5). Therefore, the PCs were equipped with solid state disc drives.
During the seven day test beam campaign large sets of data could be collected. Two different gas mixtures, He:CO_2 70:30 and Ar:CF_4:iButan 95:3:2, could be studied in detail. For both gas mixtures the gas amplification, drift distance, beam energy and track inclination were varied. All data have been taken at a magnetic field $B = 1$ T. Example events are shown in figures 7 and 8. The pictures are screen shots from the Pixelman DAQ software [5]. Figure 7a shows a track at a drift distance of 4 cm, while the track of figure 7b has a drift distance of 50 cm. Due to the longer drift distance the diffusion had visibly broadened the track. Figure 7c shows a δ-electron knocked out by the high-energy electron and curling in the magnetic field. Figures 8a and 8b show rare multi track events including short-ranged δ-electrons.
At the end of the test beam campaign also the laser calibration setup was tested. With this device signals of single electrons or few electron clusters could be observed at various gas amplifications. An example event is shown in fig. 8c where electrons released by the laser from two separate dots on the cathode are seen, one on each quad-board.

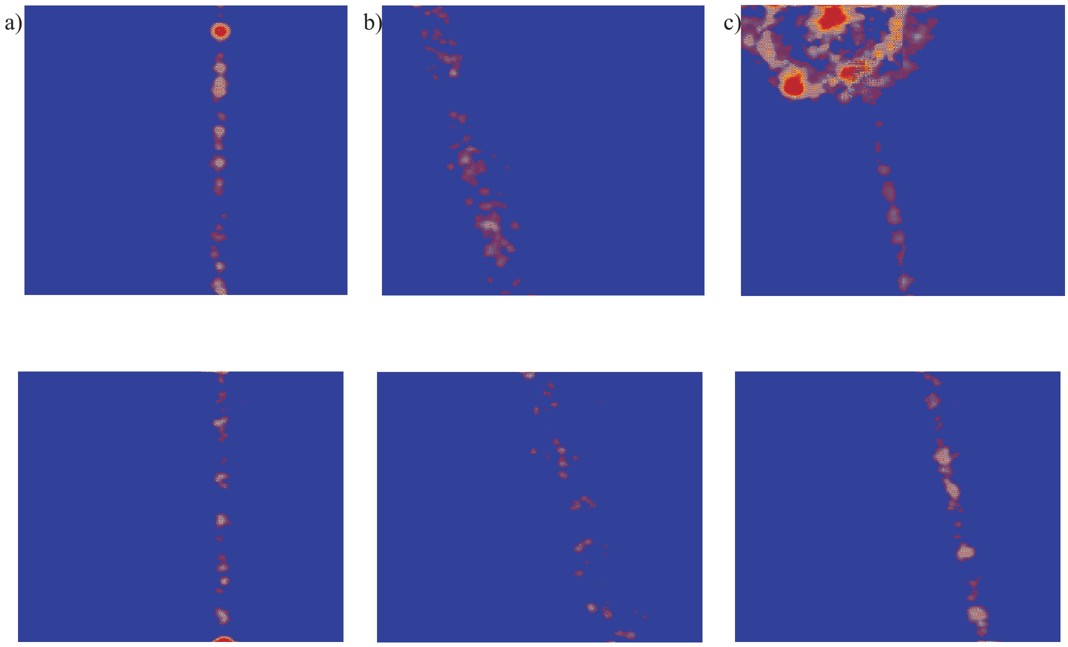

Figure 7: Various tracks in Ar:CF_4:iButan 95:3:2. a) drift distance of 4 cm, b) drift distance of 50 cm, c) δ-electron curling in the magnetic field. The screen shots taken from the Pixelman Software [5].

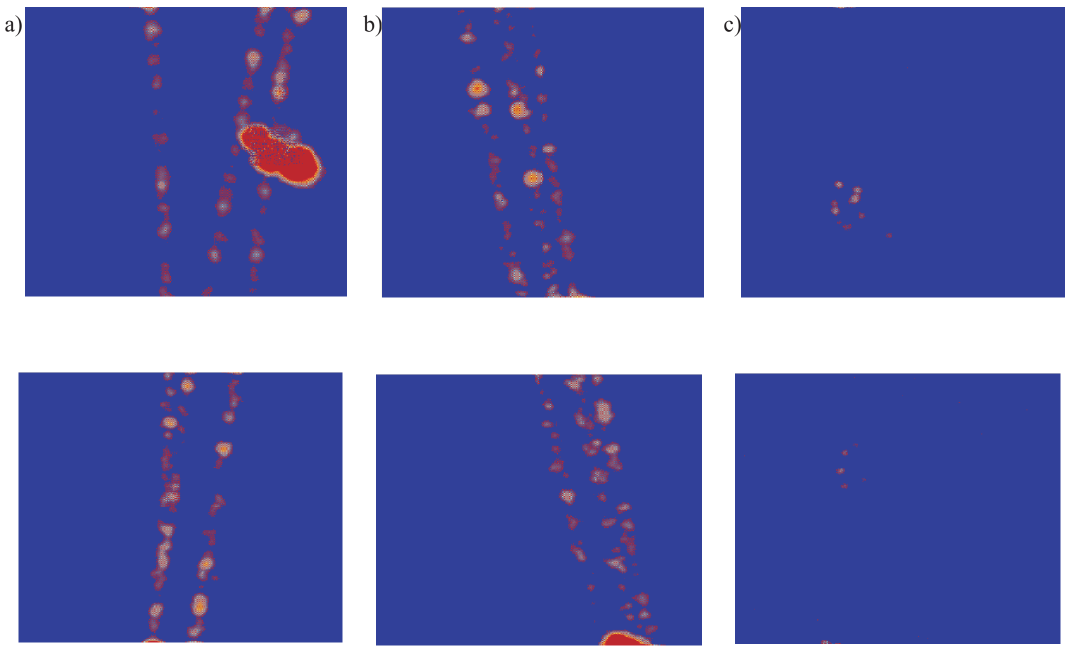

Figure 8: Various tracks in Ar:CF_4:iButan 95:3:2. a) and b) are multi track events, c) charge depositions made by multi-electrons clusters during the laser calibration. The screen shots taken from the Pixelman Software [5].

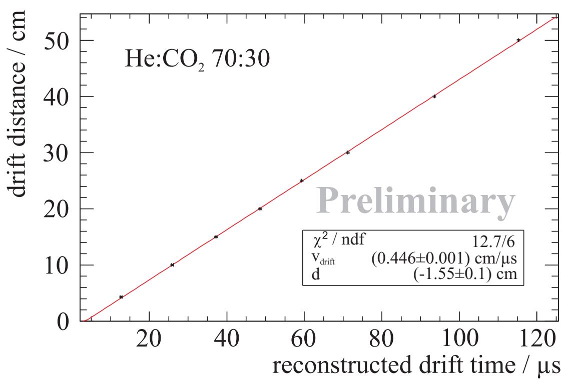

Figure 9: Dependence of the reconstructed drift time on drift the distance in He:CO_2 70:30.

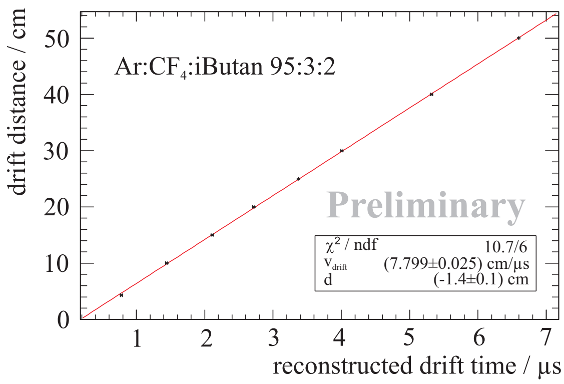

Figure 10: Dependence of the reconstructed drift time on the drift distance in Ar:CF_4:iButan 95:3:2.

4 First Results

The data of the test beam is being analyzed with MarlinTPC [6]. First preliminary results are in good agreement with expectations. As an example the figures 9 and 10 show the adjusted beam position along the drift distance versus the reconstructed drift time for the two different gas mixtures mentioned before. The drift velocities can be taken from the slope of the graphs and then compared to predictions from Magboltz 8.6. For He:CO_2 70:30 the measured value is $v_{\text{drift}} = (0.446 \pm 0.001)\ \frac{\text{cm}}{\mu\text{s}}$ while Magboltz gives $v_{\text{drift}} = (0.456 \pm 0.001)\ \frac{\text{cm}}{\mu\text{s}}$. For Ar:$CF_4$:iButan 95:3:2 the measured value is $v_{\text{drift}} = (7.80 \pm 0.0025)\ \frac{\text{cm}}{\mu\text{s}}$ while Magboltz gives $v_{\text{drift}} = (7.8 \pm 0.003)\ \frac{\text{cm}}{\mu\text{s}}$. The error stated are only of statistical nature. The small deviations towards lower drift velocities can be well explained by systematical effects such as small variation in the gas mixture (e.g. contamination by water vapor) or in the drift field.

5 Summary

A readout module for the Large Prototype TPC has been constructed. It consists of a gas amplification stage made up of three GEMs and a highly pixelized readout consisting of eight Timepix chips with a total of 524,000 readout channels. The module was operated successfully in the LPTPC during a test beam campaign. The analysis of the data is still ongoing, but first results look very promising.

Acknowledgment

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References

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