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Status of the Bonn R&D Activities for a Pixel Based TPC

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Abstract

We report on the activities at the University of Bonn to set up a laboratory for the development of a pixel based TPC readout. It is planned to install a test stand with a small TPC field cage and all the infrastructure necessary to operate the detector, like gas system, high voltage supply and readout electronics.

A module with eight TimePix chips and a triple GEM amplification structure will be constructed for use in the large TPC prototype which is being built within the EUDET context.

Algorithms for the reconstruction of TimePix data are currently being implemented in the MarlinTPC software package.

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1 Introduction

To take full advantage of the small patterns of a GEM[1] gas amplification foil, the TimePix chip[2] has been developed, based on the MediPix2 chip[3]. Originally designed to be operated together with a silicon sensor, in a TPC the bare readout chip without silicon sensor is used and the charge coming from the gas amplification structure is collected on the bump bond pads of the TimePix.
The TimePix chip consists of 256×256 pixels with a size of $55\,\mu\text{m} \times 55\,\mu\text{m}$ each, resulting in an active area of $14.08\,\text{mm} \times 14.08\,\text{mm}$. The pixels can be operated either to count the number of hits in a certain time window, to measure the number of clock cycles between the beginning of the first hit and the end of the time window, or to measure the time of the signal above a certain threshold, being a measure of the amount of charge arriving on the pixel. For each pixel the mode can be set individually. By setting the pixels alternately to measure the time and the charge in a chequerboard pattern, one can obtain all the information needed to read out a TPC.
So far the TimePix chip in combination with a triple GEM structure has only been operated in test chambers with a few millimetres drift distance. In oder to study the performance of this readout in detail, for instance with longer drift distances, the Bonn LC-TPC group is setting up a laboratory and a test setup with a 26 cm drift distance prototype TPC. To cross check the results obtained with the TimePix, a combined readout together with conventional pads is being developed.

2 Infrastructure

The laboratory in Bonn will provide all the infrastructure to test TPC readout modules and to operate the small prototype TPC. A laminar flow box provides the possibility to open and reassemble the detector under clean conditions. Scintillator panels above and below the detector form a trigger system for muons produced by cosmic radiation.
To read out the TimePix chip a Muros system[4], developed at NIKHEF, is used in combination with the PixelMan software[5], which was developed in Prague. The pads are going to be readout with the Altro electronics[6] which was developed for the Alice experiment[7] and is also used for the large prototype TPC.
The planned gas system and the high voltage supply will be described in more detail in the next sections.

2.1 The Gas System

The planned gas system is mainly made up of flow and pressure controllers we obtained from the dismantled gas system of the Zeus experiment at DESY, Hamburg. An embedded PC will operate these controllers and allow to constantly monitor the pressure and the gas fluxes. A schematic sketch of the gas system is shown in figure 1.
Flow meters at the gas inlet allow to mix up to three different gases. An absolute pressure meter is coupled to the exhaust valve to keep the absolute pressure in the gas volume

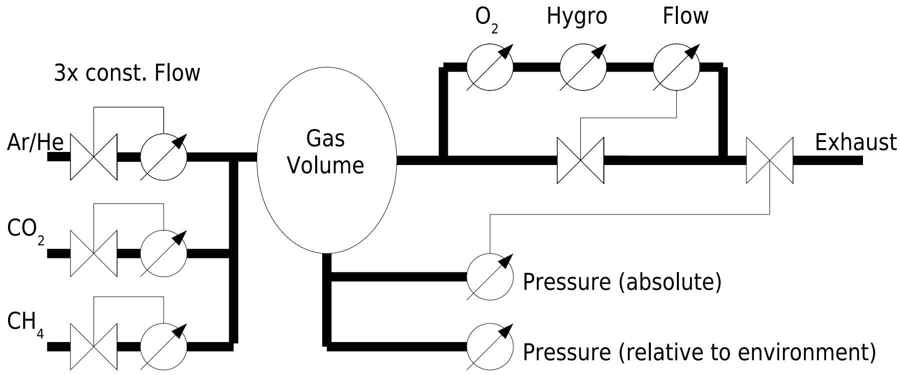

Figure 1: The planned gas system for the test setup.

constant, which is important because the gas amplification depends on the absolute pressure. A relative pressure meter monitors the overpressure in the chamber. In case the pressure in the chamber rises to more than 20 mbar above atmospheric pressure the computer will stop the gas supply to protect the chamber.
An oxymeter and a hygrometer are planned to measure the oxygen and water content in the exhaust gas. A flow controller ensures a constant gas flux in the measurement branch when the absolute flux through the chamber changes.

2.2 High Voltage Supply

To have maximal flexibility in the voltages applied on the GEM foils, each electrode is powered by an individual high voltage channel. The power supply for the GEM foils can be operated up to −6 kV. The cathode is powered by a separate module, which can deliver up to −30 kV. This allows a drift field of up to 1 kV/cm with the small prototype field cage.

3 The Field Cage

The field cage (figure 2) is a clone of a prototype field cage which has been developed in Aachen.[8] It has an outer diameter of 26 cm, which allows operation in the 5 T solenoid located at DESY, Hamburg. The inner diameter of 23 cm leaves enough space to house a readout with a 10 cm×10 cm CERN standard GEM and to place all the cables for the high voltage supply.
The maximal drift distance of 26 cm allows to study the influence of diffusion in the drift region on the spatial resolution.

4 The Readout

The gas amplification structure of the readout module consists of three GEM foils, which are mounted as a stack on top of the readout plane. The GEM facing the drift volume is

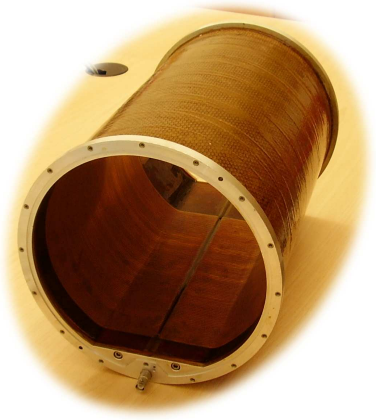

Figure 2: The prototype field cage.

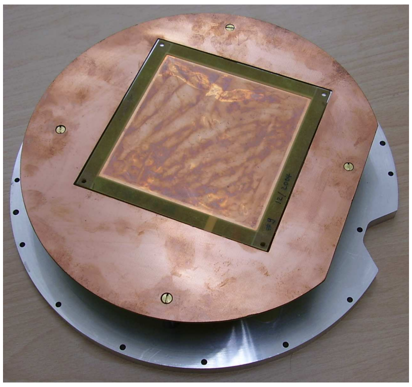

Figure 3: The electrical shield with a GEM mounted in it.

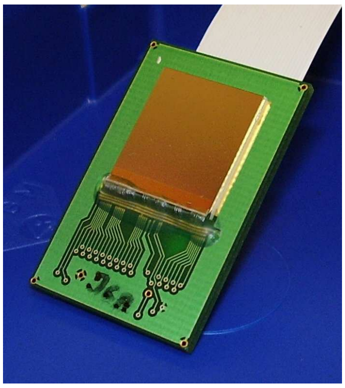

Figure 4: The single chip board.

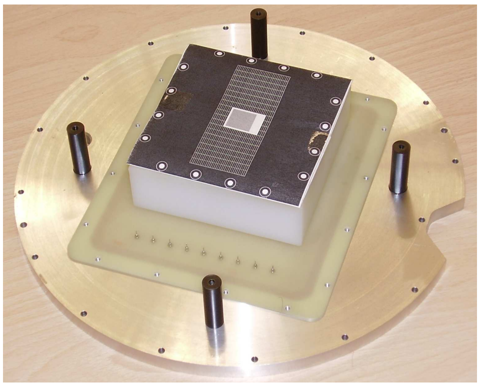

Figure 5: A paper printout of the combined pads + TimePix readout plane mounted on the readout back frame.

aligned with the surface of an electric shield (copper clad GRP board), which terminates the drift field (figure 3).
The readout module is a combined readout of classical pads and a TimePix chip. In the centre of the pad plane a rectangular area is cut out of the PCB and the TimePix chip is glued in from the back side, to be in plane with the pads.
The TimePix is mounted onto a single chip board (figure 4). This board is based on a development from Freiburg and was redesigned to be as small as possible in order to leave enough space for the surrounding pad connectors. In addition the board has to be gas tight. Figure 5 shows a paper printout of the pad plane, mounted on the readout back frame.

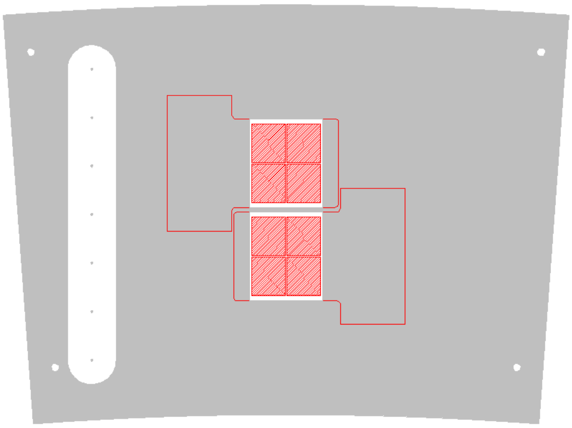

Figure 6: Sketch of the LP module's readout plane. On the left side one can see the high voltage feed through. In the middle the shapes of the two quad boards with the TimePix chips are indicated. The quad boards will be glued in from the back side.

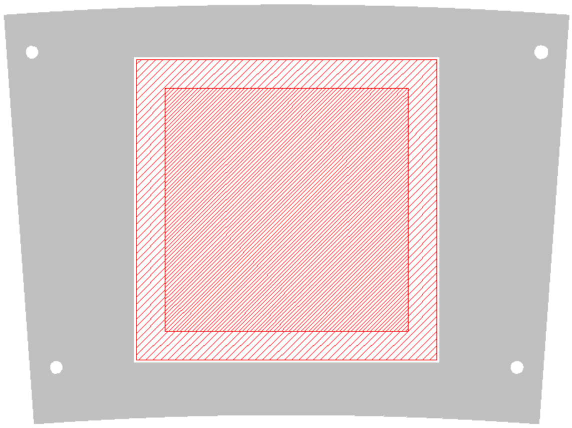

Figure 7: Drawing of the electrical shield holding the GEMs for the LP module.

5 A TimePix + GEM Readout Module for the Large Prototype

For the common large prototype (LP) a readout module with eight TimePix chips is being constructed. This module will provide a high accuracy measurement of the particle trajectory inside the TPC and thus can serve as a reference measurement for other modules being tested in the large prototype.
The TimePix chips are arranged two by two on *quad boards* which have been developed at NIKHEF[9]. Two of the quad boards are glued onto the readout anode from the back side (figure 6). For gas amplification three standard CERN GEMs are used, mounted to the shield which terminates the drift field (figure 7), like it is done for the small TPC prototype.

6 Reconstruction Software

MarlinTPC [10][11] is a TPC simulation, digitisation, reconstruction and analysis package for the Marlin[12] / LCIO[13] framework. So called *processors*, which are performing the individual computing tasks, have been implemented for the reconstruction of TimePix data in MarlinTPC. Table 1 shows the reconstruction flow.
Starting from the raw data, zero suppression is performed to reduce the amount of data. Afterwards adjacent pixels are grouped to clusters, called hit candidates. One

Data Structure	Processor Name	Collection Name
`TrackerRawData`		TimePixRawData
	TimePixZeroSuppressionProcessor	
`TrackerRawData`		TimePixZeroSuppressedRawData
	TimePixClusterFinderProcessor	
`TrackerHit`		TimePixHitCandidates
	TimePixClusterProjectionSeparatorProcessor	
`TrackerHit`		TimePixSepHitCandidates
	TimePixHitCenterCalculatorProcessor	
`TrackerHit`		TimePixHits

Table 1: The TimePix reconstruction flow in MarlinTPC.

of those clusters often originates from more than one primary ionisation cluster, which are merging because they are smeared out in the GEM amplification structure due to diffusion. In this case the *TimePixClusterProjectionSeparatorProcessor* tries to separate them. From these separated clusters the centre of gravity is calculated in 3D spacial coordinates and we end up with fully reconstructed `lcio::TrackerHits`.
At this point the TimePix specific reconstruction chain ends and the track finding and fitting is performed with the same algorithms and together with the TrackerHits from the pad readout. This allows a combined track fit for different readout techniques in one module (like the Bonn prototype readout) as well as for different readout modules like in the large prototype.

7 Conclusion

The Bonn LC-TPC group is currently setting up a laboratory to operate a small TPC prototype. A readout module with a tripe-GEM amplification structure and a combined pads + TimePix pickup board is under development.
With a similar technique a module for the large prototype is being built. It will have a triple GEM structure and 8 TimePix chips. This module is supposed to deliver an additional high resolution measurement of the particle trajectory, which can serve as a reference for the readout modules being tested in the large prototype TPC.
The reconstruction of TimePix data is being implemented in MarlinTPC to allow combined track fits and comparison with data from other detector modules.

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[12] Marlin Homepage: `http://ilcsoft.desy.de/portal/software_packages/marlin`

[13] LCIO Homepage: `http://lcio.desy.de/`