Time Projection Chamber with triple GEM and highly granulated Pixel Readout

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A new readout consisting of a gas amplification stage made of three Gas Electron Multipliers (GEMs) and a highly granulated active anode was installed in a Time Projection Chamber (TPC). This setup was tested in various environments and an excellent spatial resolution close to the diffusion limit could be observed.

1 Introduction

Micro pattern gas amplification stages such as Gas Electron Multipliers (GEMs) [1] have many interesting features: high granularity, intrinsically suppressed ion back flow, almost no distortions due to $E \times B$ effects and a complete decoupling of the gas amplification and readout geometry. These devices improve the performance of Time Projection Chambers (TPCs) because they allow ungated operations and improve the spatial resolution. To fully exploit the potential of this combination the pad size in the readout plane has to be optimized according to the structure size of the gas amplification stage. The Timepix [2] is a suitable readout chip for the use in Micro Pattern Gas Detectors (MPGDs) by providing metalized pads to pick up the charge. The pitch of these pads is 55 µm and therefore of similar structure size as the holes of standard CERN GEMs having a pitch of 140 µm between holes and hole sizes of 60 to 70 µm. Each pad is connected to an on-chip readout chain, containing a preamplifier, discriminator and 14-bit counter. The pixel electronics can be operated in different modes. Some of these modes allow the measurement of the arrival time of the charge collected on the pad, or the "time-over-threshold" related to the amount of deposited charge.

2 Experimental Setup

To test the new readout structure with signals originating over a wide range of drift distances, we have designed and constructed a small and highly flexible TPC prototype with a cylindrical drift volume (maximum drift distance of 26 cm, inner diameter of 23 cm - see Fig. 1). The readout has been equipped with a stack of three GEMs with transfer gaps of 1 mm in between. The Timepix chip has been placed 1 mm below the last GEM. The pixels were operated in a checkerboard pattern of time and charge measurement. In Fig. 2 four charge depositions are shown and the two different modes are clearly visible: The pixels measuring the arrival time give the same value shown in black, while the pixels measuring the Gaussian charge distribution

Figure 1: Detector set up in the cosmic ray test stand.

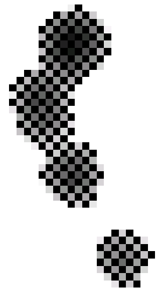

Figure 2: Charge depositions on the Timepix chip.

vary in shades of gray.
The detector was placed in a cosmic ray test stand at the Bonn lab. Here, two scintillators are used to trigger on cosmic rays and about 130,000 tracks have been recorded.

3 Results

The data was analyzed with MarlinTPC [3], a modular and flexible analysis tool. New algorithms had to be introduced to cope with the particular challenges of the readout method. For example great care was taken to split overlapping charge depositions and reconstruct the tracks from the single hits.

In Figs. 3 to 5 some results are shown that were obtained while using a gas mixture of He:CO_2 70:30. The average value of the size and the charge of a charge deposition are constant for drift distances larger than about 7 cm (see Figs. 3 and 4). This leads to the conclusion that charge depositions at these drift distances originate from single electrons in the

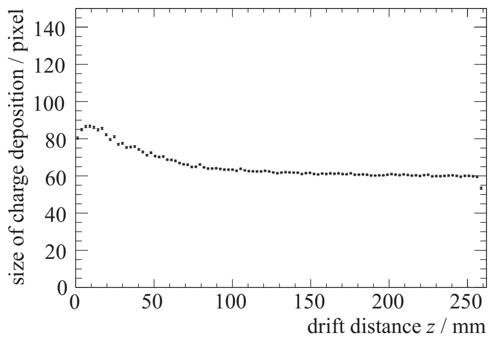

Figure 3: Number of pixels hit per charge deposition.

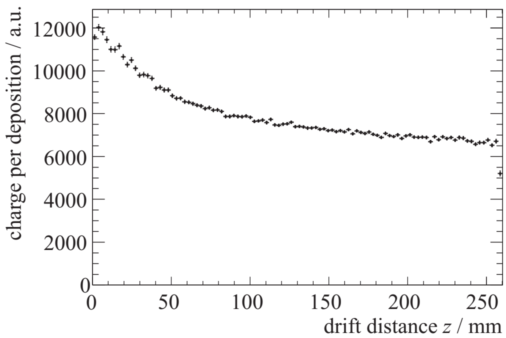

Figure 4: Charge per charge deposition in dependence on the drift distance.

drift region. For short drift distances the diffusion is insufficient to separate all electrons in the drift region. Therefore, an increasing number of charge depositions cannot be separated by the analysis algorithms leading to an increase in reconstructed charge and size.

The transverse spatial resolution is given in Fig. 5. For easier comparison the diffusion limit of single electrons is shown with a dashed line. The diffusion coefficient has been determined with the help of Magboltz 7.1 [4]. The fit function shown in a dark solid line is given by:

$$\sigma = \sqrt{\sigma_0^2 + \frac{D_t^2}{n_{ele}} z},$$

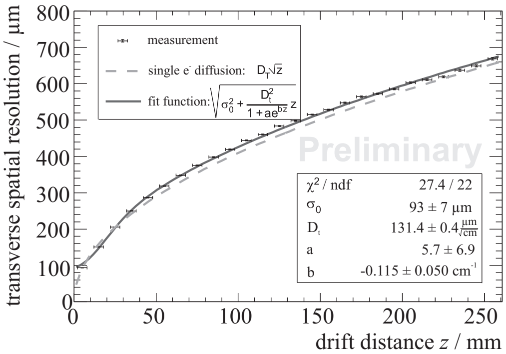

Figure 5: Transverse spatial resolution of the test detector.

where D_t is the transverse diffusion coefficient, σ_0 the intrinsic detector resolution and $n_{ele} = 1 + a\,e^{bz}$ takes into account the varying number of electrons per reconstructed charge deposition.

The result shows little deviation from the diffusion limit. For short drift distances the spatial resolution is below the diffusion limit due to $n_{ele} > 1$. In separate measurements quasi no dependence on the track inclination was observed and full functionality and excellent behavior in high magnetic fields with B up to 4 T could be demonstrated (see [5]).

4 Summary

For the first time the combination of a triple GEM and a Timepix chip was tested with signals drifting up to 26 cm. We have strong evidence that charge depositions seen on the chip originate from single electrons in the drift volume. The transverse spatial resolution of these charge depositions follows the diffusion limit with a small constant offset.

5 Acknowledgments

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