# Results of studies with a Small TPC Prototype Readout with GEMs and TimePix

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**Abstract**

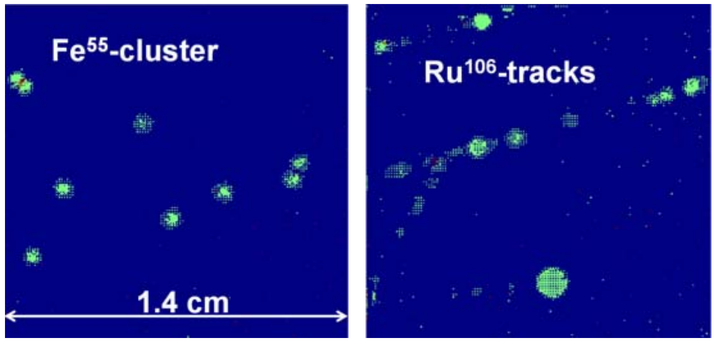
This contribution reports on the development of a highly pixellated and integrated readout system for a Time Projection Chamber (TPC). A drift volume of $10 \times 10 \times 0.6\,\mathrm{cm}^3$ is joined with a triple Gas Electron Multiplier (GEM) stack used for gas amplification. A single TimePix CMOS ASIC with an active surface of $1.4 \times 1.4\,\mu\mathrm{m}^2$ serves as readout for the amplified charge. This chip allows to register either the signal amplitude or time of arrival for each pixel (size $55 \times 55\,\mu\mathrm{m}^2$. The spatial as well as the time resolution of the GEM-TimePix system are probed in a 5 GeV electron test beam at DESY. A Si-telescope tags the $e^-$-beam and allows the external determination of track positions. Different GEM orientations and geometries are investigated. The point resolution transverse to the track with drift distances smaller than 1 mm is $\lesssim 20\mu$m. A time resolution of $\approx 10$ ns is observed in drift direction. Furthermore, experimental studies with an enlarged pixel size of MediPix2/TimePix chips are ongoing to optimize the readout granularity for a new generation of chips for Micro Pattern Gas Detectors (MPGDs). These activities are performed in collaboration with the Freiburg Material Forschungszentrum (FMF) in Freiburg.

The development of Micro-Pattern-Gas-Detectors (MPGD) allows an extended field of application for detectors with gas multiplication. The successful operation of GEMs (140 $\mu m$ hole pitch, hexagonal configuration) with a highly pixellated readout using the TimePix chip has been demonstrated with 5 GeV electrons [1]. This prototype represents a proof of principle for a gaseous detector readout envisaged for a TPC at the ILC. The modified setup is tested in a second run at DESY. The test beam is equipped with a Si-strip-telescope, which is used for an external determination of track positions.

The TimePix is a CMOS pixel ASIC based on the layout of the MediPix2 chip [2] developed by the MediPix collaboration. The TimePix consists of $256 \times 256$ pixels each of $55 \times 55\,\mu\mathrm{m}^2$ size, forming an active surface of $1.4 \times 1.4\,\mathrm{cm}^2$. Every pixel cell has a charge sensitive input and is equipped with amplifying, shaping and discriminating front-end electronics. Signals of positive and negative polarity can be processed. A reference clock is distributed throughout the entire chip. An on-pixel shift register counts the number of clock cycles. The design value for the clock speed is up to 100 MHz. There are three distinct ways of counting. In case of the TIME mode the time of arrival of the charge signal is recorded, which provides information on the drift time. The Time-Over-Threshold (TOT) mode records the duration of a pulse above the adjustable threshold. This value is related to the total charge delivered to the input. The dynamic range is limited by the maximum number of counts per shift register to 11810. A situation in which every other pixel is set to TIME or TOT mode resulting in a checkerboard like pattern is called Mixed-Mode (MM).

The signals generated in the amplification process of the primary charge are recorded in great detail. Primary clusters are smeared out and overlap due to the extended electron cloud after the gas amplification. The detector is mainly operated with $ArCO_2$ (70/30) and $HeCO_2$ (70/30) gas mixtures. The separation of merged clusters from primary ionization is performed with an algorithm adopted from the "island"-algorithm of the ZEUS experiment. For a given gain this number depends slightly on the used gas. The track position is determined in height above the first GEM by the external telescope. The resolution $\sigma$ is analysed as function of the drift distance $y$[1] in

[1] A right handed coordinate system is used with z along the beam and y parallel to the drift field. The chip is placed in the $x-z-$plane.




(a) $Fe^{55}$ (b) $Ru^{106}$

Figure 1: Image (a) shows clusters from $Fe^{55}$ conversion. In image (b) tracks from a $Ru^{106}$ source are recorded. The detector is operated with $ArCO_2$ (70/30).

steps of 0.5 mm. A fit to these values using the following parameterization $\sigma = \sqrt{\sigma_0^2 + D_t^2/n_{eff} \cdot y}$ results in a resolution at zero drift length $\sigma_0 \lesssim 20\mu m$, which is smaller than the pixel size. $D_t$ is the constant of transverse diffusion and $n_{eff}$ is the effective number of primary electrons contributing to a cluster. The evaluation of the MM mode reveals that the measured ($\triangleq$TIME) time depends on the signal amplitude ($\triangleq$TOT). The correlation of TOT and TIME can be used to correct for this effect due to the finite threshold. With this correction the resolution improves by more than a factor of two from about 20 ns to $\lesssim$ 10 ns.

The influence of the GEM geometry on the spatial resolution will additionally be discussed in this contribution. It is found, that the distribution of cluster centers shows a periodic structure of 120 $\mu$m under specific conditions. First a projection has to be performed onto a coordinate transverse to the track. Second the track should have minimal distance ($\lesssim$ 1 mm) in order to avoid dispersion of the primary electrons by diffusion. The structure seen is due to the orientation of the first GEM. A GEM developed for X-ray polarization measurements [3] with a smaller hole pitch of 50 $\mu$m is tested, too.

So far for the detection of minimum ionizing particles (MIPs), like the 5 GeV electrons, a gas gain in the order of $\approx 10^5$ is sufficient with a TimePix. In conventional analog readout of TPCs with MPGDs the used gas amplification is usually two orders of magnitude less. Threshold effects might become important with high pixelation, since the charge per pixel is decreasing. For the TimePix the same charge is spread on $\approx$ 65000 pixels compared to about 100 channels in an analog readout.

For this reason studies are ongoing to determine, if there is an optimal granularity for a new generation of pixel ASICs dedicated to the readout of MPGDs. In collaboration with the FMF in Freiburg a post processing technique is developed to enlarge the $55 \times 55\,\mu m^2$ pixel size of the TimePix. First successful tests with a MediPix2 chip having a pixel size of $110 \times 110\,\mu m^2$ show promising results, further tests with a TimePix chip are the next step. Fig. 1(a) shows an image from conversions of $Fe^{55}$ X-rays ($\approx$ 5.9 keV). In Fig. 1(b) tracks from a $Ru^{106}$ $\beta$-source are visible. The post processing confines the charge collection to every fourth pixel. However the inner part of the clusters is filled, which can be seen in both images of Fig. 1. Possible reasons for cross talk are studied and discussed.

We will report upon our latest results an conclude if a TimePix-TPC readout is feasible for the ILC. This work is supported by the Commission of the European Communities under the 6th framework program "Structuring the European Research Area", contract number RII3-026126.

# References

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