

# Resolution Studies of GEM/Timepix Detector with 5 GeV electrons

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This contribution investigates a prototype of a TPC readout with a highly pixelated CMOS ASIC, which is an option for charged particles tracking of the ILC. A triple GEM stack was joined with a TimePix and MediPix2 chip (pixel size of  $55 \times 55 \mu\text{m}^2$ ) and its readout properties were investigated with 5 GeV electrons. The spatial resolution of the cluster center reconstruction was determined as a function of drift distance using different cluster algorithms and compared with Monte Carlo predictions.

## 1 General consideration

The recent development of Micro-Pattern-Gas-Detectors (MPGD) allows an extended field of application for detectors with gas multiplication. For Time-Projection-Chambers (TPC) the readout with Gas-Electron-Multipliers (GEM) [1] has been demonstrated in conjunction with an unconventional readout option with high pixelation using the MediPix2 chip [2]. The TimePix [3] and MediPix2 is investigated the first time with 5 GeV electrons from DESY II. They have the virtue of negligible multiple scattering. An external tracking with Si-telescope provides information on the track position which is used for resolution determination and for the drift velocity measurements using a TimePix chip.

## 2 Basic setup for the GEMs and the MediPix2/TimePix chip

A cross sectional view of the triple GEM plus Medipix2 and Timepix detector with an electron beam crossing the drift region is shown in Fig.1 (left part). The drift volume of 6 mm thickness and  $10 \times 10 \text{ cm}^2$  in size serves for charged track detection. The drift field is about 1.1 kV/cm. Three CERN-produced GEMs of the same area as the drift volume with  $70 \mu\text{m}$  holes of  $140 \mu\text{m}$  pitch are arranged in a stack above the readout plane with 2 mm (2-2-1) or 1 mm distances (1-1-1) for the transfer gaps, the latter provides a collapsed setup in order to study possible effects on the spatial resolution. With the triple GEM stack gas amplification of  $\approx 10^5$  can be achieved with Ar/CO<sub>2</sub> and He/CO<sub>2</sub>-mixtures for the high resolution detection of minimum ionizing particles. The MediPix2 and TimePix chip is positioned at a distance of 1 mm from the last GEM exposed to a field of  $E_I = 4.0 \text{ kV/cm}$ . The advantage of a GEM setup is the robust operation, since the fields of the gas multiplication region ( $\approx 70 \text{ kV/cm}$ ) are well shielded inside GEM holes, see [2].

## 3 The test beam setup

The MediPix2 and Timepix chip has a surface of  $14 \times 14 \text{ mm}^2$  and a pixel size of  $55 \times 55 \mu\text{m}^2$ . It is positioned close to the border of the GEM stack, see Fig. 1 (right part). The remaining

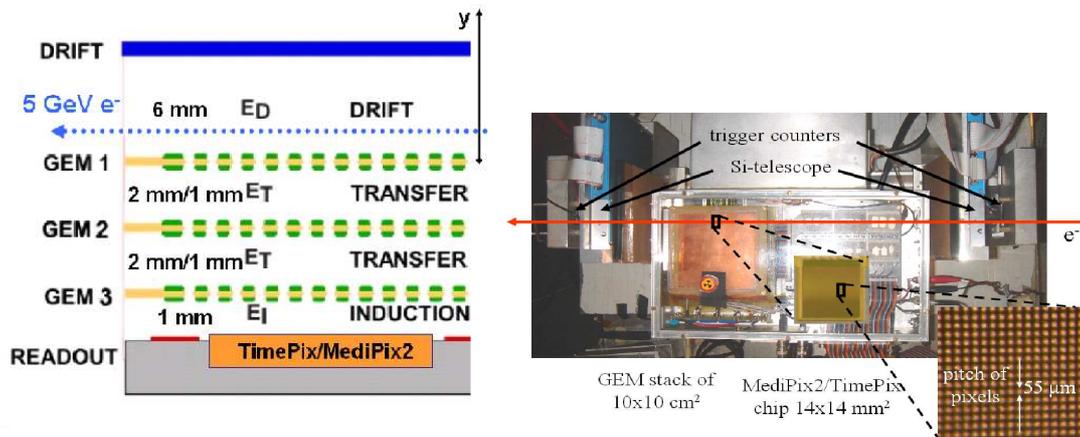


Figure 1: Setup of drift volume: stack and MediPix/TimePix (left) and test beam setup where inserts show size of MediPix2/TimePix and the size of a pixel (right)

surface of the GEMs is covered with 24 anode pads of  $2 \times 2 \text{ cm}^2$  size for monitoring purposes. The gas tight box contains the GEMs, the resistor chain, the TimePix and MediPix2 chip and the readout electronics of the pads.

The readout of the MediPix2 and TimePix is done with MUROS2 using the fast shutter option. The thresholds for the pixels used were  $990 e^-$  and  $830 e^-$  for the MediPix2 and the TimePix, respectively. The electron beam is defined by trigger scintillating counters of  $1 \times 1.5 \text{ cm}^2$  in size and a Si-telescope with 3 planes of strips (two planes allow measurement of the x-coordinate in front and behind the GEM plus Medipix2 and Timepix, and one plane is used for the y-coordinate measurement in front of the detector). The effective readout pitch of Si-telescope is  $50 \mu\text{m}$ .

#### 4 TimePix: The TIME, TOT and MIXED modes

The TimePix has a clock, which is distributed throughout the entire chip. A register on each pixel counts the number of clock cycles in a way depending on the chosen mode of operation. For each pixel this mode can be set individually. In TIME-mode the cycles are counted from the point when the signal crosses the threshold till a common stop by the gate signal (= "Fast shutter"). The other mode "Time-Over-Threshold" records the clock cycles as long as the pulse is above the threshold. The maximum number of counts in this measurement is limited by the chosen gate width of  $12.6 \mu\text{s}$ , which is about 600 counts at a given clock frequency of 48 MHz.

In a special configuration "Mixed Mode" every other pixel switches the TIME and TOT mode in checker board fashion. This results in 1/2 of all pixels are of TIME-type and another 1/2 of the TOT-type. This allows a proximity information of both TIME and TOT.

## 5 Cluster reconstruction and point resolution

Typically, 8 - 9 non-separated clusters per track were observed, see Fig. 2 (left part). Images with double tracks were not considered in the current analysis. The following three clustering methods were used, where last two can separate the overlapping clusters using the charge deposition information (TOT or MIXED modes) resulting in average 10 - 11 clusters per event:

- “Contiguous areas” method leaves overlapping clusters not separated. That method is applicable for any TimePix mode. The result is a lower number of clusters depending on the effective threshold settings and therefore not covered here
- “Saddle Point” method separates the contiguous clusters making a line for secondary maximum in a projection transverse to track. The line divides the merged clusters at the saddle point
- “Island” method joins the adjacent pixels with a nonzero TOT values into clusters in the way that a pixel is joined into the cluster of its neighbor with a highest TOT value. The procedure is repeated for each pixel to produce a unique assignment of pixels to clusters. It results in a separation in two spacial coordinates available compared with the above case

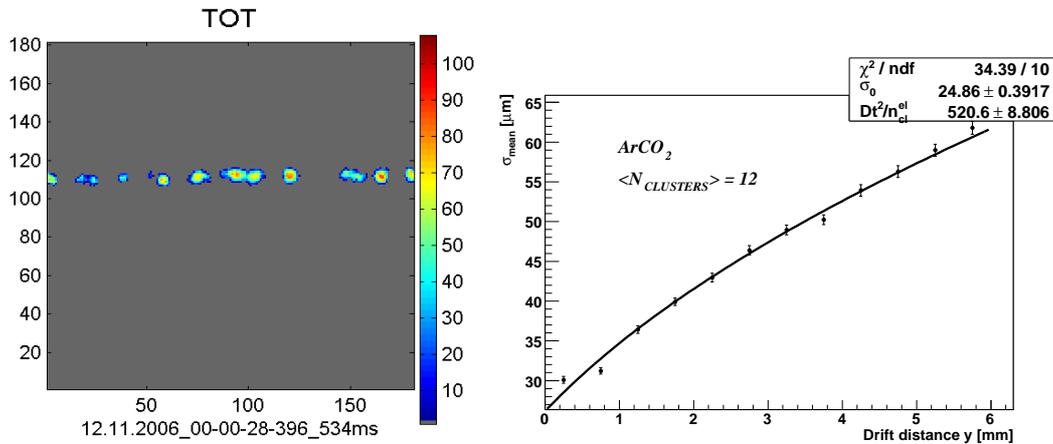


Figure 2: Image of 5 GeV electron track (left part) and  $\sigma_0$  and  $D_t^2/n_{cl}^{el}$  for Ar/CO<sub>2</sub> (right part)

The evaluation follows basically [2]: A cluster is rejected if it contains less than 9 hits. The noise is removed beyond the cluster region. Two different methods of the straight line fits to the centers of the clusters result in an unbiased estimation of the standard deviation. Residuals of the fit to all cluster centroids (N) and a fit to (N-1) centroids resulting in a residual of the exempt cluster which is permuted over all clusters. These residuals enter into two Gaussian fits which produce  $\sigma_{\text{unbiased}} = \sqrt{\sigma_N \times \sigma_{N-1}}$ .

The left part of Fig. 2 shows a measured dependance of the resolutions versus the drift space for Ar/CO<sub>2</sub>. In the drift region to separate the lateral diffusion within the drift space from the intrinsic GEM plus TimePix and MediPix2 resolution the y-coordinate information of the external telescope is used. The following parametrisation is applied for the fit:  $\sigma^2 = \sigma_0^2 + \frac{D_t^2 \times y}{n_{cl}^{el}}$ . The  $\sigma_0$  equal to  $24.9 \pm 0.4$  results from the fit for Ar/CO<sub>2</sub>.

## 6 Comparison with Monte Carlo simulations

The results of spatial resolution  $\sigma_0$  and  $D_t^2/n_{cl}^{el}$  corresponding to different clustering methods for Ar/CO<sub>2</sub> and He/CO<sub>2</sub> are summarised in Tab. 2. The comparison with HEED simulations [4] is also given in the table.

	DATA			Simulations	
	Gas	$\sigma_0$	$D_t^2/n_{cl}^{el}$	$\sigma_0$	$D_t^2/n_{cl}^{el}$
"Island"	Ar/CO <sub>2</sub>	$24.9 \pm 0.4$	$521 \pm 9$	–	–
	He/CO <sub>2</sub>	$29.4 \pm 0.5$	$660 \pm 14$	–	–
"Saddle Point"	Ar/CO <sub>2</sub>	$18.4 \pm 2.7$	$467 \pm 36$	$15.2 \pm 3.8$	$726 \pm 41$
	He/CO <sub>2</sub>	$27.1 \pm 4.9$	$547 \pm 78$	$19.4 \pm 4.0$	$989 \pm 54$

Table 1: The values of  $\sigma_0$  and  $D_t^2/n_{cl}^{el}$  for the data and Monte Carlo simulations. The comparison with Monte Carlo simulation is present at the moment only for the "Saddle Point" clustering method.

The agreement between two clustering methods is found to be good for both  $\sigma_0$  and  $D_t^2/n_{cl}^{el}$  values. It is found that simulations considerably overestimate the slope  $D_t^2/n_{cl}^{el}$  comparing to the measurements for both gases.

The slope depends on the size of merged clusters because a higher number of electrons per detected cluster than for an ideally resolved cluster is present. This leads to a reduction of the effective transverse diffusion through the active volume and reduces the slope parameter. Based on this observation it is possible that the discrepancy of the Monte Carlo with respect to the slope is present, since the average number of detected clusters lower by a factor of 2 than expected from simulations [4].

## 7 Acknowledgments

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## References

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