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Test beam studies of the GasPixel transition radiation detector prototype

F. Hartjes [a], N. Hessey [a], M. Fransen [a], S. Konovalov [b], W. Koppert [a], S. Morozov [c], A. Romaniouk [c,d,]*, V. Tikhomirov [b], H. Van der Graaf [a]

[a] Physics Department, NIKHEF, Amsterdam, Netherlands
[b] P.N. Lebedev Physical Institute, Russian Academy of Science, Moscow, Russia
[c] National Research Nuclear University "MEPHI", Moscow, Russia
[d] European Laboratory for Particle Physics (CERN), Geneva, Switzerland

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ABSTRACT

A combination of a pixel chip and a gas chamber opens new opportunities for particle detectors. These "GasPix" detectors have vector tracking features offering at the same time a L1 track trigger and a particle identification using transition radiation and dE/dX measurements. Test-beam and MC studies of tracking and particle identification properties have been performed with a GasPix prototype. The properties of the detector very much depend on the gas mixture. For one layer of the GasPix detector one can obtain a spatial accuracy down to 11 μm and a vector angular accuracy of about 10 mrad for a beam incident angle of 10°. For particle identification studies the detector was filled with a Xe/CO_2 (70/30) mixture. A block of transition radiation radiator of 19 cm was installed in front of the detector. The pion rejection power using both cluster counting and full dE/dX methods was studied. It was shown that for 5 GeV particles a single layer of the detector gives a pion suppression by about a factor of 7 at an electron efficiency of 90%. Two layers of this detector provide a pion rejection factor of 50 at 90% electron efficiency. A comparison of the data and MC results is presented.

1. Introduction

Operating conditions in future accelerator experiments such as Super LHC (sLHC) create many challenges for detector technologies. Probably the most difficult one is the high track density in the inner tracking volume requiring detectors with high granularity and good pattern recognition properties.

One of the new technologies, which promises large benefits if it is implemented is based on recent developments of the GasPix detectors. Preliminary studies show that GasPix detectors may combine the best properties of the silicon and gaseous detectors. This technology is intensively developed now [1–3].

The GasPix tracker is supposed to be placed at the outer radii of the Inner Tracking system. It can provide a space point (like all other track detectors) and, in addition, a track segment, which will help for the pattern recognition and can be a source of a L1 track trigger. The latter is a natural sequence of the data-driven processing technique, which is required to be realized at the front-end part of the electronics to be able to compress data from these detectors. Filled with Xe-based mixture, this detector would also serve as a transition radiation detector to enhance electron identification abilities of the experiment. Fig. 1 explains the operation principle of this detector. The design of the GasPix chamber is based on a specially prepared pixel electronics chip placed in the gas volume. The gas volume has a drift gap of 10–16 mm (depending on the exact requirements) and the electron multiplication volume approximately of 50 μm, separated from the drift volume by a mesh.

Electrons produced by ionizing particles drift towards the pixel chip and after multiplications are detected by individual pixels. Depending on the exact realization of the chip functionality, it is possible to measure time or amplitude or both simultaneously if required. The expected electron collection time for the GasPix tracker is supposed to be below 200 ns. A real detector is supposed to be designed in such a way that the particles always cross the chamber at a certain angle. An example of a track image for low diffusion gas (DME/CO_2 50/50) is shown by Fig. 2.

Knowing the chamber geometry, the track image allows to obtain the most important track parameters such as a space point (point at which the particle crosses the pixel plane) and an angle ϕ between the projected track and the pixel plane axis. With less accuracy it can provide a value of the angle between the particle track and the pixel plane.

The basic features of this detector would be:

- reconstruction of the track segment with precise space point and track angle (vector);
- suppression of low p_T tracks (low p_T track blind detector);
- possibility to realize a L1 trigger for high Pt tracks;

* Corresponding author at: European Laboratory for Particle Physics (CERN), Geneva, Switzerland. Tel.: +41 22 767 11 76; fax: +41 22 767 83 50.
E-mail address: Anatoli.Romaniouk@cern.ch (A. Romaniouk).

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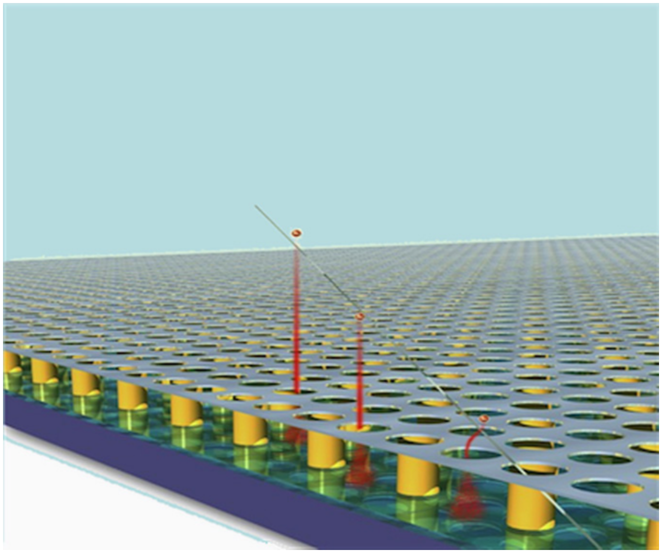

Fig. 1. Schematic view of the GasPix detector. The pixel chip is separated from a drift volume by a mesh. Electron amplification happens in the gap between the mash and the pixel chip.

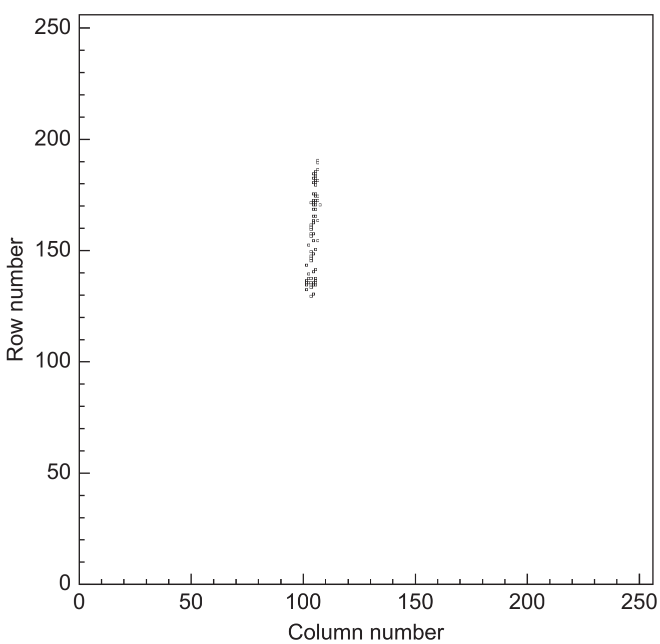

Fig. 2. Image of the particle track on the pixel array (256×256 pixels of $55\times55\ \mu m^2$). Gas mixture DME/CO_2 (50/50).

- powerful pattern recognition ability;
- enhanced particle ID if used as a transition radiation detector.

This paper presents a proof of principle, which demonstrates the potential of a new technology. Section 2 is dedicated to a description of the test beam set-up. Section 3 presents some results on the tracking performance. Particle identification properties of the GasPix chamber prototype are presented in Section 4. Conclusions are given in Section 5.

2. Test beam setup

The test beam GasPix detector prototype was made from a TimePix chip [4] which has pixel size of $55\times55\ \mu m^2$. The mesh

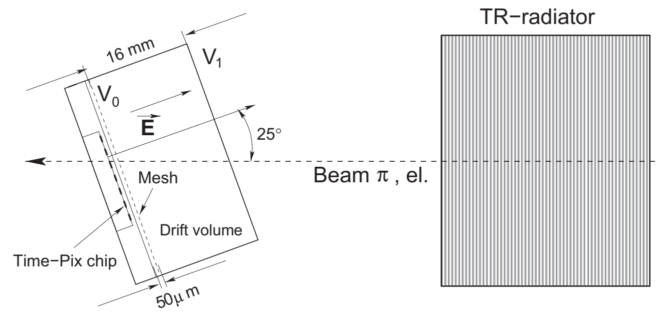

Fig. 3. Schematic view of the test beam set-up.

was made using InGrid technology (see in details [1–3]). Drift distance was 16 mm and the amplification gap was 50 μm. The chip was protected against discharges by a 30 μm Si-protection layer. The chip has a 256×256 pixel matrix providing $\sim14\times14\ mm^2$ of sensitive area. The arrival time of the electrons was measured in each pixel with a binning of 10 ns. Time information was not used for the track reconstruction mainly because of a large rise time of the front end amplifiers: at least 150 ns, giving significant time-walk. For the particle identification the amplitude of the signal is measured by setting the TimePix chip in time-over-threshold (ToT) mode. The test beam set-up is sketched in Fig. 3.

The chamber was tilted with respect to the beam line such that particles crossed it at 80–70° to the sensitive plane. The detector was filled with a Xe/CO_2 (70/30) gas mixture for transition radiation studies and with DME/CO_2 (50/50) mixture for tracking studies (low diffusion gas). Because of some production defects a maximum gas gain of about 1.8×10^3 was achieved for Xe-filled chamber. An estimate shows that the lowest effective threshold corresponding to 1.3 primary electrons could be obtained for this gas gain. The chamber filled with the low diffusion gas was able to reach a higher gas gain and the estimated operating threshold was about 0.3 electrons.

The prototype of the GasPix detector was exposed to the T9 test beam at CERN with a mixed pion/electron (93/7) beam of 5 GeV. Coincidence of small size counters provided a $3\times5\ mm^2$ beam spot and was used to supply a preliminary trigger for the timing measurements. Finally particles were marked as electrons or pions using a trigger logic based on the signals from the pre-shower counter (5 mm Lead+scintillator), the LeadGlass Calorimeter and a Cherenkov counter. With this combination of detectors, clean electron or pion data samples were obtained (purity level of about 10^{-4}).

A detailed comparison of the experimental data with MC simulations has been done. In order to trace the particles though the beam equipment and test chamber, the GEANT3 package was used. Simulations of the ionization losses in the active gas were done with the help of the PAI model [5]. The transition radiation was simulated using the ATLAS TRT simulation code [6]. Because of uncertainties in the threshold and diffusion coefficient these parameters in the MC simulation were tuned to fit the number of pixels that fired on a particle track and the width of the track image. For dE/dX and TR measurements a calibration coefficient was used in the MC simulations to match the energy scale of the experimental data.

3. Tracking properties

Since no reference telescope was available, in order to measure the track reconstruction accuracy, the method of the overlay chambers was used. It uses artificial separation of the chamber in