EUDET-Memo-2007-33

Recent results with discharge protected Timepix detectors

Y. Bilevych, M. Bosma, [1]***Maximilien Chefdeville****,*
M. Fransen, H. van der Graaf, F. Hartjes, J. Timmermans, J. Visschers

December 03, 2007

Abstract

We report on ongoing NIKHEF R&D activities towards a pixel readout TPC for the future linear collider. These activities concern the fabrication and test of micro-TPCs readout by Timepix chips.

The protection of the chips against gas discharges using an amorphous silicon layer was proved to work in He and Ar based gas mixtures, which is a crucial result.
Some of those detectors were equipped with an integrated Micromegas grid (InGrid), resulting in uniform detection efficiency and gain homogeneity across the detector.

Several grids of various geometries were integrated on bare silicon wafers to study the ion backflow properties of Micromegas detectors. Measurements performed in Ar:CH_4 90:10 gas mixture indicate that a backflow fraction of the order of few per mil at standard values of drift fields (100 to 200 V/cm) is feasible. The behaviour of the backflow fraction with electric fields and grid geometry agrees with previous studies performed with standard Micromegas grids.

[1] NIKHEF, Amsterdam, The Netherlands

1 The Timepix chambers

The fabrication of the Timepix chip was motivated by the need to measure the drift times of primary electrons from ionizing particles: the combination of the Medipix2 chip with a Micromegas grid provided only projections of tracks onto the chip plane and was thus limited to 2D tracking. A TDC was implemented inside each pixel of the Timepix chip, replacing the traditional hit counters of the Medipix.

From previous experience, it is well known that gas detectors combining "naked" pixel chips with Micromegas grids are very sensitive to gas discharges and large efforts were devoted to solve this issue. A few microns thin, high resistivity (10^{11} Ω.cm) layer of aSi:H (SiProt) deposited on bare Si wafers was previously found to attenuate discharge signals [1]. Accordingly 2 Timepix chips were covered with a 3 µm thick layer of SiProt, equipped with standard Micromegas grids and placed inside separate gas chambers.

The first detector functioned continuously in He:iC_4H_{10} 80:20 gas mixture during 1 month, recording several tracks of cosmic particles. After this time, the chamber was flushed with a mixture of Ar:iC_4H_{10} 80:20 and the detector was rapidly damaged. The second detector was operated in He:iC_4H_{10} 80:20 gas mixture during 3 months without suffering discharges. These first tests suggested that an aSi:H thickness of 3 µm provides sufficient protection when working in He based mixtures but fails in Ar based mixtures where the discharges are more severe.

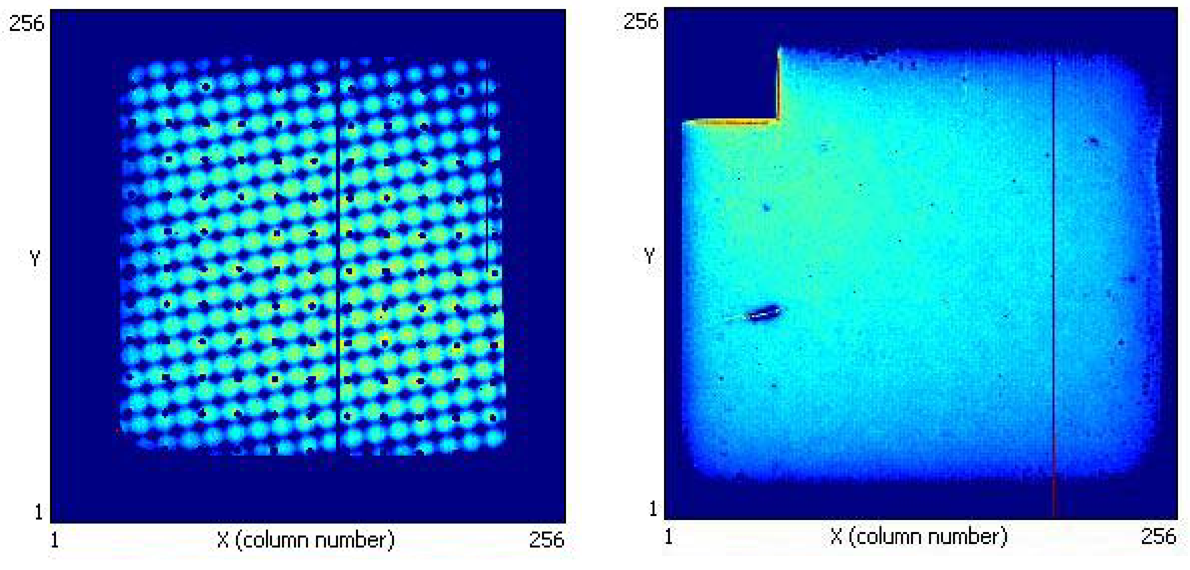

Figure 1: Integral images of ^{55}Fe quantum conversions in He:iC_4H_{10} 80:20 with a standard Micromegas equipped Timepix chip (left) and InGrid equipped Timepix chip (right). The top left corner (right picture) where no hits are recorded is used for contacting the grid. Note the complete suppression of the Moiré pattern

Three Timepix chips were later covered with 20 µm thick SiProt and 2 of those were further equipped with InGrids. Thanks to the very good alignment between grid holes and pixel input pads, InGrid equipped Timepix chips exhibit a homogeneous response (Fig. 1). After few weeks of operation in He:iC_4H_{10} 80:20 the detectors were successfully used in Ar:iC_4H_{10} 80:20 gas mixture. An example of a cosmic track recorded in this mixture is shown in Fig. 2.

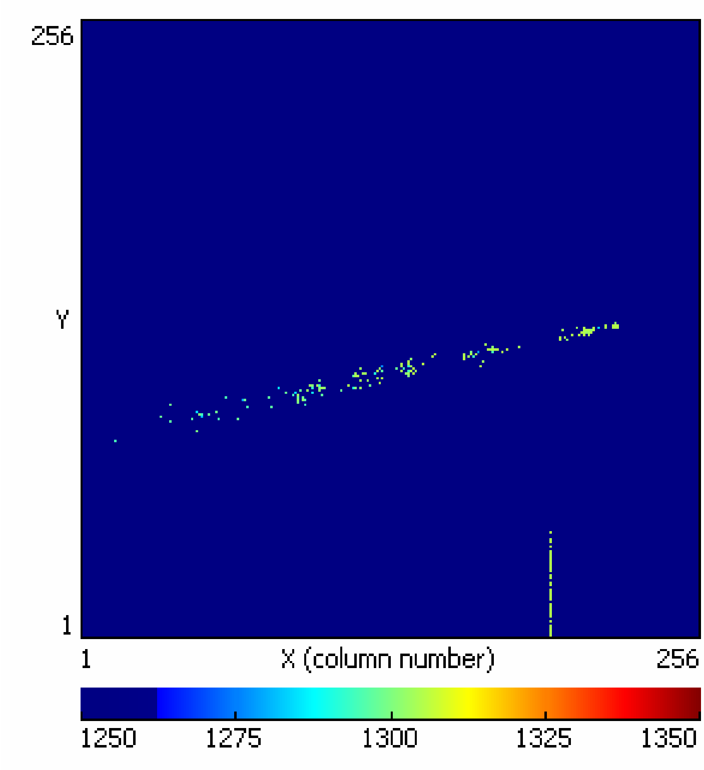

Figure 2: Cosmic ray track recorded in Ar:iC_4H_{10} 80:20 with a chamber constructed from a Timepix chip covered with a 20 µm thick protection layer and an InGrid. The readout of the chip is controlled by the Pixelman software package [2].

The effective protection against sparks in Argon-based mixtures could be assessed by generating alpha particles inside the gas. In approximately one per cent of the case, alpha tracks were triggering discharges that could be recorded. An example is shown in Fig. 3: there where the alpha enters the grid, the discharge occurs. Some 150 pixels in the area receive a large coincident charge signal and are activated. As a result, the local values of power voltage and threshold references are disturbed. Since these are common within pixel columns, many pixels above and below the discharge area are affected. This does not harm the functionality of the chip.

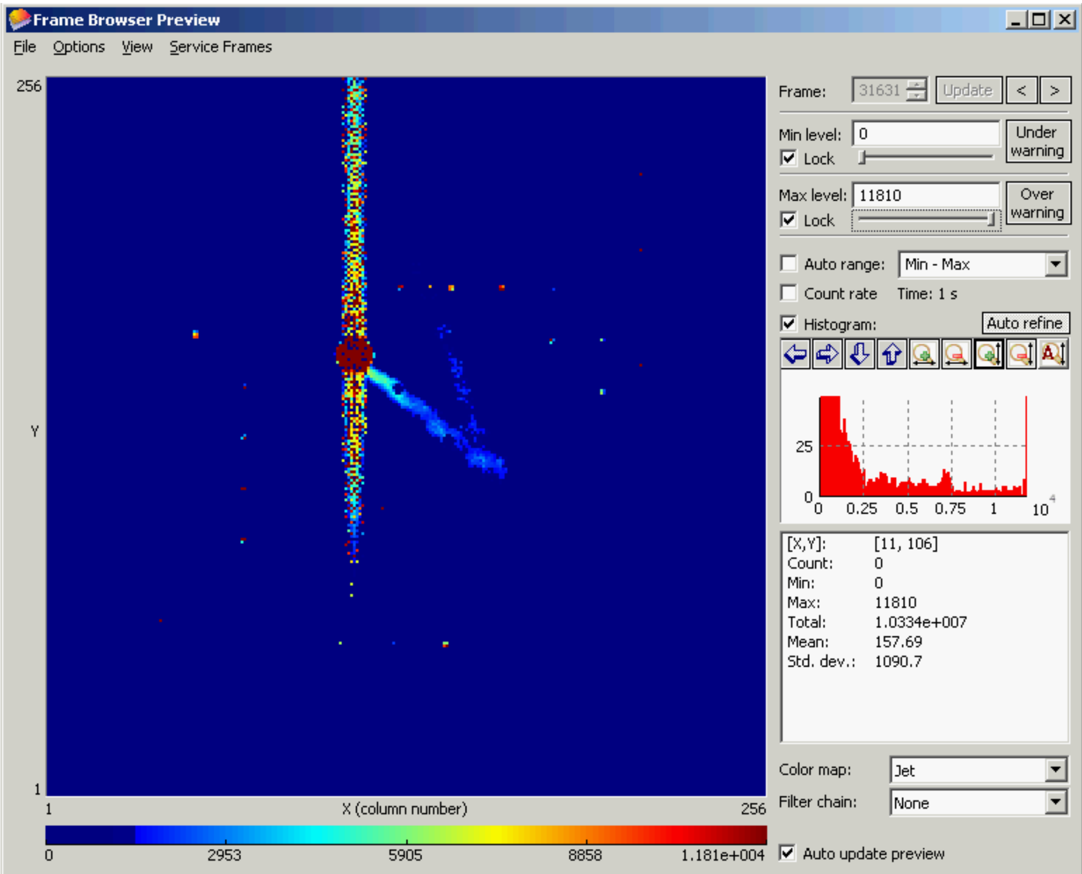

Figure 3: Typical image of an alpha particle triggered discharge in Ar:iC$_4$H$_{10}$ 80:20. Two alphas of approximately 6 MeV are emitted through the decay of a radon nucleus within a time of 0.15 sec; sometimes the characteristic "V-shaped" pattern of the alpha tracks is recorded.

2 Measurements of the ion backflow fraction of Micromegas detectors with InGrids

The ion backflow is the drift of the ions created in the avalanche, from the amplification region to the drift region. Measurements and modelling of the backflow fraction of Micromegas detectors were performed by the Orsay-Saclay group [3]. They predicted that the backflow fraction is inversely proportional to the ratio of the amplification field to the drift field and that it has a dependence on the avalanche transverse diffusion (σ_t) and the grid hole pitch (p). While the field ratio dependence was clearly established, the effects of the avalanche spread and the grid geometry could not be systematically investigated.

We completed systematic measurements of the backflow fraction of integrated Micromegas detectors (InGrids). These detectors are fabricated using techniques of photo lithography and chemical etching that offer design flexibility and accurate control of the geometric dimensions. They are therefore well suited to test the model proposed in [3].

The measurements were performed by means of a 12 keV X-ray gun in Ar:CH_4 90:10 gas mixture with prototypes of various grid hole pitches (20, 32, 45 and 58 µm) and amplification gap thicknesses (45, 58 and 69 µm). The various gap thicknesses permit to vary the avalanche transversal spread as the latter goes with the square root of the gap.

The backflow fraction as a function of the field ratio of several 58 µm gap InGrids of 4 different pitches is shown in Fig. 4. The backflow fraction is inversely proportional to the field ratio for hole pitches from 20 to 45 µm, while a steeper slope is observed with 58 µm pitch. In typical working conditions (field ratio of few 10^2) a backflow fraction of the order of few per mil can be achieved.

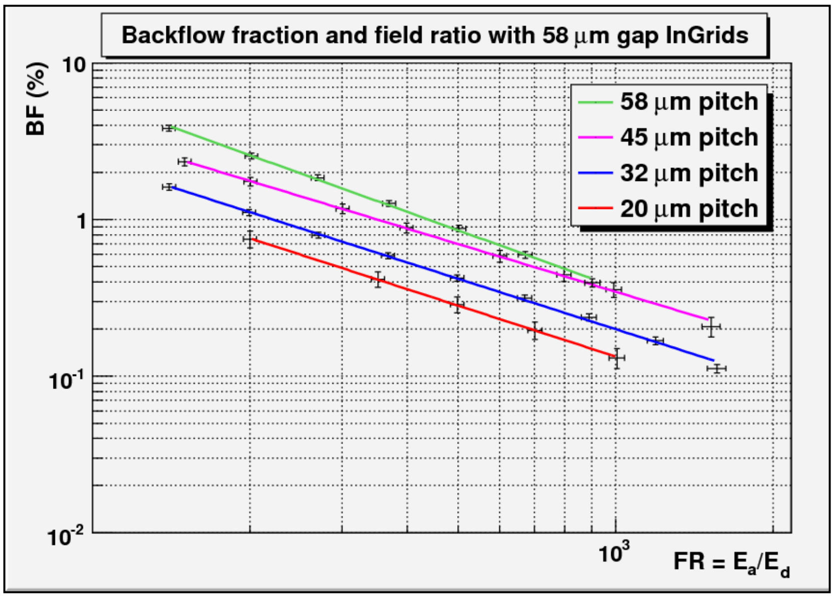

Figure 4: Backflow fraction as a function of the field ratio as measured with 58 µm gap InGrids of various hole pitches in Ar:CH_4 90:10.

The results can be summarized in a single plot that shows the backflow fraction at a given field ratio (as measured with various values of transverse diffusion σ_t and hole pitch p) as a function of the ratio σ_t/p (Fig. 5). The plot clearly indicates that below $\sigma_t/p<½$, the backflow fraction decreases with the avalanche spread and increases with the hole pitch. Above $\sigma_t/p = ½$, a plateau is suggested although more measurements are required for a definitive assessment.

Backflow fractions calculated by simulations are also shown in Fig. 5. The simulation is inspired from [3] where a 2D Gaussian distribution of the ions on the anode was assumed. Because our measurements were performed at low gas gain (few 10^2), this assumption does not hold and the longitudinal development of the avalanche was taken into account (3D model). The simulation reproduces the trend well though the absolute value of the backflow fraction is slightly underestimated.

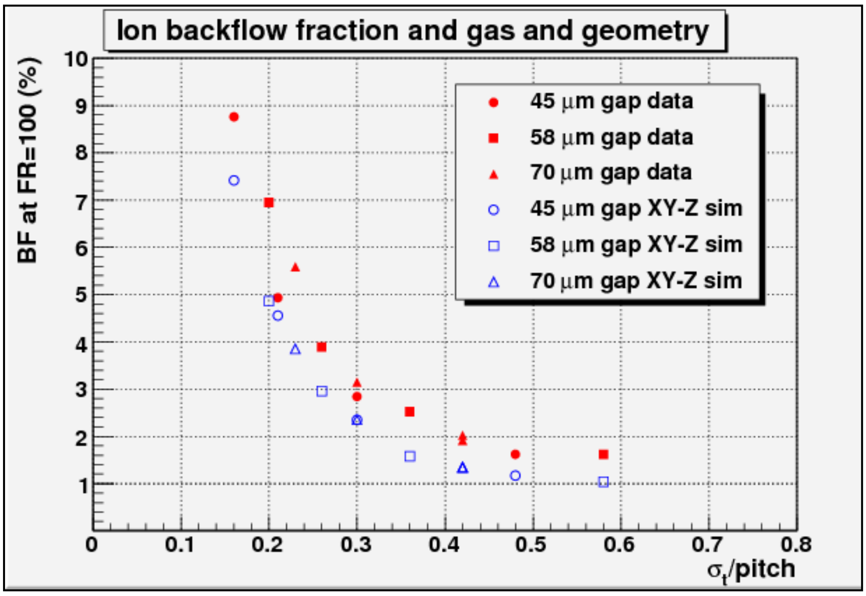

Figure 5: Backflow fraction at a field ratio of 100 as a function of the ratio of the avalanche transverse spread to the hole pitch as measured with InGrids of various geometries (full markers) in Ar:CH_4 90:10. Values from the 3D simulation are shown (open markers).

Acknowledgement

This work is supported by the Commission of the European Communities under the 6th Framework Programme "Structuring the European Research Area", contract number RII3-026126.

References

[1] EUDET-Memo-2006-09 NIKHEF activities within EUDET/SiTPC.
[2] T. Holy, J. Jakubek, S. Pospisil, J. Uher, D. Vavrik, Z. Vykydal: "Data acquisition and processing software package for Medipix2". Nucl. Instr. and Meth. in Phys. Res. A 563 (2006) 254-258.
[3] Lepeltier et al., Nucl. Instr. and Meth. A 535 (2004) 226.