Preamplification structures based on Micromegas

Samuel Andriamonje*, Stephan Aune*, Esther Ferrer Ribas*, Arnaud Giganon*, Yannis Giomataris* and
Pierre Salin†
*DAPNIA CEA, Saclay, 91191 Gif sur Yvette, France
†PCC, CdF, 11 Place Marcellin Berthelot, 75231 Paris, France

***Abstract*— The design of MICROMEGAS is offering, for several applications, substantial advantage in energy, spatial and time resolution, granularity on large surface and simplicity of construction. However the maximum achievable gain is limited, at high hadron rates, because of sparks induced by heavy ionizing particles produced by nuclear interactions.**

An issue to decrease drastically the sparking rate is to use the conversion space of the detector as a preamplification stage. In this paper, we will describe the design and laboratory results of new amplifying structures, based on the Micromegas concept that can be either used as a preamplification element or stand-alone detector for some specific applications.

***Index Terms*— Micromegas, double amplification, bulk Micromegas.**

I. INTRODUCTION

MICROMEGAS has proven to have, substantial advantage in energy, spatial and time resolution for several applications [1]. However, in a high intensity hadron environment ($>10^6$ counts/s), the maximum achievable gain is limited because of discharges induced by heavy ionizing particles produced by nuclear interactions. Nevertheless, in recent projects, by an optimisation of the gas mixture [2] or the design of the detector [3], much higher rates can be sustained with a stable functioning of the detector. An alternative issue to decrease drastically the sparking rate is to use the conversion space of the detector as a preamplification stage. Two preamplification techniques were already tested in hadron beams: a simple parallel plate 3 mm gap and an electron amplifier GEM. Compared to the single detector, two orders of magnitude can be gained in the sparking rate [4], [5]. The conclusion of these studies was that preamplification is useful to reach higher gains and prevent occasional discharges occurring in the detector.

In this paper, we will describe the design and laboratory results of two different amplifying structures, based on the Micromegas concept. The first one uses a standard Micromegas detector with an extra amplification gap between two parallel metallic micromeshes and a transfer gap [6], [7]. The second structure consists of a Micromegas detector with an extra amplification gap (no transfer gap). In this set-up, the first amplification gap is based on a novel concept of Micromegas, "bulk Micromegas", that uses a simple process based on the PCB (Printed Circuit Board) technology to manufacture the entire sensitive detector [8]. This new manufacturing method makes the mounting of the detector very simple. In addition, its low material budget and cost together with the good spatial and time resolution, will ease the fabrication of very large detectors.

II. STANDARD MICROMEGAS WITH AN EXTRA AMPLIFICATION GAP

A. Description of the detector

The detector structure resembles a standard Micromegas detector with an extra amplification gap between two parallel metallic micromeshes. Figure 1 shows a schematic view of the detector. The structure is operating as a parallel plate avalanche detector: electrons drift into the first amplification gap as they enter from the top mesh and they are multiplied in an avalanche process, in the same way as in the standard Micromegas detector. A fraction of these electrons are collected by the bottom micromesh and are lost. The rest of the electrons are released to the second amplifier element. The fraction of electrons transferred to the second amplification gap depends on the type of micromesh and on the strength of the applied field. The amplification gap is typically 50-100 μm but wider gaps can also be used.

The principle of the operation is quite similar to the one of the GEM detectors [9]. However there are basic differences between the two structures. In the GEM, the electron multiplication is confined in the hole surrounded by the kapton insulator, therefore charges from one side of a hole always get out from the same hole. In our structure, electrons diffuse during the avalanche process and they can get out through many holes. The multiplication occurs in a uniform electric field as in Micromegas. It is possible to use different steps and transparencies of the two micromeshes as there is no operational obstacle. In principle the alignment of the holes of the top and bottom meshes is not a requirement, which is a considerable practical advantage simplifying the mounting of the structure.

B. Experimental set up

The measurements have been done with a Micromegas detector filled with Ar/C_4H_{10}. Figure 2 shows the experimental set-up. The drift gap is 10 mm wide and the applied voltage is HV1. The voltages applied on the two parallel meshes are HV2 and HV3. Two different gaps, 50 μm and 100 μm, were tested for the gap spacing between the two parallel meshes. To obtain a 50μm gap, two thin copper micromeshes of 500 LPI (lines per inch) were assembled: one with kapton

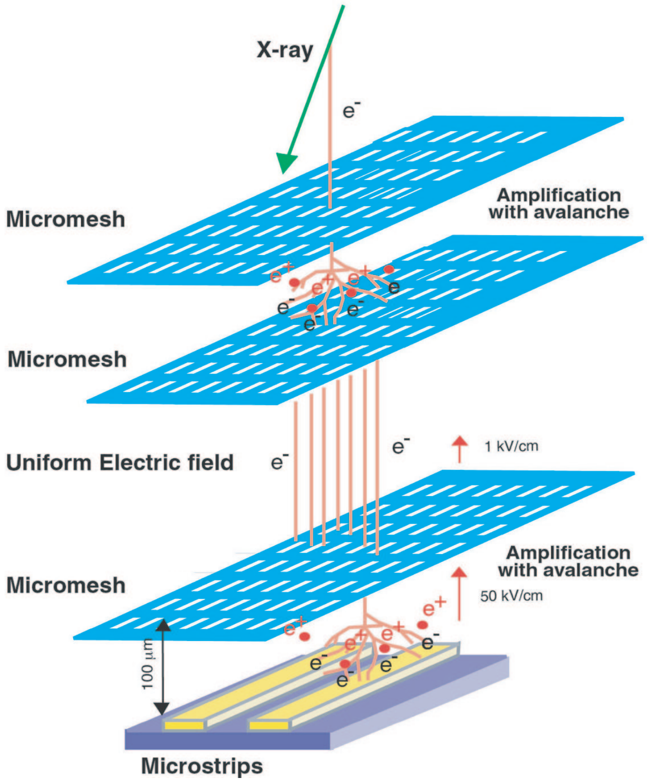

Fig. 1. Schematic view of the preamplified Micromegas detector.

spacers and the second one without spacers. In order to obtain the second configuration, the 100 μm gap, both micromeshes were carrying kapton spacers. They were assembled with the kapton spacers back to back with careful alignment to have the pillars of one micromesh exactly on top of the pillars of the second micromesh defining the 100 μm gap (2×50 μm). The micromeshes are made by kapton etching technology described in reference [10].

The cathode voltage is noted HV4 and the anode is at ground potential. The transfer gap is 3 mm and the second amplification gap is 100 μm wide. The fields in the amplification gaps are typically of the order of 50 kV/cm.

The detector can be used in double amplification or in single amplification mode by switching off the drift voltage. In the latter case detected X-rays are converted in the 3 mm transfer gap.

C. *Results*

Gains were measured with a Fe^{55} source in an Argon Isobutane mixture. Figure 3 shows gains as a function of ΔV,the difference between the top and bottom voltage of the two parallel micromeshes structure for the 50 μm and 100 μm gap. It can be observed that gains greater than 10^5 may be achieved.

In order to further increase the total gain, the field of the second amplification gap can be increased by increasing the cathode voltage (HV4). This effect is illustrated in Figure 4 for the 100 μm gap. This plot shows that the gains of 8×10^5 are then obtained.

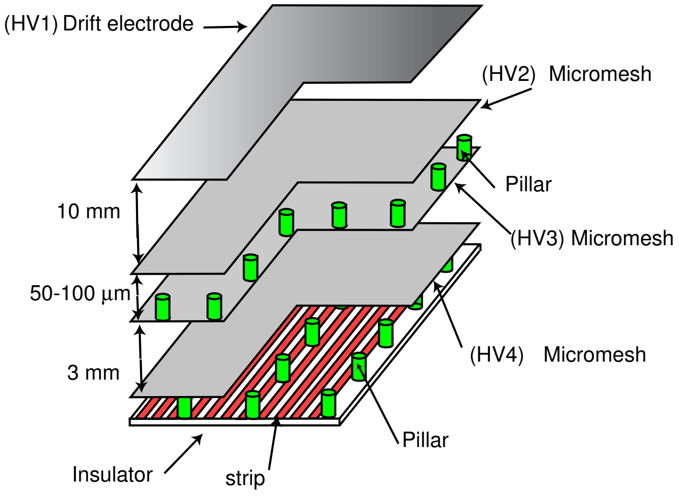

Fig. 2. Detailed view of the preamplified Micromegas detector.

Figure 5 shows pulse height distributions from a Fe^{55} source for a 100 μm gap between the two parallel micromeshes. An energy resolution of around 30 % (FWHM) is obtained at 5.9 keV.

III. BULK MICROMEGAS WITH AN EXTRA MICROMESH

A. *Description of the detector*

In this set-up we use a bulk micromegas with a second micromesh to provide the extra amplification gap. The bulk micromegas consists of a PCB board with an integrated micromesh separated by pillars. This detector is manufactured in one single process. Having the micromesh integrated into the detector means that the problems related to the flatness and parallelism between the anode and the mesh are avoided. Therefore the mounting of the detector presents no difficulty. The gains and the resolution obtained with this type of Micromegas are comparable to standard Micromegas detectors [8]. Figure 6 shows a schematic view of a bulk detector. In order to use the Micromegas bulk detector in double amplification mode, a second micromesh was laid on the pillars of the bulk Micromegas, as can be seen in figure 7.

In this structure electrons drift into the first amplification gap as they enter from the top mesh and they are multiplied in an avalanche process. A fraction of these electrons will be released to the second amplifier element were they will undergo a second avalanche process. The fraction of electrons transferred to the second amplification gap depends on the type of micromesh and on the strength of the applied field.

B. *Results*

A bulk Micromegas of 150 μm gap was tested. A second micromesh was laid on the pillars of the bulk Micromegas defining a gap of 150 μm width. The drift region was 8 mm wide. The gas filling was a mixture of Argon(95%) and

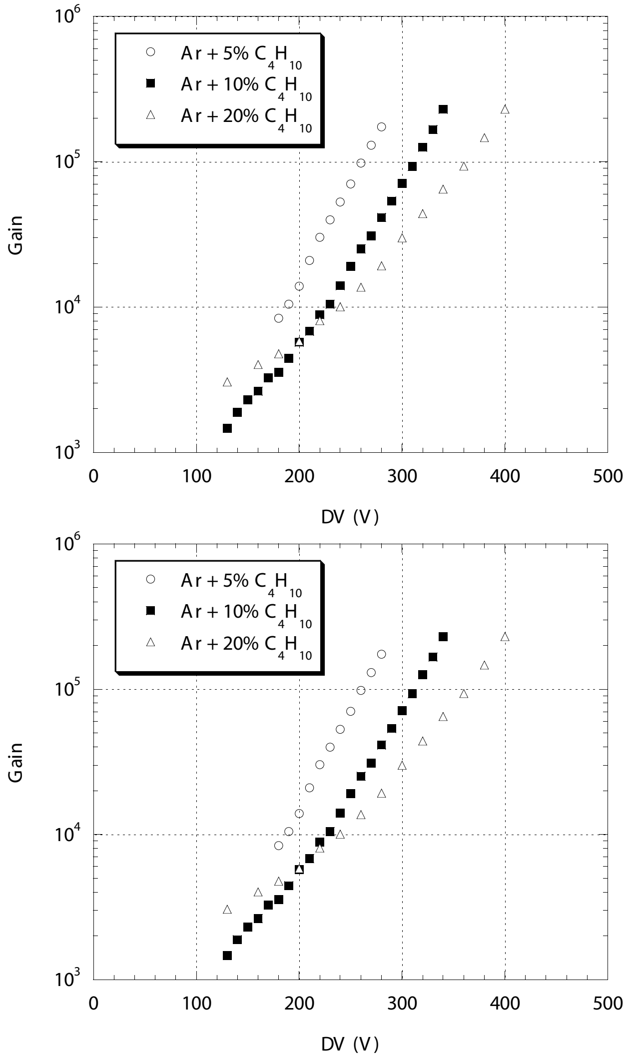

Fig. 3. Gain as a function of voltage difference between the two parallel micromeshes structure for a gap of 50 and 100 μm respectively for different mixtures of Ar/C_4H_{10}.

Isobutane(5%). The primary charges were produced in the drift volume by an X-ray Fe^{55} source, amplified once in the first amplification gap and a second time in the bulk amplification gap.

Figure 8 shows gains as a function of the field in the second amplification gap where the detector was functioning in double amplification. In this same figure gains for the single amplification mode are also plotted for comparison. In double amplification, a factor of 4 is gained with respect to the maximum achievable gain obtained in single amplification mode. An energy resolution of around 38 % (FWHM) is obtained with X-rays at 5.9 keV, as can be seen in Figure 9.

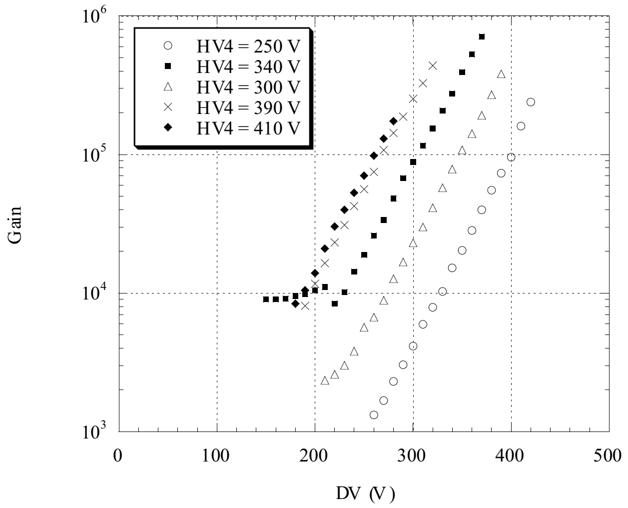

Fig. 4. Gain as a function of voltage of the second amplification gap for a Micromegas detector with a 100 μm gap between the two parallel micromeshes.

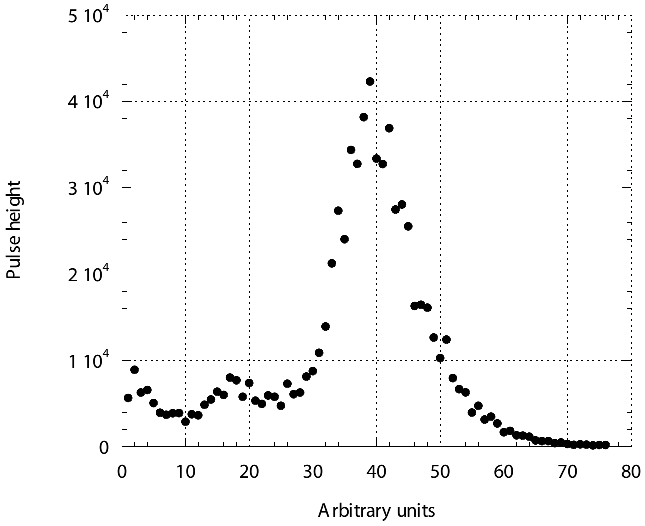

Fig. 5. Pulse height distributions from a Fe^{55} source with a 100 μm gap between the two parallel micromeshes.

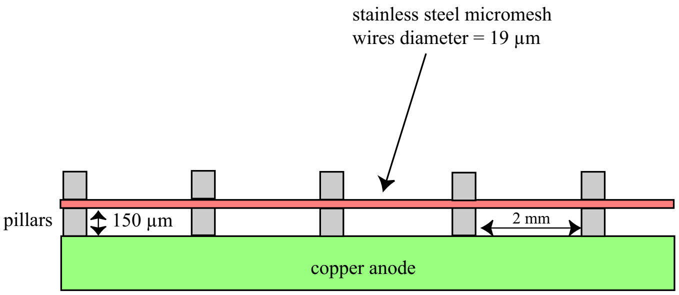

Fig. 6. Schematic diagram of a Bulk Micromegas detector. The mesh and the anode are integrated in a single

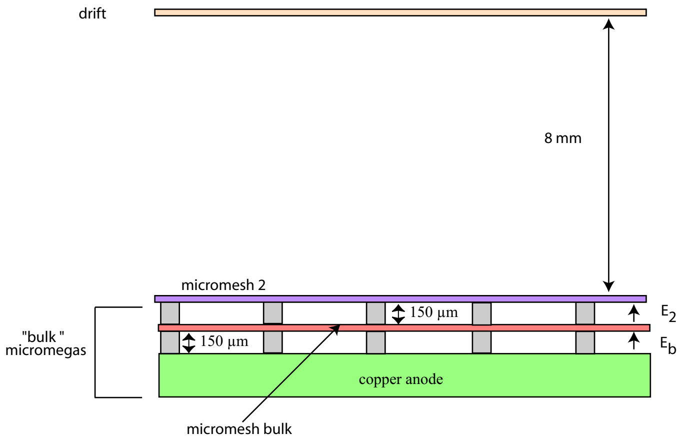

Fig. 7. Schematic view of a Bulk Micromegas detector used for double amplification.

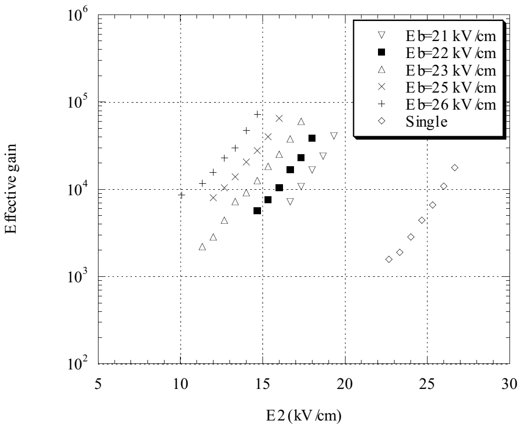

Fig. 8. Gains obtained with a bulk Micromegas for single amplification (empty squares) and with an extra amplification 150 μm gap as a function of applied field.

IV. CONCLUSION

The use of preamplification in Micromegas has been shown to be useful to reach high gains and prevent occasional discharges occurring in the detector. In this paper we have shown that high gains can be obtained using double amplification. Two different techniques have been used to realise the double amplification. In the first method two amplification gaps have been used separated by a transfer gap. With this set-up, gains of $\sim 10^6$ can be reached with an Ar/C_4H_{10} mixture and using 50 and 100 μm gaps. In the second method, two amplification gaps have been set up one after the other. Higher gains than with a single amplification have been reached (factor of 4) with a reasonable energy resolution. In the future we hope to improve the bulk energy resolution by decreasing the micromesh width. The absolute achievable gains are lower than in the first method. However this last method can be advantageous in some applications where energy and time resolution are important. Further studies need to be done using asymetric gaps which will increase the maximum attainable gain. These techniques open a wide range of possibilities for applications in high intensity hadron beams environments.

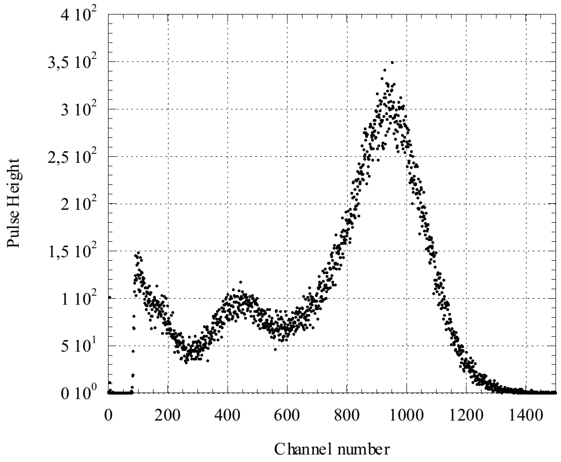

Fig. 9. Energy resolution obtained with a bulk Micromegas of 150 μm gap for double amplification using a Fe^{55} source.

For the last set-up, a novel concept of Micromegas, the ”bulk Micromegas”, has been used. It has been observed that the good characteristics, in terms of energy and time resolution, of the traditional Micromegas are maintained. This new manufacturing method makes the mounting of the detector very simple. The low material budget and cost together with the good spatial and time resolution, will make it very attractive for the fabrication of large surface detectors.

REFERENCES

[1] Y. Giomataris, Ph. Rebourgeard, J.P. Robert and G. Charpak, Nucl. Instr. Meth. A **376**, 29 (1996).

[2] F. Kune et al., Nucl. Phys. A721:1087-1090, 2003.

[3] B. Peyaud et al, KABES a nouvel beam spectrometer for NA48, Proceedings of the 10^{th} Vienna Conference on Instrumentation, VCI-2004.

[4] A. Delbart, J. Derré, Y. Giomataris, F. Jeanneau, I. Papadopoulos, Nucl. Instr. and Meth. A **478**, 205 (2002).

[5] S. Kane et al., A study of Micromegas with preamplification with a single gem, DAPNIA 02-48.

[6] A. Delbart, Presebted at the ”1^{st} Workshop on large TPC for low energy rare event detection”, Paris, December 2002.

[7] Y. Giomataris, Proceedings of ”Mesure de sections efficaces différentielles Neutron-Noyau ”, Saclay, 24th October 2001.

[8] I. Giomataris, R. De Oliveira, S. Andriamonje, S. Aune, G. Charpark, P. Colas, A. Giganon, Ph. Rebourgeard, Micromegas in a bulk, DAPNIA-04-08.

[9] F. Sauli, Nucl. Instr. Meth. A **386**, 531 (1997).

[10] A. Delbart, R. De Oliveira, J. Derré, Y. Giomataris, F. Jeanneau, Y. Papadopoulos, Ph. Rebourgeard, New developments of Micromegas detector, DAPNIA/SED/00-01.