LHCb 99-020
Inner Tracker
June 14, 1999

PSI run report of the Micromegas detector March 28 – April 13 1999

J.P. Perroud, F. Ronga

Institut de physique des hautes énergies, université de Lausanne

Abstract

A Micromegas prototype has been tested at PSI in a high flux pion beam. The main goal was the study of the rate of discharges in this environment, but we also report results on time resolution and pulse height distribution measurements. Discharge probabilities per particles of 4×10^{-5} for a pure π^- beam of 215 MeV/c momentum and 10^{-4} for a mixed π^+ and protons beam of 350 MeV/c momentum have been measured. It turned out to be constant up to high rates of 48 MHz in the chamber. These results on the discharges may have been worsened by the gas mixture used for this run, namely argon and CO_2. Micromegas doesn't seem to be LHC compliant in it's actual form, in spite of its many qualities, which merit more investigation.

Contents

1 Introduction

The candidate chambers for the LHCb inner tracker went to the Paul Scherrer Institute pion beam to test their high rate capabilities and aging. Among them was a Micromegas prototype, which has already been extensively tested in various environments with encouraging results [1]–[4]. More studies in severe environments were needed to establish its behavior at high flux and in presence of highly ionizing particles induced by interactions of 215 MeV/c pions in the chamber itself.

We specially focused on the discharge behavior of Micromegas, this phenomenon being the gain limiting factor of this detector, otherwise very suitable. A special setup and large amount of data allowed us to extract convincing results on the discharge rates at various gains and beam intensities. This rate has been found to be proportional to the number of particles crossing the chamber, up to rates as high as 50 MHz.

Besides these results, we also present measurements of the time resolution and pulse height distributions for minimum ionizing particles, showing that Micromegas offers reasonable performances at high rate and gain.

We finally give our present research status, our future prospects and our judgment on Micromegas' LHC compliance.

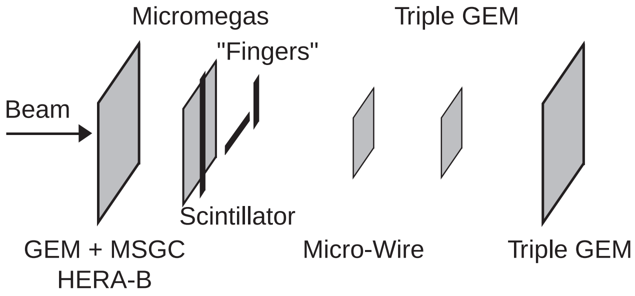

Figure 1: *The whole PSI setup, with the different chambers and scintillators.*

2 Experimental Setup

The whole setup is shown on figure 1. Two $5 \times 5\ mm^2$ 'finger' scintillators, mounted on an x-y scanner were used in coincidence to measure the beam profile and for triggering purpose. Another $2 \times 20\ cm^2$ scintillator, close to our chamber, covered all the strips, which were set horizontally.

2.1 Chamber

A complete description of the detector can be found in [1]. Our tests were performed with a $15 \times 15\ cm^2$ chamber having a 3 mm conversion gap, a 100 μm amplification gap and a strip pitch of 317.5 μm, with 70 μm spacing between each strip. It was filled with a mixture of argon and CO_2 at two different concentrations, namely 93%–7% and 60%–40%.

2.2 Readout

We haven't got enough electronics to instrument all the strips. The following scheme was therefore used:

- Sixteen strips, near the upper edge of the chamber, were connected to a single slow Tennelec charge amplifier and used to monitor the gas amplification with an Iron 55 source.
- Seven strips, in the middle of the chamber, were individually connected to a channel of fast charge amplifiers.
- On each side of these individually connected strips we had 3 groups of 16 strips, connected 4 by 4 to 4 channels of the fast amplifiers. The output of these 4 channels then fed a linear adder, whose

output was used for pulse height analysis. Another output was used as trigger for the relevant group, after amplification and discrimination.

We used for these test the STAR fast, CMOS amplifier designed at Cern [5]. Its sensitivity is about 10 mV/fC, with a noise of 800 electrons rms, for an input capacitance of 20 pF, and a noise slope of 30 electrons rms/pF. The peaking time is about 24 ns.

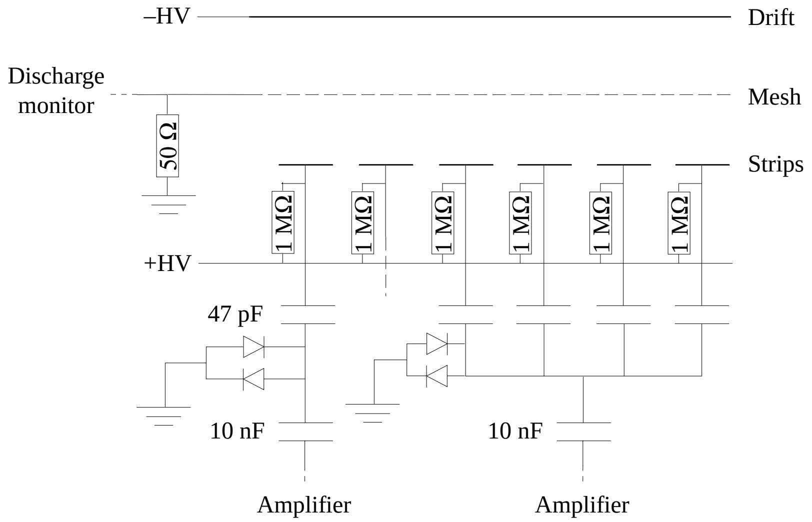

Figure 2: *High voltage and readout connections setup. The individual strip and four strips connections are shown.*

The drift electrode was put at −600 V during the test; this high voltage has little influence on the gain or the discharges, as long as it is higher than a minimum (absolute) value of about 400 V. The mesh is set at the ground to facilitate the measure of the discharges, which can then be measured through a 50 Ω resistor. The strips are thus set at a high voltage through a 1 MΩ resistor. This connection is made individually for the read strips, and by groups of 4 for the unread strips.

Finally, the instrumented strips are AC coupled to the amplifiers through a 47 pF capacitor, which also limits the amount of charge available in a discharge.

Figure 2 shows this electronic setup for individual or grouped connections to the amplifiers.

2.3 Beam

The studies were fulfilled on the PSI proton accelerator, providing an intense beam of either 215 MeV/c negative pions, or 350 MeV/c positive pions together with protons. In this latter case, protons have a kinetic energy of 63 MeV, with a range of 3.65 g/cm^2. There are also 4 times more protons than π^+ in this kind of beam. We will thus consider it as a proton beam.

These momenta correspond to the minimum ionization energy for pions, with a very high cross section, thus allowing an excellent test for the LHC compliance.

Our settings for the two kinds of beams, π^- or protons, respectively led to a 75% or a 98% fraction of the beam in the active area of our detector (in order to satisfy the requirements of the different chambers). An example of the π^- beam profile is shown on figure 3.

3 Results

3.1 Time resolution

The time resolution was measured in a fairly straightforward manner: we triggered the oscilloscope with the coincidence between the chamber scintillator and a group trigger signal, and measured the time between the scintillator signal and the group signal. The result, after random substraction, is shown on figure 4.

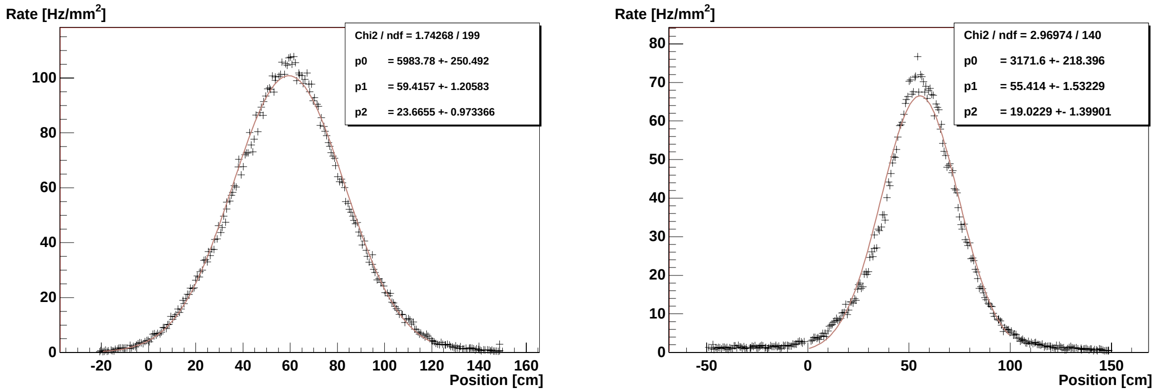

Figure 3: *x and y beam profiles for the* π^- *beam at a rate of 0.33 MHz (0.25 MHz in the chamber).*

More precise measurements (using constant fraction triggers and optimized electronics) could improve the value that we found. Nevertheless, we should stress that it was measured at a gain of 8500 and a rate of more than 2 MHz π^- in the chamber.

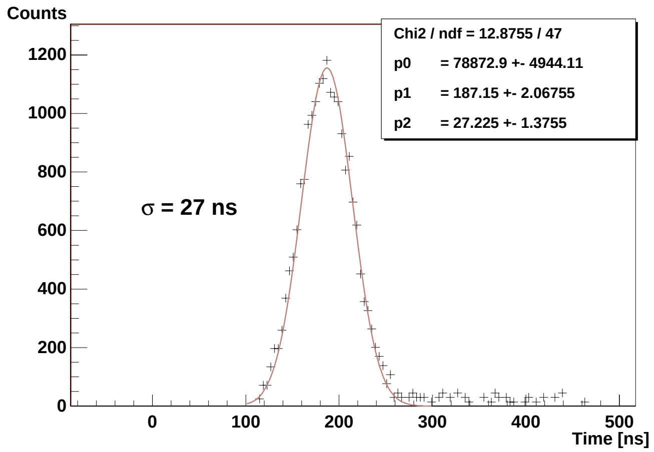

Figure 4: *Time resolution, measured at a gain of 8500 and a rate of more than 2 MHz in the chamber.*

3.2 Amplitude spectrum for minimum ionizing particles

The amplitude distribution is shown on figure 5, again measured at a gain of 8500, the beam rate being about 0.4 MHz π^- in the chamber. The signal we used is the sum of the signals of two individual strips, triggered by their coincidence. The pedestal corresponds to the amplitude of the background noise measured with a random trigger. Note that this noise is the sum of the noise of two amplifiers, thus worsening. However, the center of gravity of the energy distribution curve divided by the sigma of the pedestal gives us a good signal over noise ratio of about 20, although we don't take in account the overflows cut by the ADC and therefore moving the center of gravity to the left.

Figure 6 shows an example of an output signal used to measure the energy distribution. This signal's amplitude, however, corresponds to the tail of the distribution. Nonetheless, it shows that even in a very severe environment and at high gains, Micromegas is able to supply nice signals.

3.3 Discharge studies

The discharge amplitude and rate has been carefully studied with a suitable setup (figure 2). We indeed measured the discharges rate and probability for different beam intensities and gains, and for two different gas mixtures (see § 2.1).

First, the discharge probability per particle crossing the chamber was found to increase fairly linearly with the gas amplification, as shown on figure 7 with the 93%–7% mixture of argon and CO_2, and for the two kinds of beams, namely 215 MeV/c π^+ or 350 MeV/c protons. The slope of these curves is about

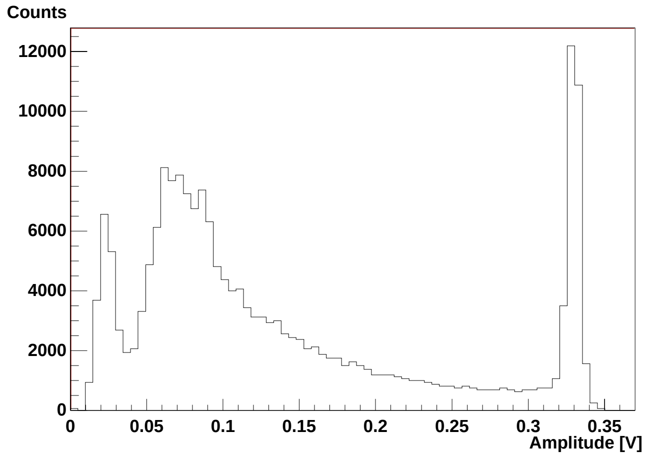

Figure 5: *Amplitude spectrum for minimum ionizing particles, at a gain of 8500 and a rate of 0.4 MHz in the chamber.*

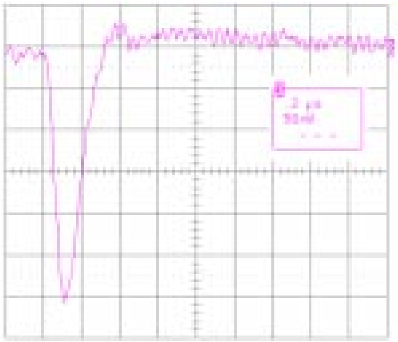

Figure 6: *Output signal at a gain of 8500 and a rate of 0.4 MHz in the chamber.*

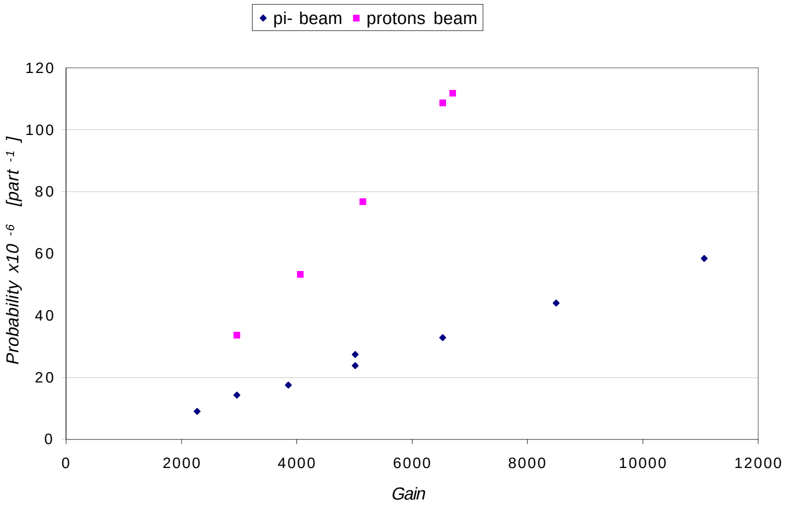

Figure 7: *Discharge probability per particle crossing the chamber versus amplification for the* π^- *and the protons beam.*

three times greater for the protons case than for the negative pions. In the latter, we also compared the probability with two different gas mixtures of 93%–7% and 60%–40% argon–CO_2. The result is shown on figure 8. We see that, at a given gain, the second mixture is better, indeed giving a discharge probability of 2 times less than the first mixture.

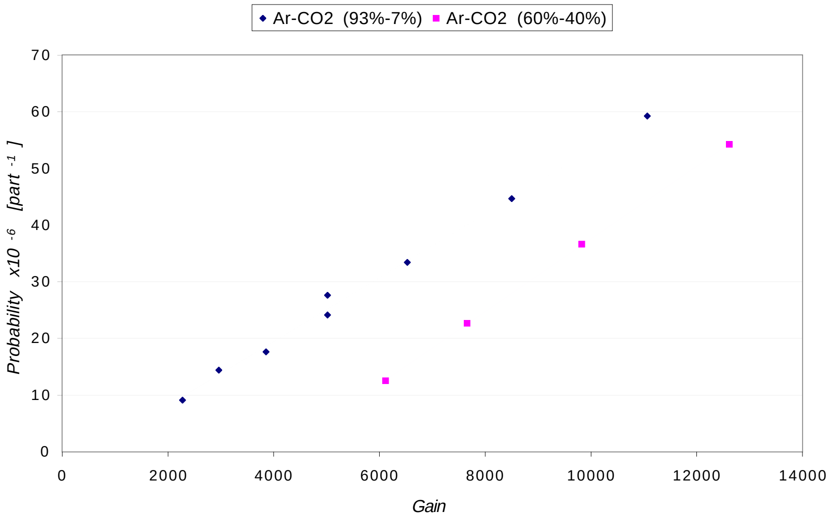

Figure 8: *Discharge probability per particle crossing the chamber versus amplification for the 93%–7% and 60%–40% argon–CO_2 mixtures.*

Secondly, at a gain of 6500, the discharge rates for the two kinds of beams shown on figure 9 is found to be proportional to the number of particles crossing the chamber. This has been observed up to 2 MHz crossing particles for the negative pions, the discharge probability per particle being 4×10^{-5}, and up to 48 MHz for the protons beam, with a higher probability reaching 10^{-4}. This couldn't be checked at higher rates, since the scintillator weren't able to provide reliable counts anymore. This constant probability indicates that discharges are strictly induced by beam particle interactions and are not influenced by the heavy load of the chamber due to particles at minimum ionization energy.

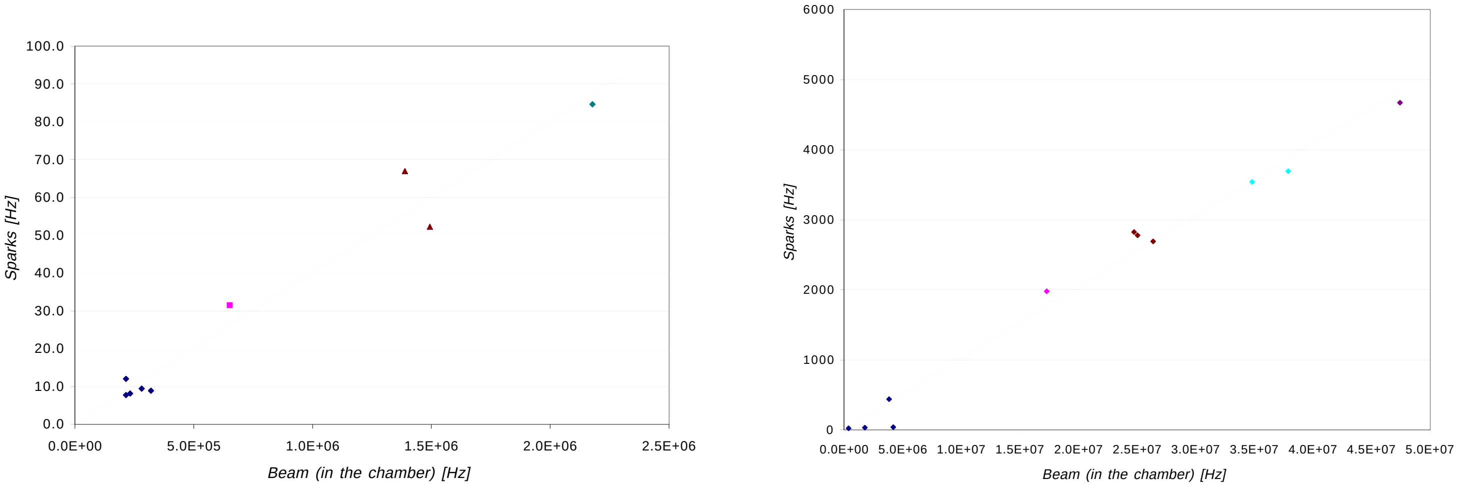

Figure 9: *Discharge rate versus beam rate for the π^- beam and for the protons beam.*

We also studied the discharges strength and size. The top signal shown on figure 10 represents a typical discharge mesh current. It was measured in the π^- beam at gain of 6500 and with the gas mixture of argon and CO_2 (93%–7%). The integration of this current gives us the total charge released by this discharge; the integrated charge distribution is shown on the bottom of the same figure. Quantization of the charge is obvious. The high peak on the left of the distribution is due to discharges occurring on non-instrumented strips. Its position, 16 nC (10^{11} electrons), corresponds to the discharge of 2 adjacent strips having a parasitic capacity of 14 pF each. Each other peak, on the right part of the distribution, corresponds to a spark occurring on the instrumented zone of the chamber, and involving a given number of strips, the main peak corresponding to the discharge of 4 strips. The average charge of this part of the distribution is 86 nC (5.4×10^{11} electrons), and the average size is 5.2 strips, covering 1.6 mm. This must be compared to an average charge of 1.7×10^{7} electrons for a minimum ionizing particle.

The rise time of a discharge is fast, about 30 ns; the time duration varies from event to event, but does never exceed 1 μs. At high beam rates, the mesh current is dominated by the discharges; we thus measured currents up to 2 mA without seeing any significant gain loss nor any other clue of aging.

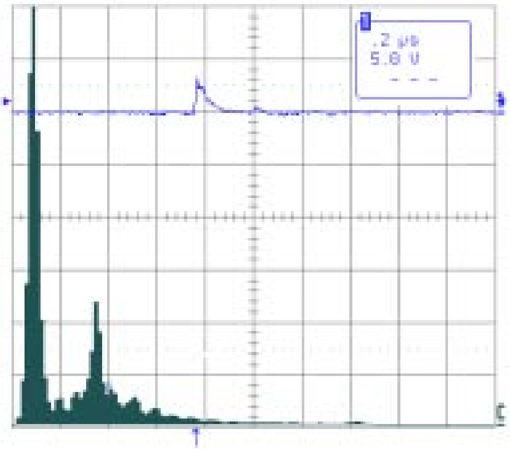

Figure 10: *Discharge signal and amplitude distribution.*

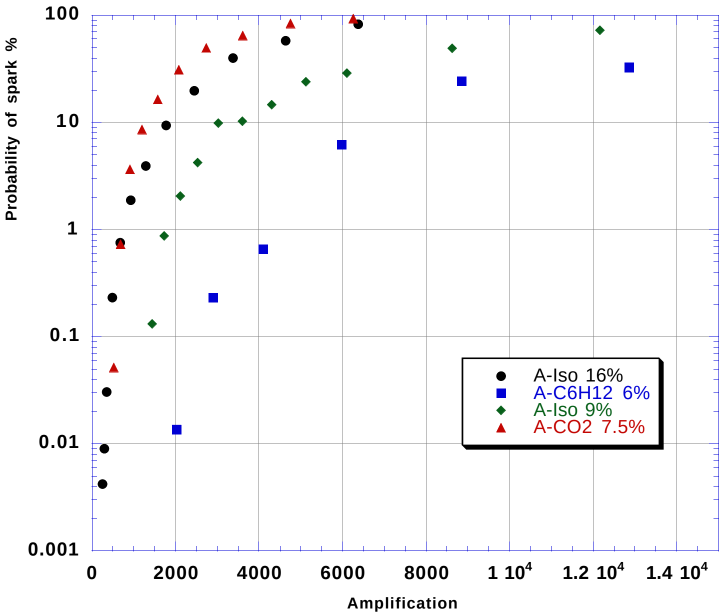

Figure 11: *Discharge rate comparison for different gases.*

3.4 Gas comparison

Micromegas was extensively tested with argon and CO_2 for the first time during this test. The discharge strength turned out to be much greater than what had been observed in the laboratory with a good quencher such as isobutane, thus killing many amplifier channels, despite the diode protection shown on figure 2. A comparison between several gas mixture has therefore been fulfilled in the laboratory. We used an Americium 243 source with a 1 mm diameter collimation to inject alpha particles in the chamber at a rate of 100 Hz. The average number of pairs produced by these particles in the conversion gap has been measured at low gas gain to be about 15,000. The discharge rate was then measured as a function of gas amplification for 4 different gas mixtures: argon–CO_2 (92.5%–7.5%); argon–isobutane (91%–9%), the standard mixture; argon–isobutane (84%–16%); argon–cyclohexan (94%–6%). The result (figure 11) confirmed our feeling: CO_2 is not a good candidate for Micromegas, whereas cyclohexan seem to be able to decrease the rates to a more reasonable level, even much better than the standard argon–isobutane mixture.

4 Conclusion and outlook

Micromegas showed during these tests that it could resist to very high beam intensities, at quite high gains and giving satisfactory results for the time resolution and the signal over noise ratio, even with rough measurements due to our setup.

But the main, crippling problem is still the high rate of discharge. At a gain of 6500 we found a breakdown probability per particles of 4×10^{-5} for π^- and 10^{-4} for protons beams. If the PSI picture is a valid description of conditions prevailing at LHC, this would correspond to a sparking rate of about 1 per mm^2 and per second at the nominal rate. This is clearly too high. However, this rate could be decreased by lowering the gain and by a better choice of the filling gas. When compared to a good quencher like isobutane or cyclohexan, CO_2 seems to be a very poor candidate for Micromegas. If a gain of 3000 is enough, a reduction of the sparking rate by 2 orders of magnitude is not excluded if cyclohexan is used. More investigation along this track is needed.

From these result, we must conclude that Micromegas is not LHC-compliant in its actual form, in spite of its many other good properties such as robustness and low cost, which are also key features for LHC tracker candidates. More efforts on gas and electronics seem to be worth the pain, the sparks apparently being the only, but crippling, problem. We also intent to investigate a Micromegas prototype with two meshes, in order to eliminate the sparks.

References

[1] Y. Giomataris et al. MICROMEGAS: a high-granularity position-sensitive gaseous detector for high particle-flux environments. Nuclear Instruments & Methods In Physics Research, A 376 (1996) 29–35.

[2] J. Derré et al. First beam test results with Micromegas, a high rate, high resolution detector. Nuclear Instruments & Methods In Physics Research, A 412 (1998) 47–60.

[3] J.P. Cussonneau et al. Test of the spatial resolution of MICROMEGAS detectors. Nuclear Instruments & Methods In Physics Research, A 419 (1998) 452–459.

[4] G. Barouch et al. Development of a fast gaseous detector: “Micromegas”. Nuclear Instruments & Methods In Physics Research, A 423 (1999) 32–48.

[5] P. Jarron, F. Anghinolfi, W. Dabrowski, E. Delagnes, L. Scharfetter A transimpedance amplifier using a novel current mode feedback loop Nuclear Instruments & Methods In Physics Research, A 377 (1996) 435–439.