EDIT school

Excellence in Detector and Instrumentation Technologies

Gaseous Detectors, Micromegas

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A - Introduction

During 2 ½ hours, the group of five students will get in touch with new detectors of the Micromegas type. Detectors of three types will be used: a standard Micromegas detector, a bulk Micromegas based TPC with a resistive anode, and a Microbulk detector. Basic notions as electron drift, collection and multiplication will be illustrated in various ways. Quantitative measurements will be carried out, as gain curves, collection curves, maximal gain and electron drift velocity. Some of them could be compared with simulations as taught in the corresponding course. It is recommended to bring a laptop with internet connection and with plotting software (Excel, PAW, ROOT, …).

B – Principle of Micromegas operation

A high-field region is created by setting a mesh to a high voltage (few hundred volts), the mesh being kept at a distance of typically 50-150 microns from an anode plane. In the region above the mesh, a moderate electric field is maintained: charged particles crossing this region ionize the gas, and the electrons drift under the action of the field. They enter through the holes of the mesh into the high-field space, where they can reach the ionization energy of the gas before losing this energy in elastic collisions. Seen by a fast amplifier, the signal is the superposition of a fast component due to electrons and to a slower component due to ions. The collection of the electrons and ion is fast and efficient, allowing high rates to be sustained.

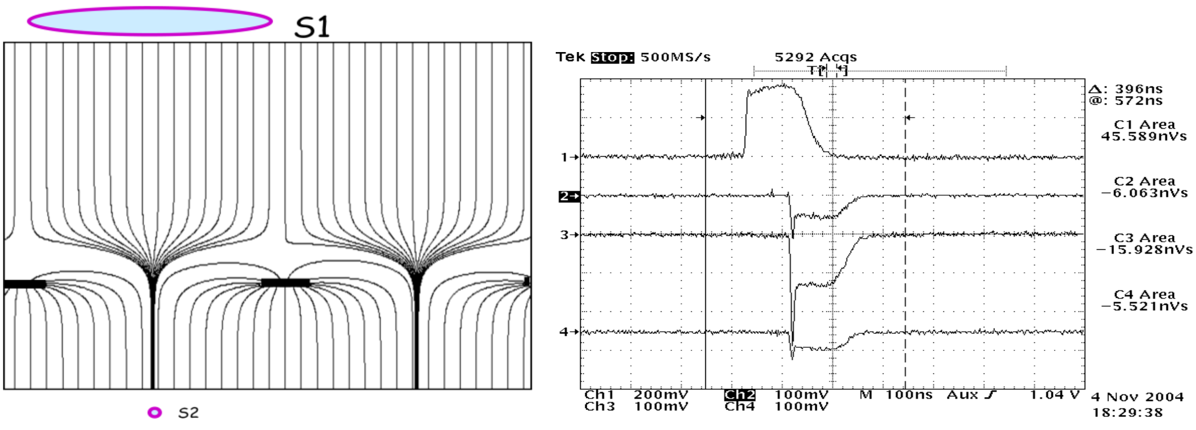

Fig. 1. a) field lines of a micromegas detector. b) mesh signal and 3 anode signals

C - Laboratory session

1) Launching the cosmic-ray Data Acquisition of the Micromegas TPC.
2) Measurement of gain curve and maximal gain for an Ar-CF4-isobutane mixture with the standard Micromegas detector (Wasbox)
3) Normalisation of the gain
4) Measurement of the resolution of a Microbulk detector
5) Comparison of collection curves between a Standard Micromegas and a Microbulk
6) Measurement of electron drift velocity in T2K gas in the TPC.

1) Launching the cosmic-ray Data Acquisition of the Micromegas TPC.

This setup is the most sophisticated of the three. It includes a complete chain of readout and acquisition for the 1726 pads. The front-end cards bear the AFTER ASIC (Application Specific Integrated Circuit). The AFTER chip contains 72 channels of preamplifier-shaper. The keystone-shaped module is read out by 6 cards with 4 ASICs each. The signal is 'sliced' in up to 511 'time buckets', the duration of which can be chosen. A 12-bit ADC digitizes the signal. A mezzanine card (FEM, Front-End Mezzanine) reads the whole module and converts the digital electronic signals into optical signals sent through a back-end card to the DAQ computer.

The parameters of the data taking (sampling frequency, electronic gain, peaking time of the shaper, etc…) have to be chosen for the measurement and entered through an ad-hoc user interface, the DCC, running on the data acquisition computer.

To take data with zero suppression, first a pedestal run will be taken, and the system will be configured. Then the data taking will be monitored and some cosmic-ray tracks will be scanned.

Exercise: A pad receives an ionization deposit of 2 keV in an Argon mixture with 25 eV per electron at a gas gain of 1000. The electronic gain is set to 120fC full scale. The pedestal is 250 ADC channels. What is the ADC channel for the signal? Assuming a zero suppression at 4 sigma, and a noise rms of 8 channels, what is the minimum visible signal?

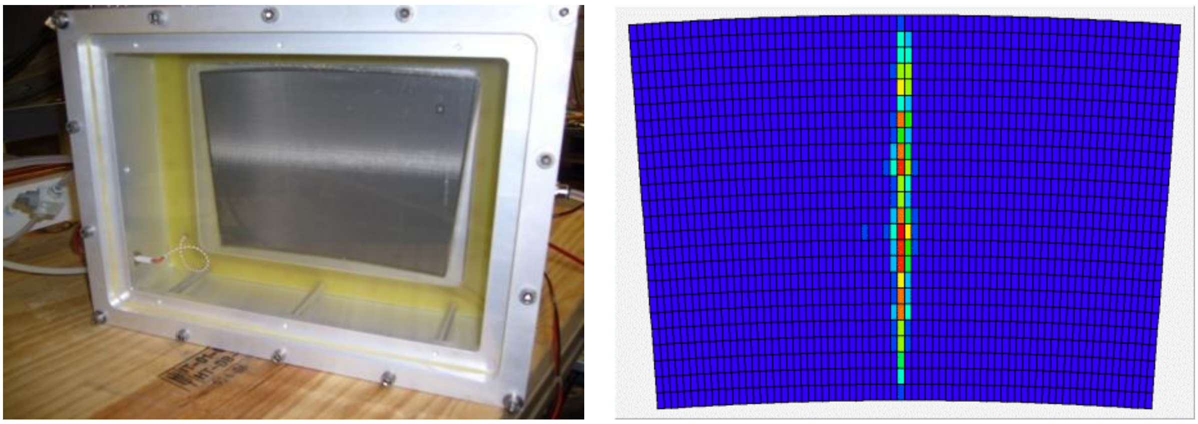

Fig. 2 – The TPC gas box (left) and a recorded charged track.

2) Measurement of gain curve and maximal gain for a given mixture

The setup is a plexi-glass gas box containing a standard Micromegas with a 50 micron amplification gap. The signal is read out by an ORTEC 142 PC pre-amplifier and a 672 pre-amplifier.

The high voltage is provided by a 2-channel CAEN N471A supply. The channel A is for the drift and the channel B is for the gas amplification. The signal is histogrammed using a multi-channel analyzer MCA8000 from AMPTEK. Beware that the digitizer of the MCA is limited to rates below 30 000 Hz. For higher rates the result might be meaningless.

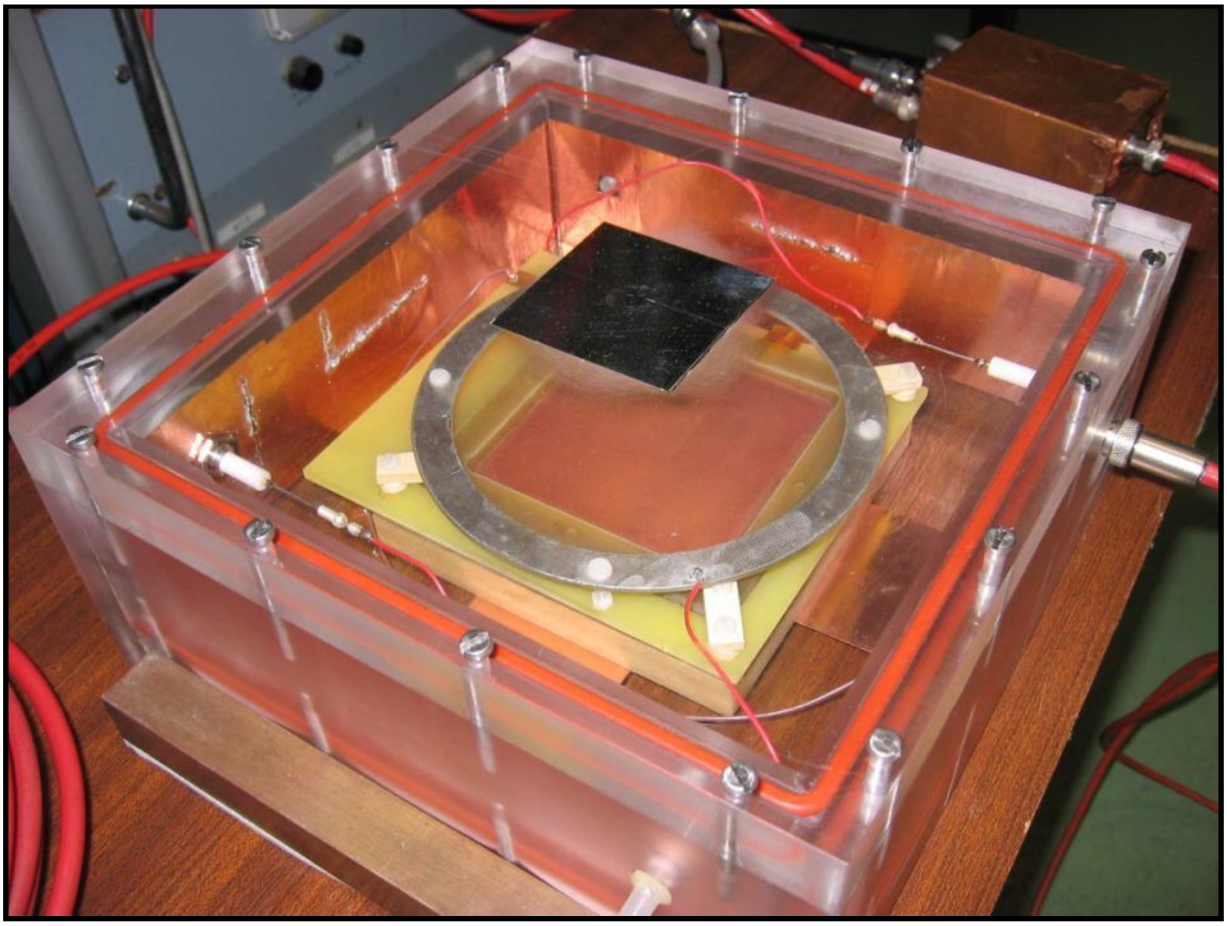

Fig. 3 – The 'Wasbox' standard Micromegas detector for gain measurements.

Crank the voltage up by steps of 5V and plot the ^{55}Fe peak position against the mesh voltage. What is the shape of the dependence of the gain with respect to the amplification electric field?

Exercise: What is the mesh current when the detector Is illuminated by 5.9 keV X-rays (assuming 220 electrons per X-ray) at a rate of 10 kHz with a gain of 10^4?

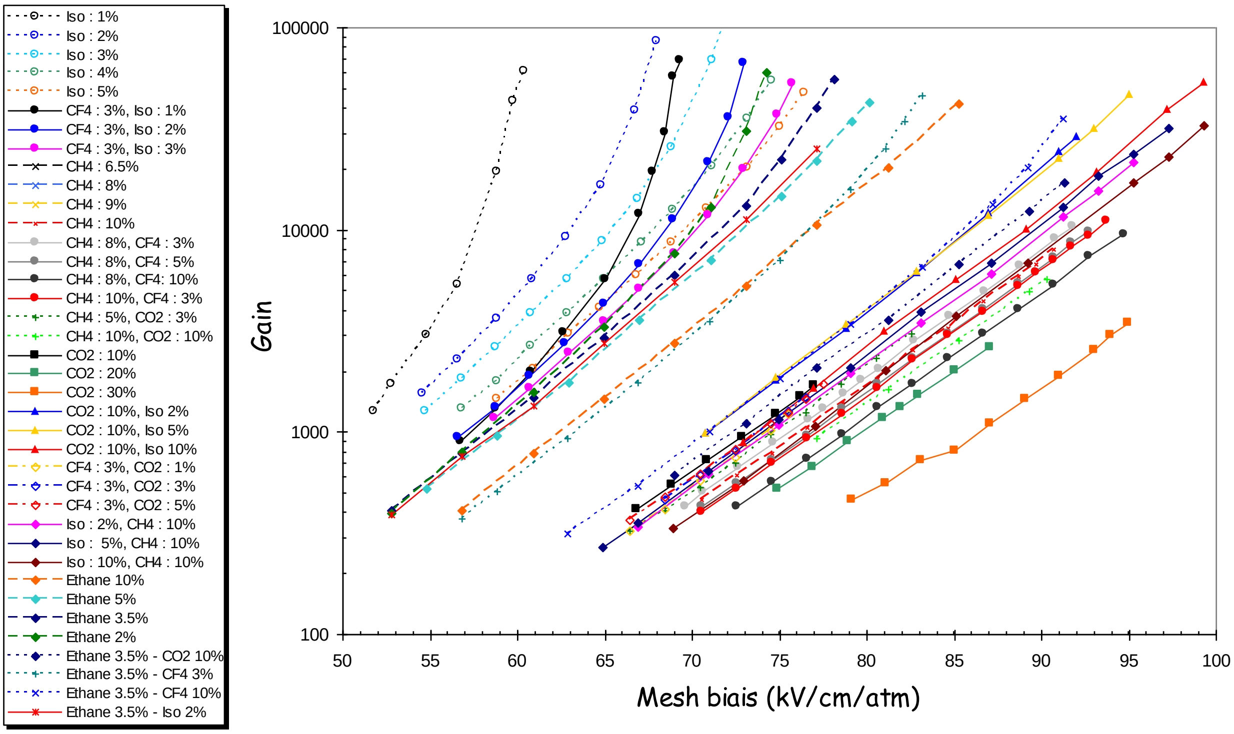

Fig. 4 – Gain vs field for some argon mixtures, for a Micromegas gap of 50 microns

3) Absolute gain. Assume a photon from the 55Fe peak (5.9 keV) gives rise to 240 electrons in this argon mixture. Determine the total number of electrons, knowing that the sensitivity of the preamp is 1.08 µV/e-ion pair.
Exercise: Derive the absolute gain and normalize your gain curve accordingly.

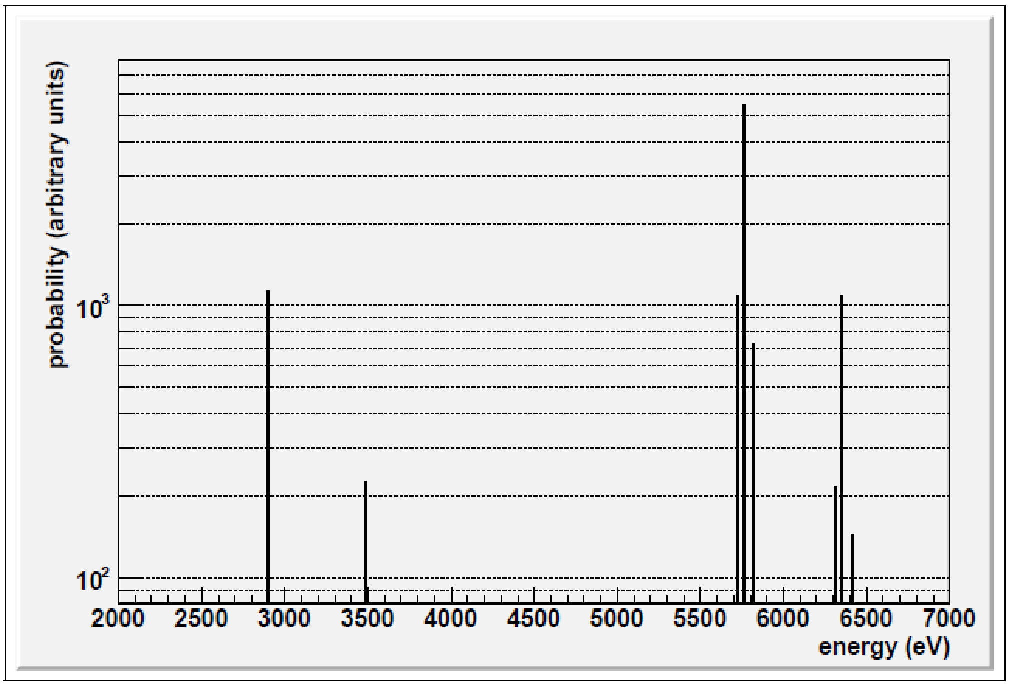

Fig. 5 – Main expected lines of a 55Fe source in argon (from M. Chefdeville, thesis).

5) Measurement of the resolution of a Microbulk detector.

The same readout chain as in 2 is used. Measure the relative width of the main peak. In fact the main peak is a superposition of two unresolved peaks: the K_{α} and K_{β} lines at respectively 5760 eV and 6492 eV. A way to separate the two lines it to fit the peak with the sum of two Gaussians. Another possibility is to use a chromium foil: its absorption increases by a factor of 10 abruptly at 6 keV and thus cuts the K_{β} line. By one method or the other, find the resolution or the microbulk detector at 6 keV. Compare with the standard detector.

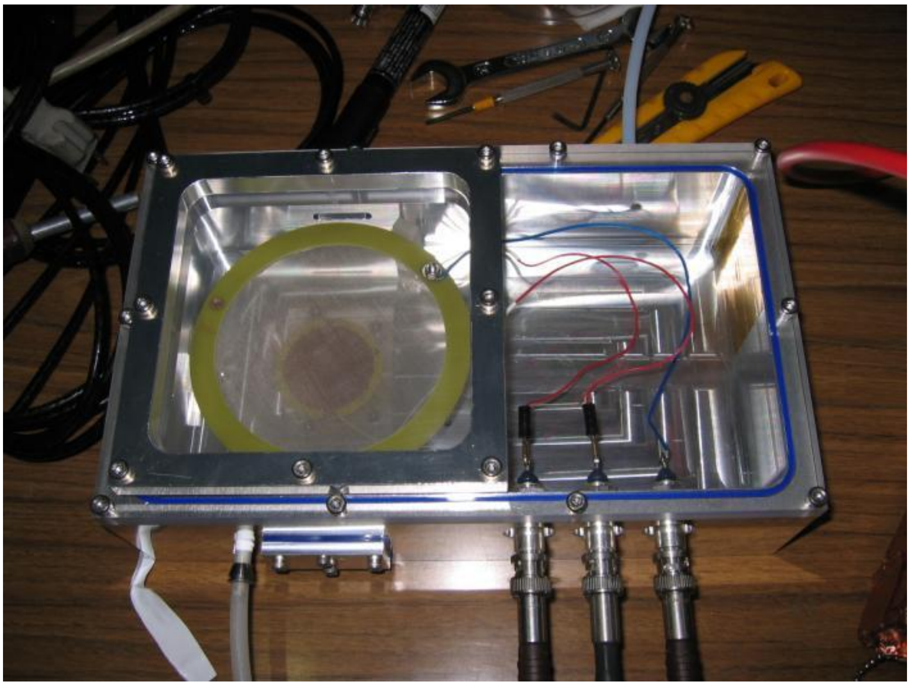

Fig. 6 – The Microbulk detector

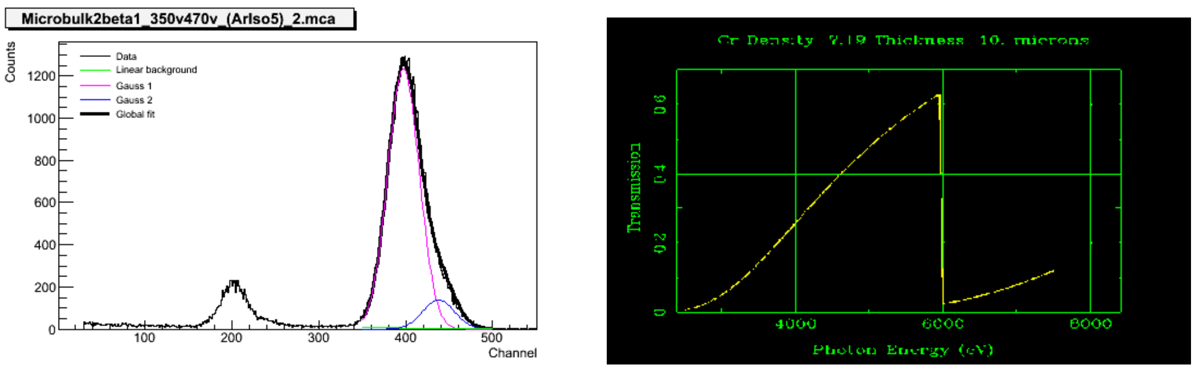

Fig. 7 – ^{55}Fe 5.9 keV line and escape line at 2.9 KeV. Transmission vs photon energy of a 10 micron-thick Chromium foil.

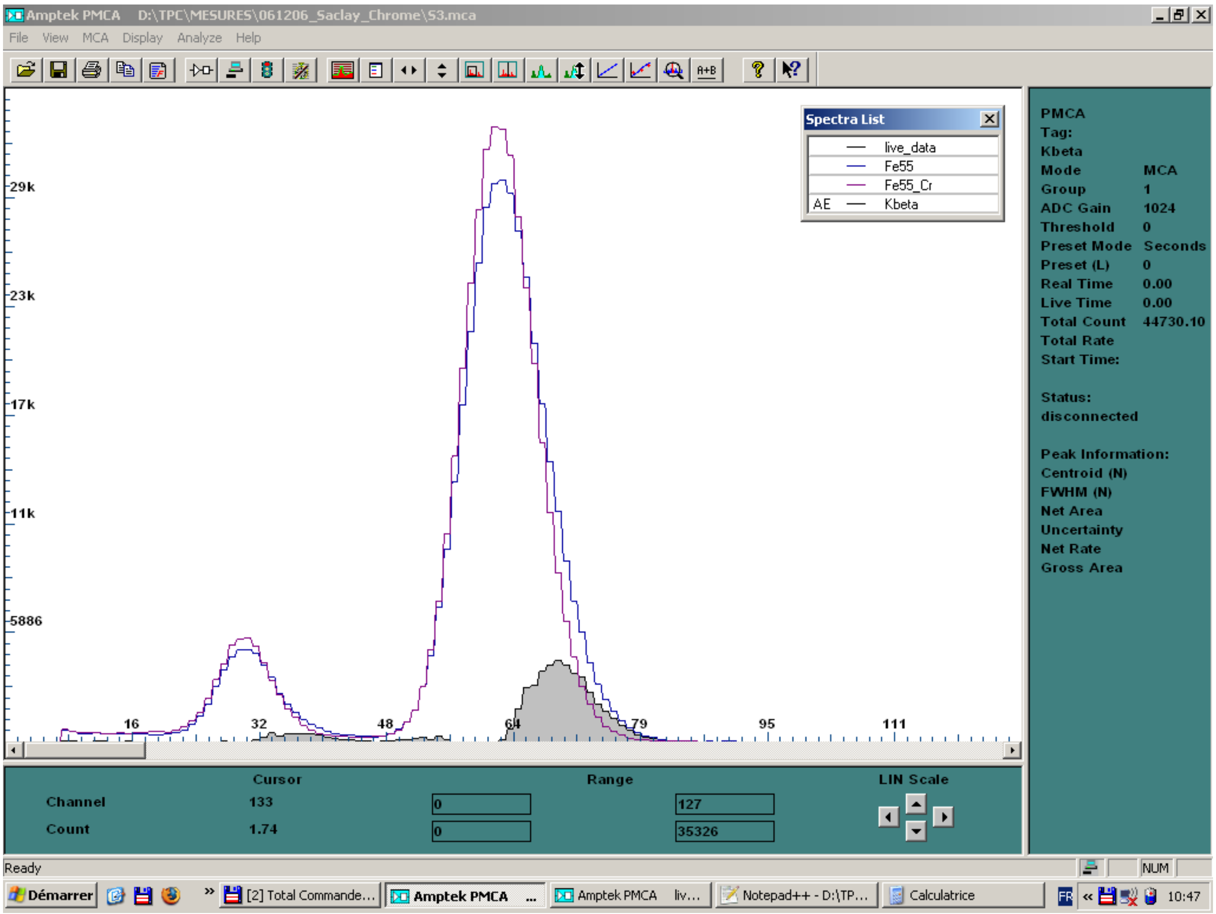

Fig. 8 – comparison of spectra with and without the chromium foil.

6) Comparison of collection curves between a Standard Micromegas and a Microbulk
Plot the position of the main peak as a function of the field ratio (amplification field over drift field), for a given mesh voltage.

7) Measurement of electron drift velocity in the T2K gas. Using the time distribution of the signals in the 28 mm gap, measure the drift velocity of electrons in the gas mixture at various drift fields. Compare with Magboltz prediction.

D – Preparation and practical use of a Micromegas detector

'Burning' or 'cooking' your detector

Prior to operating the detector, some preparation is needed. For reason of time effectiveness, this preparation is skipped in the proposed exercise. We give here a few hints for this preparation.

To make the detector stable for further operation, it must be 'cooked': raise the voltage slowly to 550-600 V (50 micron gap) or 800-900 V (128 micron gap), step by step, to the level where it starts sparking.

This has to be done in air. It consists of burning small dusts (mostly cloth fibres). A relatively high (ionic) current (200-250 nA) can remain. It will decrease after circulation of the gas and go down to 0(1nA).

A detector which stands its voltage in air will always work in gas.