Development of MicroMegas for a Digital Hadronic Calorimeter

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Recent developments on the MicroMegas prototypes built by use of the bulk technology with analog and digital readout electronics are presented. The main test beam results of a stack of several MicroMegas prototypes fully comply with the needs of a hadronic calorimeter for future particle physics experiments. A technical solution for a large scale prototype is also introduced.

1 Introduction

Future particle physics experiments at the International Linear Collider (ILC) [1] will employ the Particle Flow Algorithm (PFA). In order to achieve an optimal PFA performance, a highly granular hadronic calorimeter with a good shower separation is required. One of the suitable and affordable choice for an active part of the hadronic calorimeter is a thin gaseous detector with embedded digital (1-bit) or semi-digital (2-bit) readout. This concept allows the construction of the so-called Digital Hardronic CALorimeter (DHCAL) with very fine granularity (a cell size of about 1 cm²) providing high MIP efficiency, low hit multiplicity as well as negligible performance degradation due to high dose rates, hadronic showers and aging.

One of the promising candidate for a DHCAL is the MICRO MEsh GAseous Structure (MicroMegas) which is a micro-pattern gaseous detector [2]. Prototypes developed at LAPP consist of a commercially available 20 µm thin woven mesh which separates the 3 mm drift gap from the 128 µm amplification gap. This simple structure allows full efficiency for MIPs and provides a good gain uniformity over the whole detection area. Due to the fast collection of the amplification charge, the MicroMegas counting rate is very high and not constrained as in the case of the Glass RPC. Moreover, the tiny size of the amplification avalanche results in fast signals without physical cross talk and, consequently, low multiplicity. The chosen bulk technology based on industrial PCB processes, offers a robust large area detector with working voltages lower than 500 V. The MicroMegas with 1 cm² anode pads is therefore a very appealing possibility to equip a DHCAL well optimized for the PFA.

2 MicroMegas Prototypes

Three different kinds of MicroMegas prototypes with 1 cm² pads, were developed and built at LAPP. The first type is equipped with analog readout and the two others with embedded digital readout ASICs.

The analog readout, intended for full detector characterization, uses 16-channel GASSI-PLEX chips connected to a 12 bit VME ADC, which provides charge determination with a

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high resolution (0.4 fC/ADC Count). The data acquisition is performed by the CENTAURE program [3]. Three MicroMegas with 6 × 12 pads and one with 12 × 32 pads were equipped with this analog readout.

Two mixed-signal ASICs are designed for the digital readout, the HARDROC [4] and DIRAC [5]. The former was chosen as a baseline for the 1 m$^3$ European DHCAL project in order to ensure the availability of the digital readout of either MicroMegas or Glass RPC at short time. Whereas, the latter is a long-term R&D which aims to obtain a low cost ASIC with an easy signal routing implementation on the detector PCB, simple calibration and digital readout down to MicroMegas MIP charges. Four MicroMegas with 8 × 32 pads (see Fig. 1 left) and one with 8 × 8 pads (see Fig. 1 right) were built with HARDROC and DIRAC readout, respectively.

![Figure 1: MicroMegas prototype with HARDROC (left) and DIRAC (right) readout. Both photographs show the pad and ASICs sides.](image)

All MicroMegas bulks are realized by lamination at high temperature of photosensitive foils and a mesh laid on a PCB with different signal routing depending on the readout. By photo-lithography, the photosensitive foils are etched producing the 128 µm pillars. A thin copper foil, glued to part of the calorimeter absorber medium (2 mm thick plate out of a 2 cm thick absorber), defines the drift cathode. The top of the chamber is therefore not contributing to the active medium thickness. The drift gap is realized with a 3 mm thick frame which provides also the gas inlets and outlets.

### 3 X-ray response

In order to determine the gain and energy resolution, each prototype was exposed to an $^{55}$Fe X-ray source. The gain with the analog readout was measured up to 10000 and the energy resolution down to 8.5% corresponding to a FWHM of 19.6%. The gain and FWHM were also measured as a function of the drift and amplification fields, gas flow and pressure. The expected exponential dependence on the gain on the amplification field was verified and an absolute pressure dependence of -2 fC/mbar was determined.
4 Test beam results

The behavior of the MicroMegas prototypes under high energy particle irradiation was studied during two test beam periods at CERN. In the first period, four prototypes with analog readout and one prototype with DIRAC digital readout were assembled in a stack and tested in 200 GeV muon and pion beams at the H2 SPS line. In the second period, four prototypes with digital readout based on the HARDROC chip with associated electronics were exposed to 7 GeV pions at the T9 PS line. Since the analysis of data collected during the second period is ongoing, only results obtained during the first period in summer 2008 are presented below.

The mapping of each chamber was performed in terms of pedestal and electronic noise, Most Probable Value (MPV) of deposited energy distribution and its standard deviation. The pedestal Gaussian distribution showed very good noise performance with an average noise of 0.6 fC. A clear Landau distribution of deposited energy was obtained for each pad with a MPV around 45 fC. The MPV is well uniform for all the chambers (see Fig. 2 left) with an average dispersion of 11% RMS (see Fig. 2 right).

Figure 2: Map of the MPV of deposited energy distribution for one chamber (left) and the relative MPV distributions (right) for four MicroMegas prototypes with analog readout.

For efficiency and multiplicity studies, the hit threshold was set to 27 ADC Counts (2.8 fC). The counted hit in a chamber is considered only in case when three hits of three other chambers are sitting on the extrapolated straight line with respect to the chosen chamber. The efficiency of each pad is then computed as the ratio of the counted number of hits in the central or adjacent pad, so in a $3 \times 3$ pad array, and the expected number of hits. The efficiency varies from $(92, 99 \pm 0, 10)\%$ to $(97, 05 \pm 0, 07)\%$ for the oldest and newest prototype showing considerable progress in the manufacturing process. The hit multiplicity is measured by counting the number of hits in the same pad array. A multiplicity smaller than 1.1 was found for all of the four prototypes.

In the same test beam period, the first prototype with digital readout using DIRAC ASIC was tested in a 200 GeV pion beam. The functionality of the prototype was verified by beam scanning across the chamber. Nevertheless, further tests with a stack of several prototypes are compulsory to measure threshold dependence, efficiency and multiplicity. These tests are foreseen for spring 2009.
5 Future developments

The next step is the development of a 1 m$^2$ MicroMegas prototype with 9216 readout pads. The 1 m$^2$ is an assembly of six Active Sensor Units (ASUs) with 24 ASICs each closed by two plates of 2 mm thick stainless steel (see Fig. 3). In order to avoid destructive sparks from the increased capacitance of a too large area mesh, one mesh per ASU will be used. The total thickness of the prototype should not exceed 6 mm (without absorber). The construction of such a 1 m$^2$ prototype is scheduled for the beginning of 2009 and its first test in a beam for late 2009. The 1 m$^2$ design is foreseen for large quantity production in order to build a 1 m$^3$ DHCAL prototype.

Figure 3: 1m$^2$ MicroMegas prototype

6 Summary and Conclusion

Several MicroMegas prototypes with analog and digital readout have been successfully built and tested. The summer 2008 test beam results have shown very good performance complying with the DHCAL requirements. The first operational bulk MicroMegas with embedded digital electronics was realized and exposed to a pion beam. Further studies with a stack of these new thin prototypes are foreseen. Development of a large scale prototype compatible with the CALICE DAQ is well underway to be ready for a test beam in 2009.

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