Appendix

MICROMEGAS a compact approach

A very interesting alternative for the DHCAL active medium is the MICRO MEsh GAseous Structure (MICROMEGAS) [1], a detector based on micro-pattern technology, today widely used by many experiments: COMPASS, CAST, NA48, n-TOF, T2K and the ILC TPC project. Our prototypes consist of a commercially available 20 μm thin mesh which separates the drift gap (3 mm) from the amplification gap (128 μm). The mesh is supported by insulating pillars placed according to a square pattern every 2.5 mm which provides good gas gain uniformity over the whole area. This simple structure allows full efficiency for MIPs. The rate obtained with MICROMEGAS chamber is not constrained, as it is the case of Glass RPCs. Moreover, the tiny size of the electron avalanches results in fast signals without physical crosstalk and leads to low hit multiplicity. The chosen bulk technology based on industrial PCB processes, offers a robust detector with working voltages lower than 500 V. MICROMEGAS, with anode pads as small as 1 cm^2, is therefore a very appealing option for a DHCAL optimized for a Particle Flow Algorithm.

Description of Prototypes

Three different kinds of prototypes with 1 cm^2 pad size were developed and built at LAPP: one type with analog readout for characterization and two types with embedded digital ASICs.

The analog readout is performed with boards from the CEA-IRFU laboratory, each equipped with 6 GASSIPLEX chips (96 channels in total), connected to VME ADCs which provide high resolution charge determination (12 bits, 0.4 fC per ADC Count). The data acquisition is performed by the CENTAURE program from SUBATECH [2]. Three chambers with 6×96 pads and one with 12×32 pads (see Fig. 1) were built with this analog readout.

Two mixed-signal ASICs are foreseen for the digital readout, the HARDROC [3] and the DIRAC [4]. The former was chosen as a baseline for the 1 m^3 European DHCAL project in order to get rapidly the digital readout of either MICROMEGAS or Glass RPC. The latter

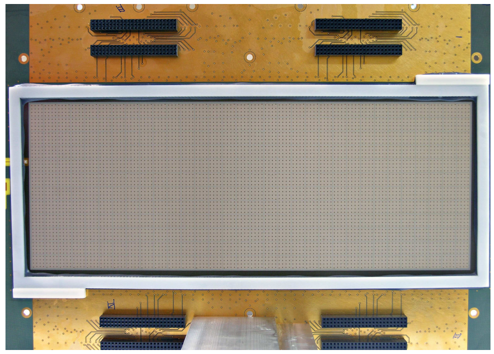

Figure 1: MICROMEGAS 12×32 cm^2 prototype with 1 cm^2 pads designed for analog readout.

is a long-term R&D which aims to obtain a low cost ASIC with an easy signal routing implementation on the detector PCB, easy calibration and digital readout down to MICROMEGAS MIP charges.

All MICROMEGAS bulks are realized by lamination of photosensitive foils and a mesh laid on a PCB with different signal routing depending on the readout. By photolithography, the photosensitive material is etched in some places producing the 128 μm high pillars. The drift gap is realized with a 3 mm thick frame which also provides the gas inlets (see Fig. 1 and 8). A thin copper foil, glued on the calorimeter absorber medium (2 mm thick plate out of a 2 cm thick absorber), defines the drift cathode. The top of the chamber, therefore, does not contribute to the active medium thickness.

The 1 m^2 prototype is an assembly on a single mask of six bulks with 24 ASICs each. The chamber is closed by two plates of 2 mm thick stainless steel (see Fig. 2). This prototype should not exceed a total thickness of 6 mm (without absorber). Its construction is on-going and it should be available for beam tests, with the former smaller prototypes, for late summer 2009. The 1 m^2 design is foreseen for large quantity production in order to build a 1 m^3 DHCAL prototype.

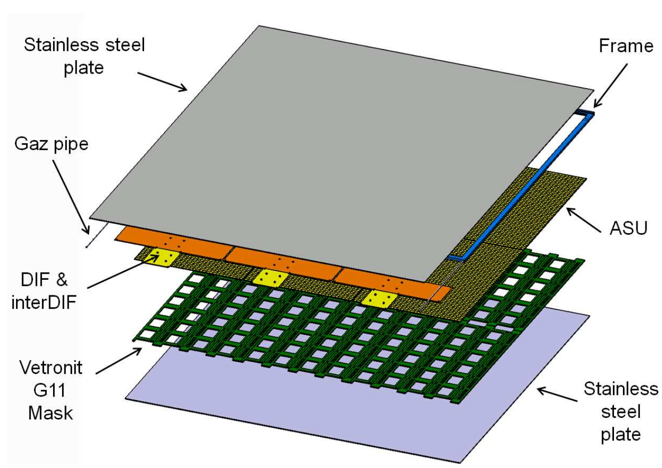

Figure 2: Design of the 1 m^2 MICROMEGAS prototype.

Analog Readout Prototypes

Using an ^{55}Fe X-ray source, the gain was measured with the analog readout up to 10^4 and an energy resolution down to 8.5% corresponding to a FWHM of 19.6 % was obtained (see Fig. 3 and 4). The gain and the resolution were measured as a function of the drift field, amplification field, gas flow and pressure variables. The expected exponential behavior of the gain versus the amplification field was verified (see Fig. 4) and an absolute pressure dependence of -2 fC/mbar was determined.

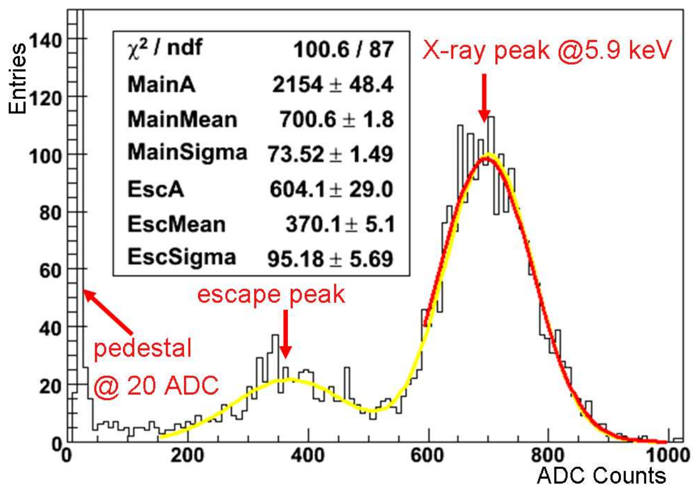

Figure 3: ^{55}Fe X-ray spectrum in 3 mm Ar/iC_4H_{10} 95/5 with E_{mesh} = 35 kV/cm and E_{drift} = 167 /cm. A gain of about 7600 is deduced from the 5.9 keV photopeak position (680 ADC Counts above perdestal, 277 fC).

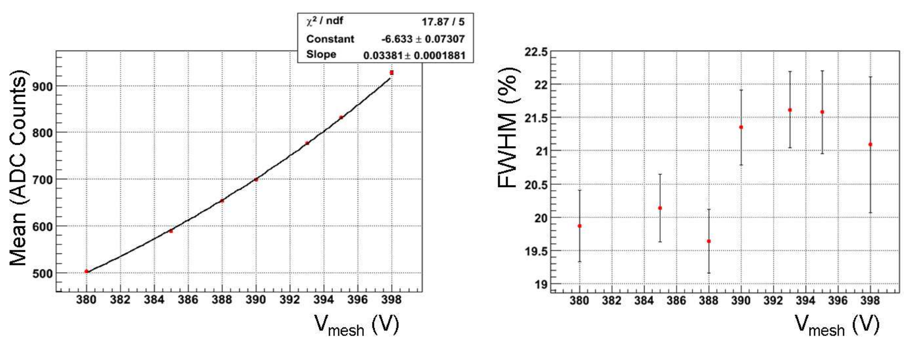

Figure 4: MICROMEGAS response and energy resolution at 5.9 keV as a function of mesh high voltage with E_{drift} = 167 V/cm.

In the summer 2008, four prototypes with analog readout were assembled in a stack and tested at the H2 line of the SPS-CERN. A total acquisition time of 5 days allowed the collection of about 200k muon and 200k pion events without absorber plus 250k pion events with an upstream 30 cm iron block and 1.8 cm iron absorbers between each prototype.

In the preliminary analysis of the 200k muons at 200 GeV, platinum events were selected by requiring one and only one hit (ADC Counts > 27) in each chamber. The Landau distribution obtained on each pad has a Most Probable Value (MPV) around 45 fC. The four chambers mapping was performed in terms of pedestal mean and sigma, Landau distribution MPV and sigma. The pedestal gaussian fits showed very good noise conditions with an average standard deviation of 0.6 fC. The response is uniform within each prototype with a MPV relative variation of about 11 % RMS for the four prototypes (see Fig. 5). Electronics channel disparity and drift space non-uniformity are still to be quantified.

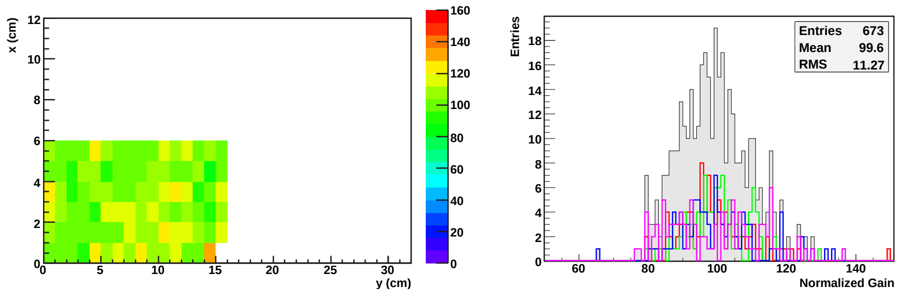

Figure 5: Example of a prototype mapping with analog readout: MPV in ADC Counts for golden events selected in a 200 GeV muons sample. MPV dispersion normalized to 100 % for the four prototypes with analog readout.

With the same muon sample, golden events were selected by requiring one and only one safe hit (ADC Counts > 51) in three of the four prototypes. A straight line was fitted to the three hits and the efficiency of the last prototype was calculated by looking for at least one hit (ADC Counts > 27, charge > 2.8 fC) in a 3×3 pad square centered around the extrapolated line (see Table 1). With the golden events the multiplicity was measured by counting the number of hits in the same square, a multiplicity of about 1.07 was found.

Prototype	Efficiency (charge > 2.8 fC)
0 (96 pads)	$97.05 \pm 0.07\%$
1 (96 pads)	$98.54 \pm 0.05\%$
2 (96 pads)	$92.99 \pm 0.10\%$
3 (384 pads)	$96.17 \pm 0.07\%$

Table 1: Efficiency of the MICROMEGAS prototypes with analog readout.

Digital Readout Prototypes

The DIRAC chip [4] was embedded on an 8×8 cm^2 PCB with additional spark protections (see Fig. 6). For the first time a functional prototype with a bulk laid on a PCB with embedded electronics reaching a total thickness of 12 mm including 2 mm of absorber could be exposed to 200 GeV pions at the H2 beam line in summer 2008. Fig. 7 shows the beam profile as measured with a threshold of 19 fC. Further tests with a stack of prototypes are foreseen to measure threshold dependence, efficiency and multiplicity.

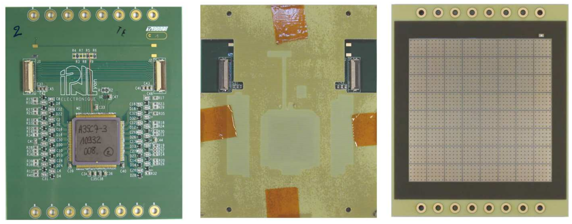

Figure 6: MICROMEGAS prototype with DIRAC digital readout. From left to right: ASIC side, ASIC side with mask for bulk laying and pad side with bulk.

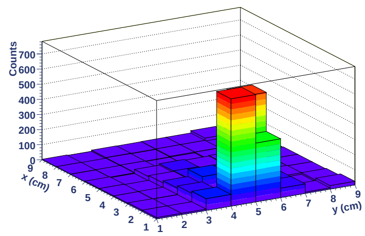

Figure 7: Chamber mapping of the MICROMEGAS prototype with DIRAC digital readout: digital counts in a 200 GeV pion sample.

Several new 8×32 pads prototypes have been realized with four HARDROC chips embedded on one PCB (see Fig. 8). The electronics is tested with the Detector InterFace board (DIF) which has been designed at LAPP in the frame of the DHCAL CALICE data acquisition system [5]. These prototypes have been exposed to 7 GeV pions at the T9 line of the PS-CERN in November 2008.

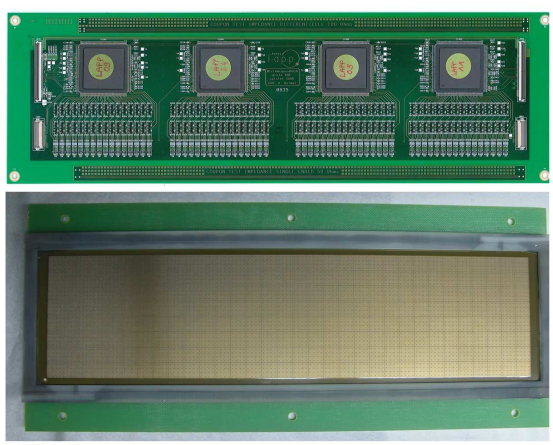

Figure 8: MICROMEGAS prototype with 4 HARDROCs digital readout. From top to bottom: ASIC side and pad side with bulk and drift frame.

References

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