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Large Surface MicroMegas with Embedded Front-End Electronics for a Digital Hadronic Calorimeter

Catherine Adloff, Ambroise Espargilière and Yannis Karyotakis

Abstract—In order to study the advantages of a digital hadronic calorimeter for particle flow algorithms, we aim to build a detector prototype with MicroMegas chambers. The bulk technology was chosen for its robustness and the possibility of industrial manufacturing process for mass production. First tests of 1 cm² granularity MicroMegas with analog readout are very promising. Larger chambers with embedded digital front-end electronics together with detector interface readout boards are being designed. The challenge also lies in the mechanical design of a 1 m² chamber with a total thickness of 6 mm.

I. INTRODUCTION

CURRENT experimental measurements as well as theoretical arguments let predict the existence of new physics at a scale lower than 1 TeV. The startup of LHC will allow the exploration of this energy domain, with the aim to discover new phenomena. However, precision measurements will be achieved at a future electron-positron linear collider with energy around 1 TeV. This latter is a compulsory continuation to bring the convincing response to the electroweak symmetry breaking, SUSY models, extra dimensions models, and more generally to any other new physics.

The now common and worldwide project International Linear Collider (ILC) generates a considerable effort on detector R&D, simulation, and understanding physics signals and backgrounds [1]. The Particle Flow Algorithm (PFA) is the way forward. It requires imaging calorimeters (short radiation-interaction length and high segmentation) located inside the magnetic coil. With about 3000 m² and 30 Million channels, a good choice for the hadronic calorimeter is a gaseous active medium with embedded digital readout, the so-called digital Hadronic CALorimeter (DHCAL). It has to provide high MIP efficiency, low multiplicity as well as no performance degradation due to high rate, hadronic showers and aging. Technologically, the challenges come from the large area (up to 1.8x3.5m²) and the little thickness (< 8mm) of a single gaseous detector, the ease of calibration and the low cost.

The Micro Mesh gaseous structure (MicroMegas) is a gaseous detector, based on the micro-pattern detector technology [2], today widely used by many experiments: COMPASS, CAST, NA48, n-TOF, T2K and ILC TPC project. Our prototypes consist of a commercially available

fine mesh which separates the drift gap (3 mm) from the amplification gap (128 μm). This simple structure allows full efficiency for MIPs and thanks to thin pillars, provides a good uniformity over the whole surface. The rate obtained with Micromegas chamber is not constrained, as it is the case for the Glass RPC. Moreover the tiny size of the amplification avalanche results in fast signals without physical cross talk and leads to low multiplicities. The chosen bulk technology based on industrial PCB processes, offers a robust detector with working voltages lower than 500 V. MicroMegas are therefore a very appealing possibility to equip a DHCAL optimized for the PFA.

II. PROTOTYPES DESCRIPTIONS

Three different kinds of prototypes with 1 cm² pad size were built at LAPP. One type with analog readout for characterization, two types with embedded digital ASICs.

The analog readout is performed with boards from the CEA laboratory equipped with 6 GASSIPLEX chips (96 channels in total), connected to VME ADCs and featuring high resolution charge determination (12 bits, 0.4 fC per ADC Count). The data acquisition is performed by the CENTAURE program from SUBATECH-Nantes [3]. Three MicroMegas with 6x96 pads and one MicroMegas with 12x32 pads (see Fig. 1) were designed for this analog readout.

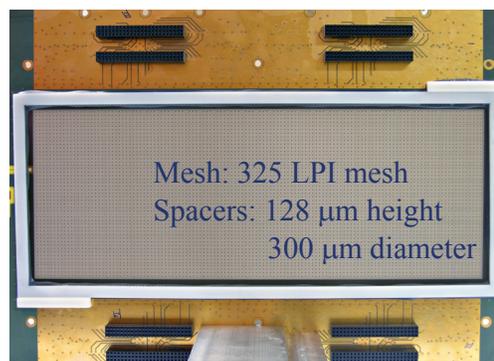


Fig. 1. MicroMegas 12x32 cm² prototype with 384 pads of 1 cm² and designed for analog readout.

Two mixed-signal ASICs are foreseen for the digital readout, the HARDROC [4] and the DIRAC [5]. The former was chosen for the baseline of the 1 m³ European DHCAL project in order to get rapidly the digital readout of either MicroMegas or Glass RPC. Whereas the latter is a longer term R&D which aims to obtain a low cost ASIC with an easy

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signal routing implementation on the detector PCB, an easy calibration and a digital readout down to MicroMegas MIP charges.

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 a photolithographic method, the photo resistive material is 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 (see Fig. 1).

III. RADIOACTIVE SOURCE TEST RESULTS

Using a ^{55}Fe X-ray source, the gain was measured with the analog readout up to 10000 and the energy resolution down to 8.5% corresponding to a FWHM of 19.6% (see Fig. 2 and 3). The gain and the FWHM 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. 3) and an absolute pressure dependence of -2 fC per mbar was determined.

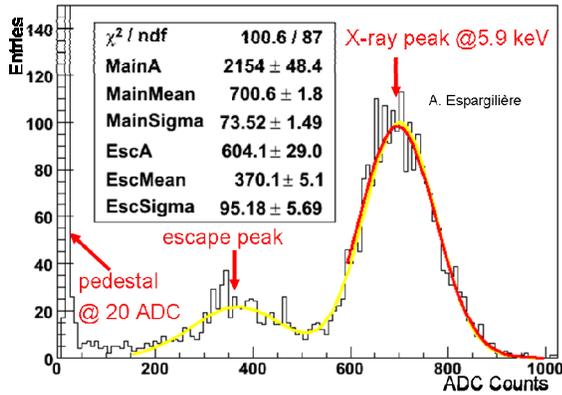


Fig. 2. MicroMegas analog response to a ^{55}Fe X-ray source with $E_{\text{mesh}} = 35$ kV/cm and $E_{\text{drift}} = 167$ V/cm. The 5.9 keV emission leads to 700 ADC Counts or 280 fC. For a 3mm drift gap and a gas mixture of 95% argon, 5% isobutane, the gain is about 7600.

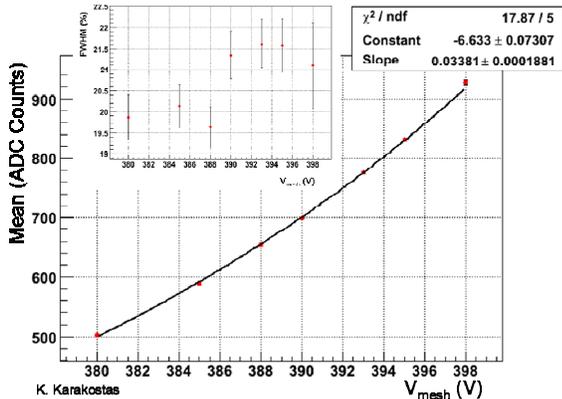


Fig. 3. MicroMegas analog response to a ^{55}Fe X-ray source with $E_{\text{drift}} = 167$ V/cm: ADC Counts and FWHM versus mesh high voltage.

IV. BEAM TEST RESULTS

A. Analog Readout Prototypes

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 has allowed to collect data with about 200k muons and 200k pions without absorber plus 250k pions 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 MIP landau distribution on each pad was obtained with a Most Probable Value (MPV) around 45 fC. The four chambers mapping was performed in terms of pedestal mean and sigma, MIP landau Most Probable Value (MPV) and sigma. The pedestal gaussian fits have shown very good noise conditions with an average pedestal sigma of 0.6 fC. The gain is uniform within each prototype except for the largest one (see Fig. 3). Electronics channel disparity and drift space homogeneity are still to be checked. The next November 2008 test beam has provide the opportunity to upgrade this prototype setup condition.

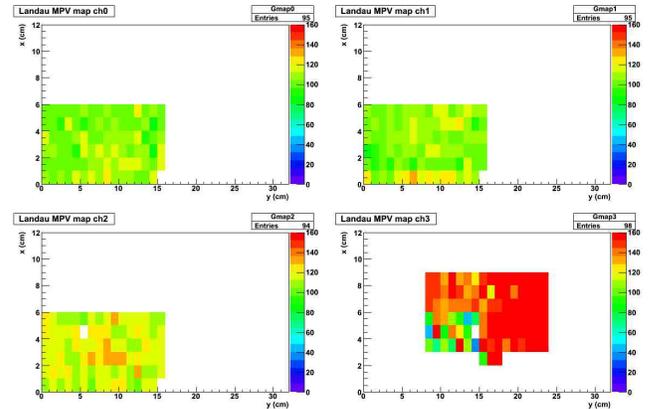


Fig. 3. Chamber mapping of the MicroMegas with analog readout : MPV in ADC counts for golden events selected in a 200 GeV muons sample.

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. Using these three hits, a straight line fit is performed. The efficiency of the last prototype is obtained by looking for at least one hit (ADC Counts > 27, charge > 2.8 fC) in a 3x3 pads square centered around the extrapolated line (see Table I). 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.

TABLE I
EFFICIENCY FOR THE MICROMEGAS PROTOTYPES WITH ANALOG READOUT

	Efficiency (charge > 2.8 fC)
Prototype 0 (96 pads)	$97,05 \pm 0,07\%$
Prototype 1 (96 pads)	$98,54 \pm 0,05\%$
Prototype 2 (96 pads)	$92,99 \pm 0,10\%$
Prototype 3 (384 pads)	$96,17 \pm 0,07\%$

B. First Digital Readout Prototype

The DIRAC chip was embedded on an 8x8cm PCB with additional sparks protection (see Fig 4) [5]. For the first time a prototype with a bulk laid on a PCB with embedded electronics reaching a total thickness of 12 mm including 2 mm absorber was operational and exposed to 200 GeV pions at the H2 beam line in summer 2008. Fig. 5 shows the beam profile with a threshold above 19 fC. Further tests with a stack of prototypes are compulsory to measure threshold dependence, efficiencies and multiplicities.

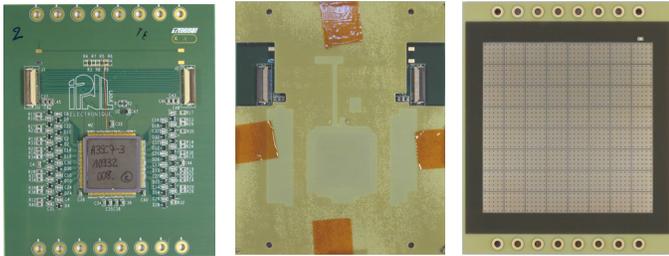


Fig. 4. MicroMegas prototype with DIRAC digital readout. From left to right: ASIC side, ASIC side with mask for bulk laying and pad side with bulk.

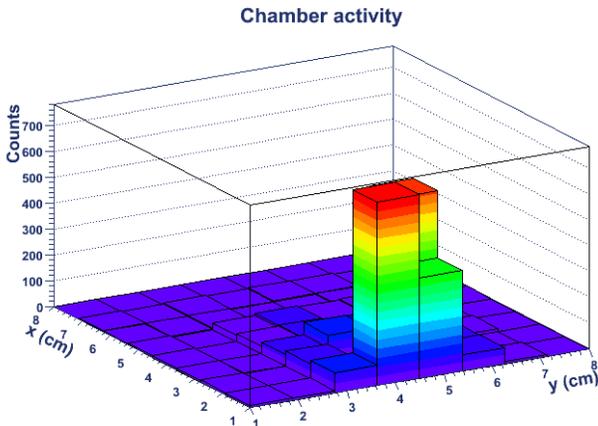


Fig. 5. Chamber mapping of the MicroMegas prototype with DIRAC digital readout : digital Counts in a 200 GeV pion sample.

V. FUTURE DEVELOPMENTS

Several new 8x32 pads prototypes have been realized with four HARDROC chips embedded on one PCB. 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 [6]. These prototypes have been exposed to 7 GeV pions during the November 2008 beam test at the T9 line of the PS-CERN, the analysis is ongoing.

The 1m² prototype is an assembly of six bulks with 24 ASICs each on a single mask. The chamber is closed by two plates of 2 mm thick stainless steel (see Fig. 6). This prototype should not exceed a total thickness of 6 mm (without absorber). It is scheduled to build this prototype beginning 2009 in order to test it in the beam with the former smaller prototypes during late summer 2009. The 1m² design is foreseen for large quantities production in order to build a 1 m³ DHCAL prototype.

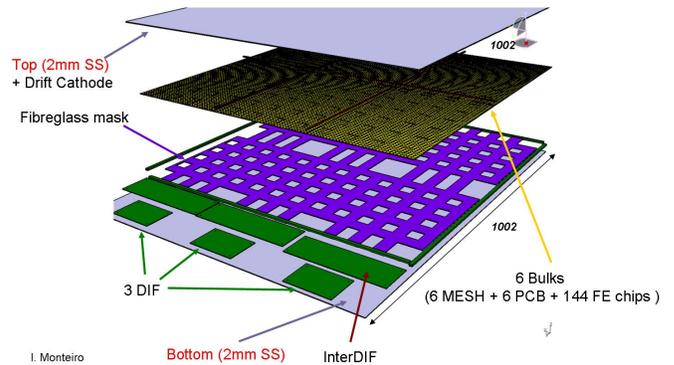


Fig. 6. Design of the 1 m² MicroMegas Prototype.

VI. SUMMARY AND OUTLOOK

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

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