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DIRAC v2: a DIgital Readout Asic for hadronic Calorimeter

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- Linear fit:

$$F(q) = 1/g \cdot q + b \qquad \begin{array}{rcl} g & : & \text{gain} \\ b & : & \text{pedestal} \end{array}$$

- Linearity error: $\frac{F-M}{M}$ normalized in %.

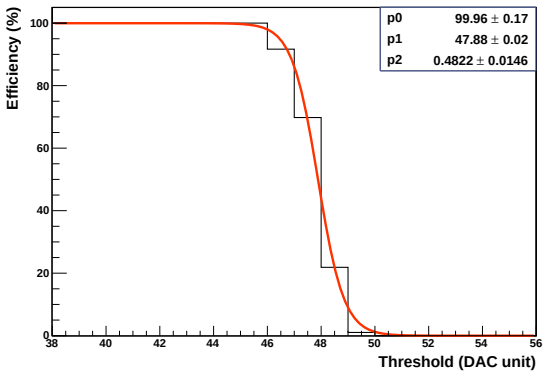

Figure 5: Example of s-curve

Input charge is injected with a GPIB controlled pulse generator delivering a voltage pulse to on-chip 1 pC test capacitor through -20 dB attenuator. All data are collected to PC thanks to Labview software, and analyzed offline with a ROOT/C++ framework.

C. Results

The characterisation of DIRAC v1 has been described in details in [4].

DIRAC v2 brings some improvements to these results: Table 3 gives results of a gaussian fit for gain and pedestal distribution for the five prototypes. These values are good enough to avoid any channel to channel ASIC calibration in the calorimeter.

The linearity is within +1/-3% on the 20–200 fC range.

The noise, extract from s-curve, is the width from 100% efficiency to 0% efficiency. At 5σ, the noise is less than 5 fC.

The minimum threshold is less than 10 fC which corresponds to half of the most probable signal from minimum ionising particles in MICROMEGAS detectors developped at LAPP.

Moreover, a power-on time less than 3 µs has been measured. To obtain this result, efficiency and inflexion point of the s-curve have been observed in function of the power-on time.

Table 3: Prototype dispersion summary

Chip ID		1	2	3	4	5
Gain (fC/DACU)	mean	1.1	1.0	1.1	1.0	1.1
	sigma	0.03	0.03	0.02	0.02	0.02
Pedestal (fC)	mean	6.2	4.0	6.7	6.9	5.6
	sigma	2.0	1.6	1.8	1.6	1.7

[1] In a DHCAL, this cover will be a part of the calorimeter absorber.

IV. ASIC EMBEDDED IN MICROMEGAS CHAMBER

To minimize shower leakage and minimize HCAL diameter, the thickness of the active medium must be thinner than 8 mm. In that respect, the Bulk MICROMEGAS is an attractive option as the fabrication process allows a PCB with front end ASICs soldered on one side, and anode pads patterned on the other side to be equipped with a MICROMEGAS mesh. This is crucial for the construction of a real scale DHCAL for which large areas should be instrumented and dead zones minimized to insure a good hermeticity of the HCAL.

A MICROMEGAS detector consists of a gas volume separated in a drift and an amplification region by a thin mesh. An industrial technology, called bulk [5] has been chosen. The drift region is defined by a 3 mm thick resin frame manufactured by stereolithography. This frame also provides gas inlet and outlet. The drift electrode (cathode) is made of a 5 µm thick copper foil and a 75 µm Kapton insulator, glued together on a 2 mm thick steel plate, which is the MICROMEGAS chamber lid[1]. The amplification electrode consists of a woven mesh of stainless steel wires (18 µm diameter, 56 µm pitch) maintained by insulating pillars patterned by photolithography (400 µm diameter) at precisely 128 µm of the anodes. This technology has been chosen for its performances (especially near 100% efficiency for MIP), its robustness [6][7] and its ease of industrialisation in a PCB workshop (big amount of detectors and large areas are expected in the future). A cut view of the detector is presented Figure 6.

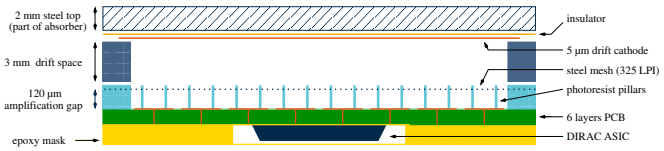

Figure 6: Micromegas with embedded ASIC

The first tests are made with an X-ray source (^{55}Fe) thanks to a small hole in the lid of the chamber. The energy resolution is measured and the gain of the detector *vs* high voltage is checked (Figure 7). The pedestal is at 5 ADC counts, the photopeak at about 770 (σ=63). This gives an energy resolution σ_E/E of 8.5% at 5.9 keV. A typical gain is 10^4 for a -420 V mesh voltage.

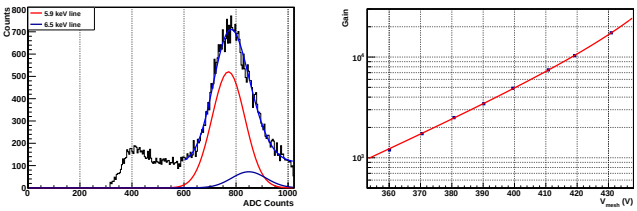

Figure 7: Detector characterisation

This chamber has been tested in a 200 GeV pion beam at the CERN/SPS [8]. A drift cathode voltage of 460 V and a mesh

voltage of 410 V have been used. Thresholds have been set to 24, 40 and 80 DAC code (respectively to 19, 32 and 64 fC). Figure 8 shows the beam profile in hit counts.

The measured hit multiplicity (mean number of pad hit for each trigger) is 1.10. This is in very good agreement with previous measurements performed with analog readout prototypes of same chamber geometry [9] [10].

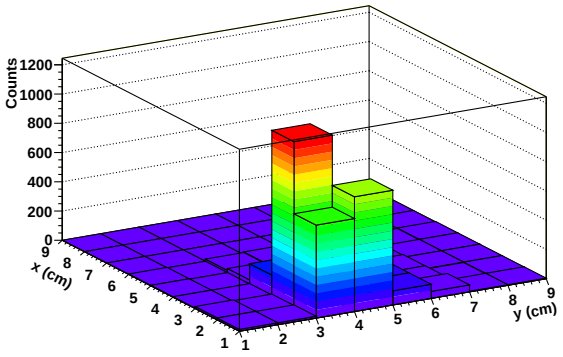

Figure 8: Beam profile

V. Future improvement

Recent physics simulation may indicate that the lowest threshold for a DHCAL should be around 1 MIP-MPV. However, a 97% efficiency for the detector invloves a minimum threshold of 1.3 fC. Thus, to perform further R&D on the micromegas detector, a new preamplifier is needed, with improved gain, improved bandwidth, and improved noise, and without rising the power consumption too much. An improved design, presented Figure 9 has started. The difference with the first version are a gain boost stage, a cascoded current source (I2) and a voltage follower at the output. With I1=200 µA, I2=20 µA, I3=I4=10 µA, the preliminary simulation results give a gain of 108 dB, a bandwidth of 8 kHz, and a gain-bandwidth product of 2 GHz. The phase margin is 72° and the minimum phase (in the bandwidth) of 51°. With no increase in the bias current, the rms noise is 2.2 mV with C_{det}=60 pF. This value will be improved with increase of I1.

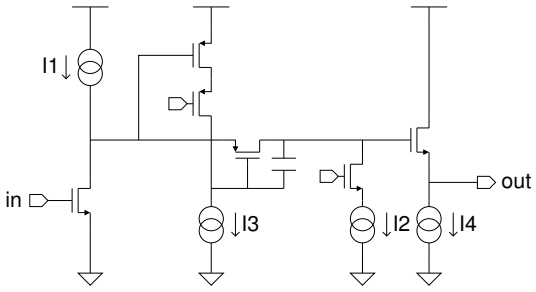

Figure 9: Preamplifier schematic

VI. Conclusion

The construction of a bulk MICROMEGAS chamber with embedded ASIC has been demonstrated by producing and testing a first prototype equipped with a DIRAC v1 chip. The second version of DIRAC ASIC is currently under characterisation. Further measurements of detection efficiency and hit multiplicity are foressen to assess in more details the performance of DIRAC based MICROMEGAS chambers. For that purpose, four chambers of small size (8×8 cm^2) are well suited and are currently under development. These measurements will be performed with beam at CERN.In parralel, the design of medium area PCB (32×48 cm^2) has began to build a 1 m^2 MICROMEGAS chamber.

VII. Acknowledgments

DIRAC v1 preamplifier has been designed by H. Mathez, acquisition board by C. Girerd and acquisition sofware by C. Combaret. The mask and the mesh lamination have been performed at CERN by R. De Oliveira and his TS/DEM group. Chamber design, assembly, handcrafting and tests have been conducted at LAPP by the LC-Detector group. Special thanks are addressed to F. Peltier for his involvement in the detector assembly.

VIII. References

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